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WebGIS final results: methodology and identification of case studies

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Executive Summary

The SPOWIND project (Spatial Planning for Offshore Wind Industry Development) addresses the critical transition from fossil fuels to renewable energy by developing a comprehensive framework for offshore wind development in the Mediterranean and Adriatic regions, where unique challenges such as abrupt depth variations necessitate the adoption of advanced floating technologies over traditional bottom-fixed structures. This deliverable establishes a multi-dimensional approach that integrates maritime spatial planning with robust energy production modeling and detailed techno-economic assessments to identify suitable areas where offshore wind can be installed with minimal conflict and maximum environmental and social sustainability. The methodology utilizes a WebGIS tool to analyze a diverse range of constraints, including the strict exclusion of protected Natura 2000 sites and national parks to preserve marine biodiversity, while also accounting for technical factors like bathymetry and wind resource consistency. Through regional case studies, the project demonstrates that while nations like Albania offer strategic locations for bottom-fixed technology in shallower coastal waters, larger potentials in regions such as Italy and Greece will require floating configurations to harness their vast wind resources. The techno-economic model evaluates the entire project life-cycle—from development and capital expenditures to operation and decommissioning—calculating key financial metrics like the Levelised Cost of Energy (LCOE) to provide a consistent benchmark for future competitiveness. The application of the SPOWIND WebGIS tool across partner regions has identified significant potential for offshore wind energy. First, the data illustrates that while technical potentials vary, the LCOE is becoming increasingly competitive, with values as low as 57.75 €/MWh in specific Italian basins. This suggests that strategic site selection, facilitated by the WebGIS tool, can significantly mitigate the financial "drawback" of offshore construction. Second, due to the Mediterranean's abrupt depth variations, floating technologies are essential for deep-water areas (60m–1000m), while bottom-fixed turbines remain viable for shallower shelves like the Northern Adriatic. Third, the radial layout has been identified as the most economically advantageous configuration, consistently outperforming d-ring and star layouts in terms of cost and productivity. Fourth, proper site selection reduces the "biggest drawback" of offshore wind—its higher construction and maintenance costs—while increasing social acceptance and minimizing disturbances to marine life and cultural heritage. Ultimately, this integrated framework serves as a decision-support system that balances energy production goals with the necessity of protecting delicate marine ecosystems and respecting existing maritime uses, thereby providing a rational and scientifically grounded roadmap for a sustainable, low-carbon future in the Mediterranean basin.





Abbreviations

Abbreviation	Full Name / Meaning
ABEX	Abandonment Expenditure
AC	Alternating Current
AEP	Annual Energy Production
AHTS	Anchor Handling Tug Supply (vessels)
ALF	Average Load Factor
BE	Blue Energy
BEMIP	Baltic Energy Market Interconnection Plan
CAPEX	Capital Expenditure
CF	Capacity Factor
CTV	Crew Transfer Vessels
DC	Direct Current
DEVEX	Development Expenditure
DSS	Decision Support System
EB-MSP	Ecosystem-Based Maritime Spatial Planning
EEZ	Exclusive Economic Zone
EIHP	Energy Institute Hrvoje Požar
EIA	Environmental Impact Assessment
EU	European Union
FSV	Field Service Vessels





HV	High Voltage
HVDC	High Voltage Direct Current
IMP	Integrated Maritime Policy
IRR	Internal Rate of Return
JUV	Jack-up Vessel
LCOE	Levelized Cost of Energy
LIDAR	Light Detection and Ranging
LV	Low Voltage
MPA	Marine Protected Area
MRE	Marine Renewable Energy
MSP	Maritime Spatial Planning
MV	Medium Voltage
NECP	National Energy and Climate Plan
NPV	Net Present Value
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PoC	Proof of Concept
Polito	Politecnico di Torino
R&D	Research and Development
SFOC	Specific Fuel Oil Consumption
SOV	Service Operational Vessels
TIP	Total Installed Power





TLP	Tension Leg Platform
TSO	Transmission System Operator
VIA	Visual Impact Assessment

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1. Introduction and definition of scenarios

European union is quickly shifting towards decarbonization of energy sector, with main accent on energy efficiency, renewables and electrification of other sectors, such as heating and cooling, transportation, industry and buildings. This shift opens possibilities and potential to research and develop some new forms of electricity production, with offshore wind view as one technology that could play major roles in decarbonization of Europe.

However, while Northern Europe has made significant strides, the Mediterranean region faces unique challenges. Its development is frequently hindered by deep waters—requiring advanced floating technologies—as well as complex regulatory frameworks and grid integration constraints. The SPOWIND project (Spatial Planning for Offshore Wind Industry Development), co-funded by the Interreg Euro-MED programme, addresses these specific barriers through the development of a transversal Marine Spatial Planning (MSP) WebGIS tool.

This document, Deliverable 4.2: Case Study Report, represents a critical phase in the project's lifecycle (Activity 4.2). It moves beyond theoretical methodology to the practical application of the developed tools, testing their capability to support decision-making processes for real-world scenarios in the Adriatic and Mediterranean basins.

The primary objective of this document is to present a detailed **Offshore Wind Case Study**





conducted within the project's partner regions. This report aims to demonstrate the complete workflow of planning an offshore wind farm using the SPOWIND WebGIS platform.

Specifically, this document serves three key purposes:

1. **Validation of Methodology:** To verify that the methodologies developed in WP2 (Spatial Planning) and WP3 (Energy Transfer) can be successfully applied to identify suitable areas and calculate techno-economic indicators.
2. **Scenario Analysis:** To present a concrete analysis of a specific location, evaluating its potential for electricity generation and/or green hydrogen production.
3. **Tool Evaluation:** To provide a critical assessment of the WebGIS tool's functionality, usability, and accuracy based on the user experience during the case study simulation.





2. WebGIS tool

The SPOWIND WebGIS tool is a strategic decision-support system designed to advance Marine Spatial Planning (MSP) within the Euro-MED region. By integrating complex geospatial datasets, the tool facilitates the sustainable deployment of offshore wind energy while balancing ecological preservation, social acceptance, and economic viability. As a core component of the Integrated Maritime Policy (IMP), it provides a practical platform for analysing and allocating the spatial and temporal distribution of human activities in marine areas.

2.1. Core Objectives and Functionalities

The tool moves beyond theoretical methodology to the practical application of testing capabilities for real-world scenarios in the Adriatic and Mediterranean basins. Its primary functionalities include:

- **Spatial Suitability Modeling:** Automatically identifies optimal locations for offshore wind parks by weighting technical factors such as wind potential against maritime constraints.
- **Conflict Analysis:** Detects overlaps between potential energy sites and existing maritime uses (e.g., shipping lanes, fishing grounds, or protected areas) to ensure a conflict-free deployment.
- **Techno-Economic Assessment:** Evaluates floating and bottom-fixed configurations by calculating key financial metrics like the Levelised Cost of Energy (LCOE), Net Present Value (NPV), and Internal Rate of Return (IRR).
- **Energy Production Evaluation:** Estimates Annual Energy Production (AEP) by considering environmental resources, turbine characteristics, and wake effects using models like the Jensen model.

2.2. Analytical Workflow and Weighting (AHP)

The development of the tool follows a multi-criteria decision-making (MCDM) framework. The analytical process involves:

- **Exclusion Mapping:** Ingesting "No-Go" areas such as Natura 2000 sites, national parks, and high-traffic navigation corridors.
- **Weighted Overlay (AHP):** Variables such as wind speed and bathymetry are assigned weights using an Analytic Hierarchy Process (AHP) to determine technical suitability.
- **Cost-Distance Analysis:** The tool calculates the complexity and cost of subsea cabling, recognizing that transmission to land is a significant factor in financial sustainability.



2.3. Input Data Architecture

To ensure a holistic assessment, the WebGIS tool integrates a wide array of data categories:

- Physical & Oceanographic: Mean wind speed (e.g., up to 7 m/s in specific Adriatic zones), bathymetry (depths up to 60m for bottom-fixed; up to 800m for floating), and wave action.
- Ecological: Locations of protected areas like National Park Kornati or Mljet, and biodiversity hotspots.
- Technical/Infrastructure: Electrical grid connection points, proximity to service ports, and existing subsea cable routes.

2.4. Validation and Output

The tool provides a comprehensive framework for investment planning by delivering:

- Suitability Heatmaps: Visualizing the "suitable area" (e.g., 30,647 km² identified in Croatia).
- Technical Potential Reports: Estimating the total TWh/year potential for specific maritime basins (e.g., 431.26 TWh/y for Italy).
- Life-Cycle Cost Breakdowns: Including Development (DEVEX), Capital (CAPEX), Operational (OPEX), and Abandonment (ABEX) expenditures.





4. Methodology

Case studies for each of participating countries consists out of definition of available area in WebGIS, estimation of annual energy production (AEP) and levelized cost of electricity for each country, estimation of various numerical indicators (technical Potential, suitable Area, LCOE, AEP) and statistical interpretation of these indicators.

The assessment of offshore wind potential within the SPOWIND WebGIS tool follows a hierarchical filtering approach. This methodology ensures that the final figures presented for each country move beyond theoretical wind maps to realistic, actionable deployment scenarios, with defined constrains.

Rather than identifying a single optimal point, this methodology applies a cascading filter to the entire national maritime territory. By overlapping wind resource stability with bathymetric suitability and environmental exclusions, the SPOWIND WebGIS tool generates a National Heat Map of Economic Viability. This allows policymakers to see the total potential Gigawatt (GW) capacity available at various LCOE price points (e.g., total capacity available under €80/MWh).

3.2. Constraints and definition of available area

3.3.1. Selection and extent of location

The selection of case study locations across the Mediterranean and Adriatic basins is the culmination of the SPOWIND spatial planning methodology. By applying the multi-criteria filters and exclusion masks defined in the previous chapters, the project has identified the specific extent of maritime space available for offshore wind development in each partner country.

The extent of suitable locations varies significantly based on coastal morphology, bathymetry, and existing maritime traffic. The project differentiates between the Technical Potential (the theoretical energy yield) and the Suitable Area (the actual geographic footprint available for turbines).

Country	Suitable Area (Km ²)	Technical Potential (TWh/y)	Dominant Technology
Italy	149,160	431.26	Floating / Bottom-fixed





Croatia	30,647	134.19	Bottom-fixed / Floating
Greece	118,520	382.40	Floating
Cyprus	12,450	45.10	Floating
Albania	5,820	22.15	Bottom-fixed
Montenegro	3,140	11.80	Floating

The extent of the selected locations was determined by analyzing high-wind corridors that do not interfere with protected ecosystems or critical shipping lanes.

- Adriatic Basin (Croatia & Montenegro): The selection is concentrated in the Northern and Central Adriatic. In Croatia, the extent of the suitable area (~30,647 Km²) is primarily located offshore from the Istrian peninsula and the Dalmatian archipelago, ensuring distance from the high-turbulence "Bora" wind zones in the Velebit Channel. In Montenegro, the extent is limited by the narrow continental shelf, pushing the selection into deeper waters suitable for floating structures.
- Ionian and Aegean Seas (Greece & Albania): Greece represents one of the largest extents of suitable space (~118,520 Km²) due to its vast archipelago. Selection here prioritizes deep-water floating sites to avoid the visual impact on tourism-heavy islands. Albania's selection is more coastal, focusing on the shallow shelf where bottom-fixed technology is more financially sustainable.
- Levantine Basin (Cyprus): The selection extent is focused on the southern and eastern offshore blocks, where wind consistency is highest and conflict with undersea communication cables is minimized.

The "extent" of these locations is not merely a measure of area but a calculation of economic viability. The methodology prioritizes locations where the LCOE is minimized.

- Near-shore Extent: Areas within 20–50km of ports like Ravenna (Italy), Split (Croatia), or Limassol (Cyprus) are favored to reduce the "drawback" of high maintenance and subsea cabling costs.
- Deep-water Extent: Floating wind sites are extended further offshore in Greece and Italy (up to 100km) where wind speeds are significantly higher, justifying the increased cost of mooring and cabling.

The final selection of these locations provides a rationalized roadmap for the transition to a low-





carbon energy future. By defining the exact geographic extent for each country, the SPOWIND WebGIS tool allows policymakers to transition from abstract targets to concrete site-specific development, ensuring that offshore wind parks are built where they offer the highest social and economic benefit with the lowest environmental impact.

3.3.2. Wind characteristics

The wind resource is the primary driver for both the energy yield and the financial viability of an offshore wind project. In the SPOWIND methodology, wind characteristics are analyzed not just as a measure of speed, but as a complex dataset including directionality, turbulence, and vertical shear, all of which influence the selection of turbine technology.

Wind characteristics are derived from high-resolution atmospheric reanalysis data (such as ERA5) and the Global Wind Atlas. These datasets are downscaled to account for coastal effects and local topography. For the purpose of the SPOWIND case studies:

- Reference Height: Wind speeds are extrapolated to typical hub heights of 100m, 120m, and 150m using the power law to account for vertical wind shear.
- Mean Wind Speed: A minimum threshold (typically 6.5 - 7 m/s) is often used as a baseline for technical suitability, though the tool evaluates the full distribution.

The project regions exhibit distinct wind characteristics that dictate project design:

- The Adriatic Sea (Italy, Croatia, Montenegro, Albania): Characterized by strong seasonal winds. The Bora (northeast) provides high energy density but also high turbulence, requiring robust turbine designs. In contrast, the Jugo (southeast) offers more consistent, steady flows.
- The Aegean and Levantine Seas (Greece, Cyprus): Influenced by the Etesian winds (Meltemi), which provide extremely consistent and high-speed wind resources during the summer months, aligning well with peak seasonal electricity demand.

The WebGIS tool utilizes these characteristics to output key performance indicators:

- Capacity Factor: The ratio of actual energy produced to the maximum possible output. In high-wind areas of the Aegean, capacity factors can exceed 45-50%, significantly lowering the LCOE.
- Annual Energy Production (AEP): Calculated by integrating the wind speed frequency distribution (typically modeled via a Weibull distribution) with the specific power curve of the selected turbine (e.g., 10MW or 15MW models).
- Wake Effects: The tool accounts for energy losses caused by the "wind shadow" of upstream turbines. In areas with a dominant wind direction (like the Bora or Meltemi), array layouts are optimized to minimize these losses.





The wind profile directly addresses the "higher cost" challenge of offshore wind. Sites with higher mean wind speeds allow for fewer turbines to reach the same energy target, reducing the amount of expensive subsea cabling and the number of foundations required. Conversely, in areas with extreme gusts or high turbulence, the methodology incorporates higher CAPEX for reinforced structural integrity to withstand heavy storm conditions.

By integrating these specific wind characteristics into the WebGIS, SPOWIND ensures that the transition to a low-carbon future is based on realistic energy yields and scientifically grounded site selections.

3.3.3. Electrical grid

The electrical grid is the vital link between the clean energy generated at sea and the onshore consumers. In the SPOWIND project, the evaluation of the electrical grid is not only a technical necessity but also a major factor in the financial sustainability of offshore wind projects. The methodology specifically addresses the high costs and technical complexities associated with subsea power transmission.

The WebGIS tool integrates data from the ENTSO-E (European Network of Transmission System Operators for Electricity) and national grid operators to identify feasible connection points. Key data inputs include:

- Onshore Substations: The location and existing capacity of high-voltage substations near the coastline.
- Transmission Voltage: Evaluation of standard voltage levels (e.g., 150kV, 220kV, or 400kV) required for the export cables.
- Subsea Cable Routes: Identification of corridors that minimize the distance to shore while avoiding sensitive benthic habitats or existing subsea telecommunications cables.

The approach considers two primary components of the offshore electrical system:

- Inter-array Cables: Medium-voltage cables (typically 33kV or 66kV) that connect individual wind turbines to an offshore substation.
- Export Cables: High-voltage AC (HVAC) or DC (HVDC) cables that transmit the total energy back to the mainland.

For the deep-water case studies in Italy, Greece, and Cyprus, the methodology incorporates the use of dynamic cables for floating platforms, which are designed to withstand the movement of waves and currents without mechanical failure.

As noted in the SPOWIND project objectives, the installation of power cables under the seafloor has a significant impact on the financial sustainability of the park.

- Cost-Distance Optimization: The WebGIS tool calculates the LCOE by factoring in the



distance to the grid. A longer cable length significantly increases CAPEX and leads to higher electrical losses during transmission.

- **Grid Capacity Constraints:** The methodology assesses whether the existing onshore grid can absorb the variable energy influx from the OFW park or if significant grid reinforcements are required, which can affect project timelines and total investment costs.

In line with the Integrated Maritime Policy (IMP), the SPOWIND project explores the potential for "Hybrid Projects" or "Energy Islands" that could connect OFW parks to multiple national grids (e.g., a connection between Italy and Croatia). Such synergies can optimize infrastructure use, reduce overall construction costs, and enhance the energy security of the Mediterranean region.

By accurately mapping the electrical grid and optimizing cable routes, the SPOWIND WebGIS tool ensures that the "biggest drawback"—the high cost of construction and maintenance—is systematically addressed. This enables the selection of sites where the proximity to robust grid infrastructure maximizes the economic return and supports a reliable transition to a low-carbon energy future.

3.3.4. Environmental data

The SPOWIND WebGIS tool adopts an ecosystem-based approach to maritime spatial planning (EB-MSP), recognizing that while offshore wind is a key driver for decarbonization, its deployment must not compromise marine biodiversity. The "Environmental Data" module serves as a critical filter in the site-selection process, ensuring that the transition to a low-carbon future is balanced with the protection of the Mediterranean's delicate marine life and habitats.

The tool integrates high-resolution geospatial data to map sensitive biological features across the Mediterranean and Adriatic basins:

- **Protected Areas:** Inclusion of core National Parks and Nature Parks where development is strictly prohibited to preserve natural heritage.
- **Natura 2000 Network:** Comprehensive mapping of Natura 2000 sites, which represent the most ecologically valuable areas in the EU. Selection of wind farm locations is designed to avoid these zones—such as the waters west of the Istrian coast and off the shore of Dubrovnik—as much as possible to minimize environmental risk.
- **Benthic Habitats:** Data on seagrass meadows (e.g., *Posidonia oceanica*) and coral formations, which are vulnerable to the physical footprint of bottom-fixed foundations and cable trenching.
- **Wildlife Migration Corridors:** Spatial data on bird migration patterns and marine mammal nursing grounds (e.g., areas near the islands of Lošinj and Dugi otok) to mitigate disturbances to natural migration and feeding behaviors.





The methodology applies these datasets through a tiered constraint system:

- **Exclusion Zones (Hard Constraints):** National parks and core protected areas are masked out, effectively reducing the geographic "Suitable Area" to ensure no turbines are placed in high-risk environmental zones.
- **Mitigation Through Site Selection:** By identifying areas with lower ecological sensitivity, the tool operationalizes the project's goal to "mitigate and minimize" the impact of construction and operation on marine ecosystems.
- **Mandatory Assessments:** While the WebGIS tool identifies low-conflict areas, the project framework mandates that every proposed site must still undergo a rigorous Environmental Impact Assessment (EIA) and a specific assessment of impact on Natura 2000 sites according to current legislation.

The following table summarizes the typical exclusion criteria and buffers applied within the WebGIS tool to categorize a cell as "unsuitable" for offshore wind development:

Environmental Category	Constraint Type	Standard Buffer / Rationale
National Parks	Hard Exclusion	100% Exclusion; No development permitted within legal boundaries.
Natura 2000 Sites	Hard Exclusion	High Priority Avoidance; Development is excluded to minimize environmental risk.
Marine Protected Areas (MPAs)	Hard Exclusion	Total exclusion of core zones to protect biodiversity.
Visual Impact (Coastline)	Soft Constraint	Typically 10–20 km from the shore to protect coastal landscapes and tourism.
Wildlife Corridors	Weighted Overlay	Targeted avoidance of high-density bird migration or mammal nursing paths.

The environmental data module is designed to fulfill the dual objectives of the SPOWIND project:

- **Decarbonization:** Reducing greenhouse gas emissions through vast renewable resource potential.
- **Conservation:** Ensuring that the deployment of advanced technologies, such as floating structures, does not lead to habitat loss or species displacement.



By integrating these robust environmental datasets, the SPOWIND WebGIS tool provides a transparent and scientifically grounded framework for identifying "Suitable Areas". This ensures that the technical potential of offshore wind—estimated at 431.26 TWh/y for Italy or 134.19 TWh/y for Croatia—is realized only in locations where ecological impact is minimized, fulfilling the requirements of the Integrated Maritime Policy (IMP).

2.3.5 Other location characteristics

Beyond wind resources and environmental protections, several "human" and logistical characteristics define the viability of an offshore wind farm. The SPOWIND WebGIS tool integrates these multi-sectoral datasets to ensure that the transition to a low-carbon energy future is a rational process that balances all maritime uses.

Marine Spatial Planning (MSP) requires the analysis of the spatial and temporal distribution of existing human activities. The tool assesses the following characteristics to minimize cross-sectoral conflicts:

- **Maritime Traffic and Navigation:** Using AIS (Automatic Identification System) data, the tool identifies major shipping lanes and navigation corridors. Buffer zones are applied around these routes to ensure safety, as offshore wind parks can affect the migration patterns of vessels and operational safety.
- **Commercial Fishing Zones:** The tool identifies high-intensity fishing grounds. While some co-location is possible, traditional trawling zones are often marked as constraints to prevent damage to subsea cables and turbine foundations.
- **Underwater Cultural Heritage:** Particularly relevant in the Mediterranean (Greece, Italy, Croatia), the tool maps known shipwrecks and archaeological sites to ensure their preservation during seafloor cabling and foundation installation.

The location's proximity to land-based infrastructure is a decisive factor in reducing the "drawback of higher cost." The WebGIS tool evaluates:

- **Distance to Service Ports:** Locations are analyzed based on their distance to specialized ports (e.g., Ravenna, Split, or Limassol) capable of serving as assembly bases or maintenance hubs.
- **Port Capacity:** Assessment of whether local ports have the requisite quay length and crane capacity to handle 10MW+ turbine components, which can reduce the need for expensive, long-distance towing.

One of the most significant "soft" characteristics is the visibility of the wind park from the coastline.



- Viewshed Analysis: The tool performs a visibility analysis to predict how many turbines will be visible from tourism-sensitive areas or residential coastal zones.
- Social Acceptance Buffers: By selecting locations further offshore (typically >15-20km), the methodology aims to increase social acceptance, ensuring that large-scale electricity generation does not conflict with the aesthetic value of the Mediterranean seascape.

Finally, the tool accounts for the physical nature of the seafloor:

- Sediment Type: Identification of sandy, rocky, or muddy seafloors determines the ease of burying power cables and the type of anchoring systems required for floating platforms.
- Seismic Activity: Especially in Greece and Cyprus, the methodology considers regional seismic risks to ensure that the infrastructure can withstand potential geological events.

By integrating these diverse characteristics, the SPOWIND WebGIS tool moves beyond a simple "wind map" to become a comprehensive decision-support system. It identifies areas where the "right choice of location" can reduce unnecessary costs, minimize impact on wildlife, and ensure a more rational use of marine space in accordance with the Integrated Maritime Policy (IMP).





3.1. Technical and Economic Potential Assessment

3.1.1. Theoretical and technical potential

The process begins with the Theoretical Potential, which encompasses the total energy available across the entire Exclusive Economic Zone (EEZ) of a country based purely on wind speed data. However, for planning purposes, we focus on the Technical Potential, which is calculated by applying the following "Hard Constraints" in the WebGIS tool:

- **Wind Speed Threshold:** Areas with an average annual wind speed below 6.0 m/s (at 100m hub height) are excluded, as they generally cannot sustain commercial-scale energy production.
- **Bathymetric Limits:** The technical potential is categorized by foundation type. Areas with depths up to 60m are earmarked for fixed-bottom structures, while areas between 60m and 800m are reserved for floating offshore wind (FLOW). Depths exceeding 800m are currently excluded due to the technical limits of mooring and cabling systems.
- **Environmental and Legal "No-Go" Zones:** All areas designated as National Parks, strict nature reserves, and primary shipping lanes are subtracted from the total area.

3.1.2. Economic potential

Once the technical area is defined, the WebGIS tool performs a spatial economic analysis to determine the economic potential. This is primarily expressed through the levelized cost of energy (LCOE).

The economic assessment considers:

1. **Distance to Infrastructure:** Proximity to the nearest high-voltage grid connection point or port facility. Increased distance directly correlates with higher CapEx (cabling) and OpEx (maintenance logistics).
2. **Capacity Factor/Annual Energy Production:** This factor covers availability and technical potential of the wind energy at given position and area. A higher capacity factor allows for the amortization of fixed costs over a larger volume of generated MWh, significantly lowering the LCOE.
3. **Regional Cost Multipliers:** Local supply chain maturity, labor costs, and depth-dependent foundation costs are factored in to provide a realistic price per MWh.

By mapping these variables, the methodology identifies "Priority Development Zones" (PDZs)—areas where the technical potential overlaps with the lowest possible LCOE, providing the highest





return on investment and the most competitive energy prices for the national market.





The selection of locations for offshore wind development within the SPOWIND project is a strategic process that moves from theoretical suitability to the identification of concrete case study areas across the partner regions. This process is governed by a multi-sectoral approach that balances high wind resource potential with technical feasibility and the necessity of minimizing conflicts with existing maritime uses and sensitive ecosystems.

The methodology for selecting these specific sites relies on three primary pillars of evaluation:

- **Resource Availability:** Locations are prioritized in areas with favourable and consistent wind conditions. For instance, in the Adriatic, focus is placed on areas like the south of the Istrian peninsula and southeast of Šibenik, where mean wind speeds at 100m can reach up to 7 m/s.
- **Technical and Bathymetric Feasibility:** Sites are categorized by depth to determine the appropriate technology. Areas with depths up to 60 meters are selected for bottom-fixed turbines, while depths up to 800 meters are identified for floating structures, which are essential for the steep bathymetry typical of the Mediterranean.
- **Conflict Avoidance (Exclusion Zones):** Selection strictly avoids "No-Go" areas to ensure environmental and social sustainability. This includes:
 - **Environmental:** National Parks (e.g., Mljet, Kornati, Brijuni), Nature Parks, and the Natura 2000 network.
 - **Human Activities:** Major shipping lanes, active fishing grounds, and military exercise zones.

The project identifies specific suitable areas within each partner country, serving as the basis for detailed techno-economic and energy production assessments:

- **Albania:** Locations are selected based on the transition from the shallow coastal shelf to deeper waters, evaluating the potential for both fixed and floating configurations to maximize energy yield for the Balkan grid.
- **Croatia:** Analysis focuses on the Northern and Central Adriatic. A "Suitable Area" of approximately 30,647 km² has been identified, primarily south of the Istrian coast and off the Šibenik-Knin county, avoiding the strong gusts of the Bora wind in the Sub-Velebit Channel
- **Cyprus & Greece:** Building on previous initiatives like THAL-CHOR I and II, locations in these regions are selected to optimize the high wind potential of the Aegean and Levantine seas while navigating the complex navigational routes and archaeological constraints of the Eastern Mediterranean.
- **Italy:** The project identifies a substantial technical potential of 431.26 TWh/y across a suitable area of 149,160 km². Case studies in Italy focus on balancing high productivity with



the complex logistics of the Mediterranean basin.

- Montenegro: Site selection considers the relatively narrow coastal shelf and the technical requirements for floating technology in deeper offshore zones.

By applying this selection methodology, the SPOWIND project ensures that the chosen locations are not only productive but also financially sustainable. The selection takes into account the proximity to electrical grid connection points and service ports to mitigate the high costs associated with subsea cabling and long-term maintenance.

4. Recommendations for locations selection

The approach for the case studies is to present possibilities of SPOWIND Web GIS tool and estimate technical and economic potential.

However, stakeholders would likely move beyond theoretical assessment into a practical, step-by-step workflow for planning offshore wind farms in the Mediterranean context. Here present approach adopts a three-pillar integration strategy to ensure that each identified location is technically viable, environmentally sustainable, and economically sound:

- Validation of Methodology: Verifying that the spatial planning constraints developed in previous phases can be successfully applied to identify conflict-free areas.
- Scenario Simulation: Testing specific technological configurations (bottom-fixed vs. floating) and energy output models (Annual Energy Production) for a selected coordinate.
- Critical Evaluation: Assessing the WebGIS tool's accuracy and usability based on the results of the simulation to refine future iterations of the platform.

The case study methodology is divided into three distinct but interconnected assessments:

- Stage 1: Spatial Suitability Assessment: The tool applies an integrated assessment of maritime constraints, including ecological, navigational, and socio-economic factors. This identifies areas where wind farms can be installed with minimum cross-sectoral conflicts.
- Stage 2: Energy Production Modeling: A realistic estimation of production potential is calculated by integrating environmental resource data with turbine characteristics. This model accounts for wake effects using the Jensen model and incorporates expected electrical losses along inter-array and export cables to shore.
- Stage 3: Techno-Economic Assessment: The final stage applies a comprehensive financial model to evaluate the project's life-cycle. It calculates key financial indicators such as LCOE





(Levelised Cost of Energy), NPV (Net Present Value), and IRR (Internal Rate of Return).

Unlike standard GIS models, the SPOWIND approach incorporates operational constraints into the case study:

- **Maintenance Strategies:** The simulation distinguishes between corrective actions for major component failures and periodic maintenance for minor issues.
- **Infrastructural Readiness:** The approach evaluates the proximity and capacity of local ports for specialized service vessels and the necessity of port upgrades to support the offshore supply chain.
- **Grid Integration:** Assessments consider the distance to the nearest onshore substation, which is a critical factor in the financial sustainability due to the high cost of subsea cabling.

By utilizing this comprehensive framework, each case study serves as a Proof of Concept (PoC) to guide future investments and energy system integration across the Mediterranean.

5. Legal framework

The Croatian legal and policy framework currently lacks explicit provisions for offshore wind farms, necessitating the application of existing legislation by analogy where possible. Key findings indicate that offshore wind is rarely directly mentioned in energy legislation. A major impediment is the absence of an adopted Spatial Plan for the Exclusive Economic Zone (EEZ) of the Republic of Croatia in the Adriatic Sea, which currently precludes the construction of offshore wind farms in the EEZ. Furthermore, obtaining an Energy Approval is currently not possible as it requires the area of interest to be included in a Spatial Plan, which is not yet available for the EEZ. Air and maritime security regulations, alongside national defense and foreign policy rules, also do not directly address OFW farm construction, and while some aspects might apply through broad interpretation, these are generally not suitable.

- **Energy Legislation:** The general energy framework is governed by the Energy Act and the Act on Renewable Energy Sources and High-Efficiency Cogeneration. While wind energy is listed as a renewable source, offshore wind is not explicitly detailed. Amendments to the Act on Renewable Energy Sources and High-Efficiency Cogeneration are in process, with a new law transposing RED III expected in Q3 2025. Notably, the Regulation on the Use of Renewable Energy Sources and High-Efficiency Cogeneration and the Regulation on the Promotion of Energy Production from Renewable Energy Sources and High-Efficiency Cogeneration do explicitly mention offshore wind farms, defining them as wind farms



installed in marine areas. These regulations also recognize offshore wind farms with installed capacity greater than 500 kW.

- **State Aid Program:** The Croatian Energy Market Operator (HROTE) is responsible for promoting electricity production from RES. However, the latest State aid program (April 2024) does not include the promotion of offshore wind energy.
- **Concessions and Maritime Domain:** Offshore wind farms can be built on maritime property up to the outer boundary of the territorial sea and in the exclusive economic zone. This falls under the Act on Maritime Domain and Seaports and the Act on Concessions. The Ministry of the Sea, Transport, and Infrastructure is expected to amend the Act on Concessions to explicitly recognize the use of marine areas for energy production from renewable sources, enabling offshore wind farm development.

2.4.1. Spatial plans and implementation of MSP directive

The sea, coastline, and islands are of particular interest to Croatia and are subject to special protection. The Spatial Development Strategy of the Republic of Croatia recognizes the sea as a natural asset and highlights the need to consider ecological network areas when selecting wind farm locations.

- **Exclusive Economic Zone (EEZ) Spatial Plan:** The process of drafting and adopting the Spatial Plan of the Exclusive Economic Zone of the Republic of Croatia in the Adriatic Sea was initiated in early 2024. This plan is crucial for defining areas where offshore wind farms could be developed. The Ministry of Physical Planning, Construction, and State Assets is the responsible authority.
- **Maritime Spatial Planning (MSP) Directive:** Directive 2014/89/EU on establishing a framework for maritime spatial planning is considered when spatial planning for territorial waters. It aims to contribute to the sustainable development of marine energy sectors and environmental protection. An Intersectoral Expert Group was established to monitor compliance with the MSP Directive.
- **Permitting Process:** A location permit is required for interventions on maritime property for which a concession is granted, serving as a confirmation of compliance with spatial plans and environmental conditions. A building permit is needed to commence construction, and a usage permit is required to put the building into operation. Proof of legal interest for a building permit, when real property rights are not possible, is the concession agreement.





2.4.2. Offshore wind in NECP and other strategic documents

Croatia is committed to EU climate targets, including climate neutrality by 2050 and a 55% reduction in greenhouse gas emissions by 2030. The updated National Energy and Climate Plan (NECP) (adopted March 27, 2025) increased the share of renewable energy in consumption from 36.4% to 42.5%, but it does not include a specific target for offshore wind.

Despite the lack of specific national targets in the NECP, Croatia has reported non-binding targets for offshore wind farms as part of the EU's South and East Offshore Grids (SE offshore) initiative: 0.5 GW by 2030, 1.2 GW by 2040, and 3 GW by 2050. These inputs are not based on the Energy Sector Development Strategy or NECP. The Low-Carbon Development Strategy of the Republic of Croatia until 2030 with a view to 2050 refers to offshore wind farms as a technology that could contribute to decarbonization. The Croatian Hydrogen Strategy also considers the development of offshore wind farm projects for producing electricity from RES and renewable hydrogen.

The development of offshore wind is addressed by two policy and regulatory measures: "RES-2 Spatial Planning Prerequisites for Renewable Energy Sources" and "RES-3 Regulatory Framework for Renewable Energy Sources". RES-2 aims to define guidelines for locating offshore wind farms in spatial plans, including updating the Spatial Plan for the Exclusive Economic Zone. RES-3 focuses on simplifying administrative procedures and addressing inconsistencies in regulations that hinder RES projects.

2.4.3. Offshore wind in TSO's plans

Connecting to Croatia's electricity transmission network is governed by laws and regulations ensuring fair access. The Croatian Transmission System Operator (HOPS) manages the transmission network and oversees connection procedures. While HOPS is generally obliged to provide access, it may restrict it due to technical or operational limits.

HOPS, as other transmission system operators, maintains its ten-year development plan, updated every year. So far, there are not specific provisions to extend transmission network for offshore wind projects, although there are some analyses how this could be made. Also, HOPS would consider every formal application for inclusion of offshore wind projects in their list and as input to ten-year development plan.

2.4.4. Plan for production of green hydrogen and ammonia from offshore wind

Croatia's strategic vision for green hydrogen is formally established in its Croatian Hydrogen Strategy until 2050, adopted in 2022. The strategy aligns directly with the European Green Deal



and REPowerEU objectives, positioning renewable (green) hydrogen as a critical decarbonization vector for hard-to-abate sectors like industry, transport (especially maritime), and long-term energy storage. The core of this plan relies on generating hydrogen through the electrolysis of water, powered exclusively by renewable energy sources (RES) like solar and wind.

While the Strategy emphasizes the rapid increase of domestic RES capacity, its connection to the offshore sector lies within the Power-to-X concept. The national strategy implicitly supports this by focusing on hydrogen use in the maritime sector and positioning Croatia as a potential future hydrogen import/transit hub (e.g., the Green Energy Park Krk project). However, the critical link remains strained: the development of the offshore wind farms required to fuel this hydrogen economy is currently blocked by the lack of an adopted Spatial Plan for the Exclusive Economic Zone (EEZ), creating a spatial barrier that prevents the strategic hydrogen vision from leveraging the Adriatic's enormous technical wind potential.

2.4.5. Environmental impact and Natura2000

The Environmental Protection Act serves as a primary law for environmental protection. Provisions impacting offshore wind farm development relate to Environmental Impact Assessment (EIA) of the project and the Ecological Network. The Marine Strategy Framework Directive, transposed into Croatian legislation, obliges Member States to achieve or maintain good status of the marine environment.

The procedure for regulating environmental protection and Natura 2000 compliance in Croatia adheres to core EU legislation, primarily through the Environmental Protection Act, Natura2000 Protection Act and the transposition of the Marine Strategy Framework Directive. These laws mandate a rigorous Environmental Impact Assessment (EIA) for any proposed offshore wind project and require careful consideration of the impact on Croatia's Ecological Network to ensure compliance with Natura 2000 standards. However, the regulatory landscape is complicated by the complete lack of practical experience: no offshore wind projects have ever reached the EIA stage, meaning the specific duration, data requirements, and environmental mitigation protocols remain untested and undefined. This practical gap, coupled with the critical reliance on the yet-to-be-adopted Spatial Plan for the Exclusive Economic Zone (EEZ) for site designation, introduces considerable legal and administrative uncertainty for developers seeking to prove environmental sustainability.

2.4.6. Concessions

The regulation of concessions for offshore wind power plants in Croatia is characterized by a significant regulatory vacuum and a major administrative blockage. Currently, there is no specific



national law dedicated to the concession process for offshore wind energy projects; instead, general legislation must be applied by analogy, primarily the Law on Maritime Domain and Seaports.

The core impediment, is the absence of an adopted Spatial Plan for the Exclusive Economic Zone (EEZ). Obtaining an Energy Approval, which is a prerequisite for launching a public tender for a concession, is legally contingent upon the area of interest being explicitly designated within a valid Spatial Plan. Consequently, the regulatory framework is effectively non-functional for new offshore projects, as the necessary spatial planning foundation is missing.

In summary, while the right to use the maritime domain for offshore wind would typically be granted by the government through a long-term maritime concession (up to 50 years), the initiation of this process is impossible due to the preceding legislative bottleneck in spatial planning. This gap creates high legal and administrative uncertainty, classifying Croatia as one of the countries in the region with a "critical regulatory vacuum" for offshore wind deployment.

2.4.7. Other legislation that could impact development

The Ministry of Economy holds public tenders for issuing Energy Approval for new offshore wind farm construction, but it relies on the inclusion of the area of interest in a Spatial Plan.

6. Results

6.1. Case study- Albania

The Albania case study explores the potential for offshore wind deployment in a region characterized by a transitioning maritime economy and a favorable coastal shelf. While the technical potential in Albania is smaller relative to regional neighbors like Italy or Greece, its strategic position and shallower coastal waters make it a key area for testing bottom-fixed technology.



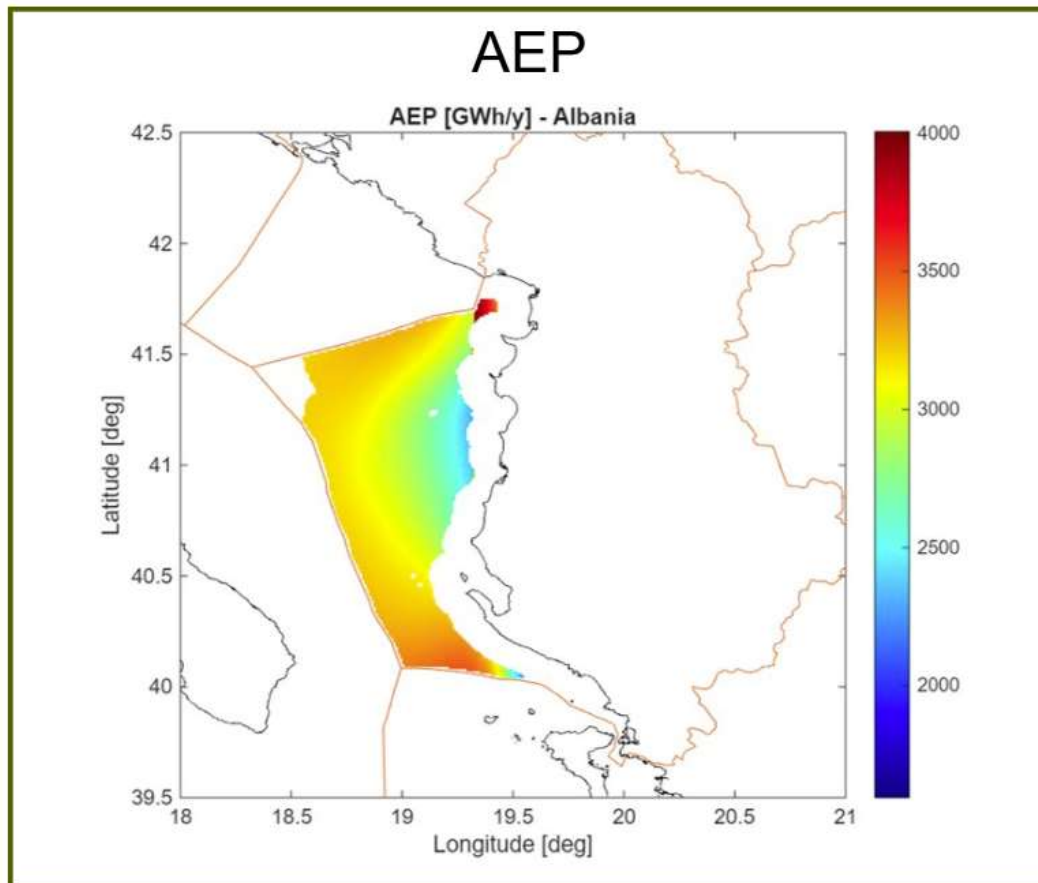


Figure 1: OWT's annual energy production (AEP) in Albania.

The wind regime in Albania is influenced by its Mediterranean climate and coastal topography:

- Wind Speed: Selection focuses on areas with consistent wind resources, generally matching the technical threshold of 6.5 - 7 m/s required for a financially sustainable capacity factor.
- Energetic Consistency: The wind profile supports stable energy production, which is critical for Albania's goal of enhancing national energy security and integrating renewable sources into the Balkan power grid.

Figure 1 shows an eligible area within the Exclusive Economic Zone of Albania, with a map of spatial distributed Annual Energy Production (AEP). The resulting area shows a good potential with an associated convenient economic metric.

The techno-economic assessment for the Albanian case study utilizes the SPOWIND model to evaluate the project's life-cycle costs and investment viability. Figure 2 shows an eligible area within the Exclusive Economic Zone of Albania, with a map of spatial distributed LCOE. The case study benchmarks the cost of energy for bottom-fixed turbines, which currently ranges from 65 to 145 €/MWh and a mean of 79,47 €/MWh, with significant potential for reduction as the supply chain matures.

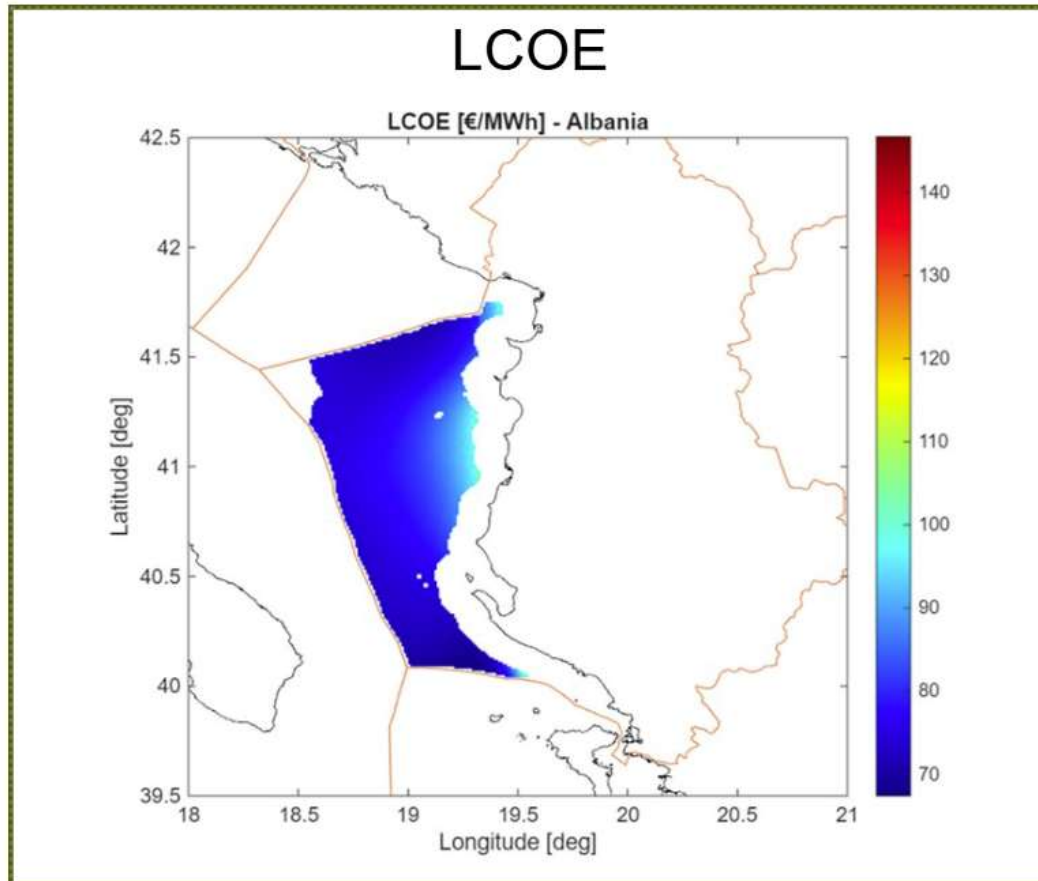


Figure 2: Levelized Cost of Energy from OWT's in Albania

After applying the integrated maritime spatial planning constraints—including ecological protections, navigational corridors, and technical feasibility—the SPOWIND WebGIS tool identified the following spatial extent for Albania, as presented in the Table:

- Suitable Area: Approximately 9'166 km² has been identified as eligible for offshore wind deployment.
- Technical Potential: The estimated energy yield for the identified area is 28,04 TWh/year.
- Mean LCOE of 79,47 €/MWh and minimum of 67,42 €/MWh.
- Mean AEP of 3,06 and maximum of 4,01 TWh/y.
- Dominant Technology: Due to the bathymetry of the Albanian shelf, the case study primarily evaluates bottom-fixed configurations, which are more financially sustainable in shallower waters.

Albania





Technical Potential	28,04	TWh/y
Suitable Area	9'166	km ²
LCOE min (mean)	67,42 (79,47)	€/MWh
AEP max (mean)	4,01 (3,06)	TWh/y

Figure 3 provides the technical potential divided by LCOE ranges and by distance from shore. Almost all the potential is within a narrow band of 70-90 €/MWh, which makes the value uniform and competitive. This is also supported by the fact that the eligible points are all relatively close to shore, with distances between 20-40 km.

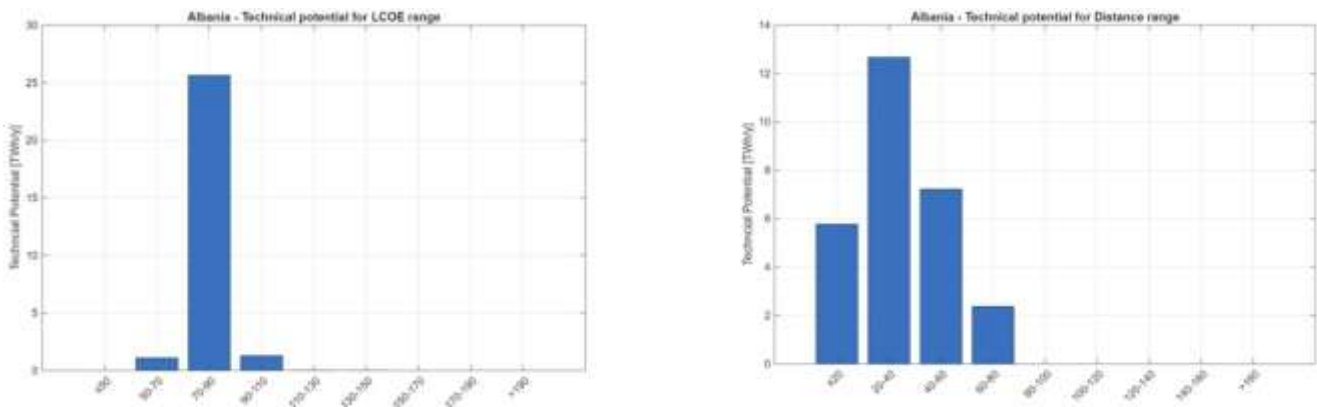


Figure 3: Technical potential for LCOE range (panel a) and Distance range (panel b) for the Albania's Economic Exclusive Zone

By applying this methodology, the Albania case study demonstrates a rational approach to maritime space allocation, providing a "Proof of Concept" for sustainable offshore wind growth in the Southern Adriatic and Ionian seas.

6.2. Case study- Croatia

The Croatia case study focuses on the Northern and Central Adriatic, regions characterized by high wind potential and a complex archipelago. This case study is critical for the SPOWIND project as it tests the integration of OFW within a sea space that is heavily utilized for tourism, fishing, and environmental conservation.

The wind regime in Croatia is highly specific and presents both opportunities and technical challenges:

- Wind Resources: The highest potential is found south of the Istrian peninsula and





- southeast of Šibenik, where mean wind speeds at 100m reach approximately 7 m/s.
- Operational Constraints: The case study excludes areas with extreme turbulence, such as the Sub-Velebit Channel, where the Bora wind (NE) can reach speeds that exceed the safety thresholds of standard turbines. Instead, the selection prioritizes more stable flow zones where the Jugo (SE) wind contributes to high capacity factors.

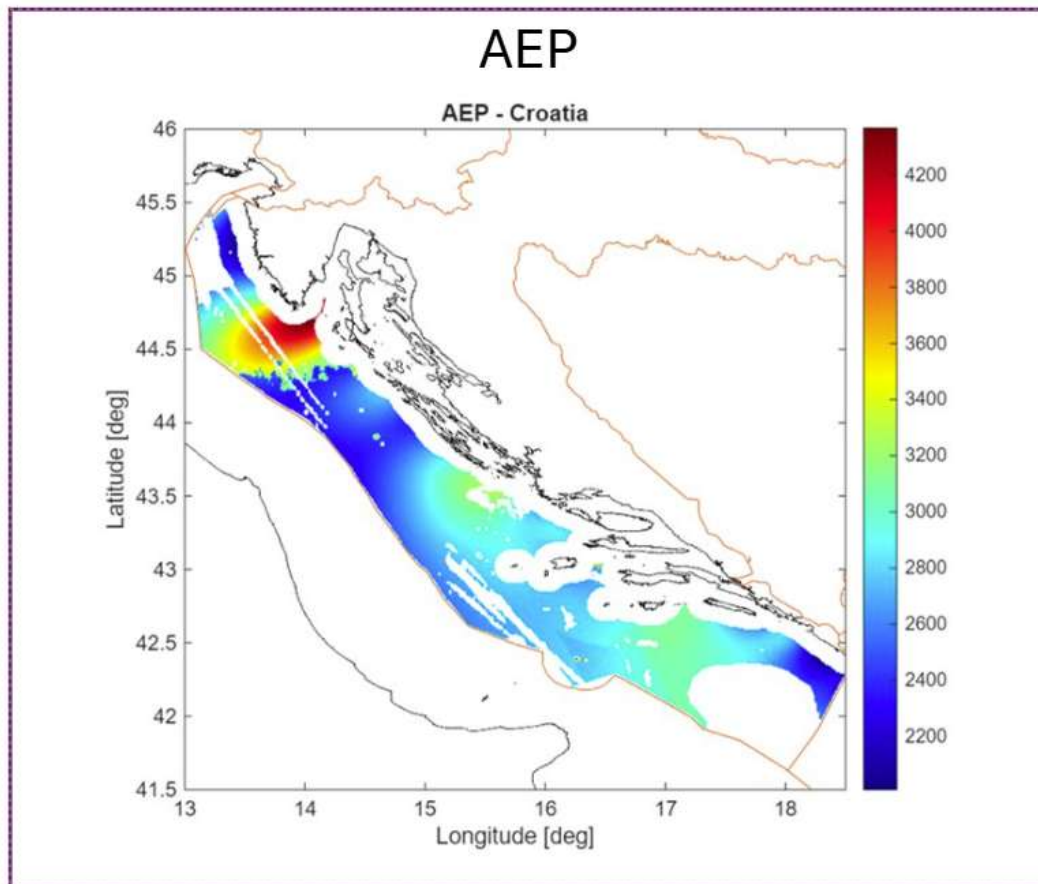


Figure 4: OWT's annual energy production (AEP) in Croatia

Figure 4 shows an eligible area within the Exclusive Economic Zone of Croatia, with a map of spatial distributed Annual Energy Production (AEP). The resulting area shows a good potential with an associated convenient economic metric.

The Croatian case study utilizes the SPOWIND WebGIS tool to calculate financial viability across the life-cycle of a project. Figure 5 shows an eligible area within the Exclusive Economic Zone of Albania, with a map of spatial distributed LCOE. The case study benchmarks the cost of energy for bottom-fixed turbines, which currently ranges from 75 to 170 €/MWh and a mean of 99,79 €/MWh, with significant potential for reduction as the supply chain matures.



Regarding the Croatia's Grid Connectivity, the simulation evaluates connection points at major coastal substations, noting that the "drawback of higher cost" is mitigated in areas where subsea cabling distances to the existing 110kV or 220kV onshore grid are minimized.

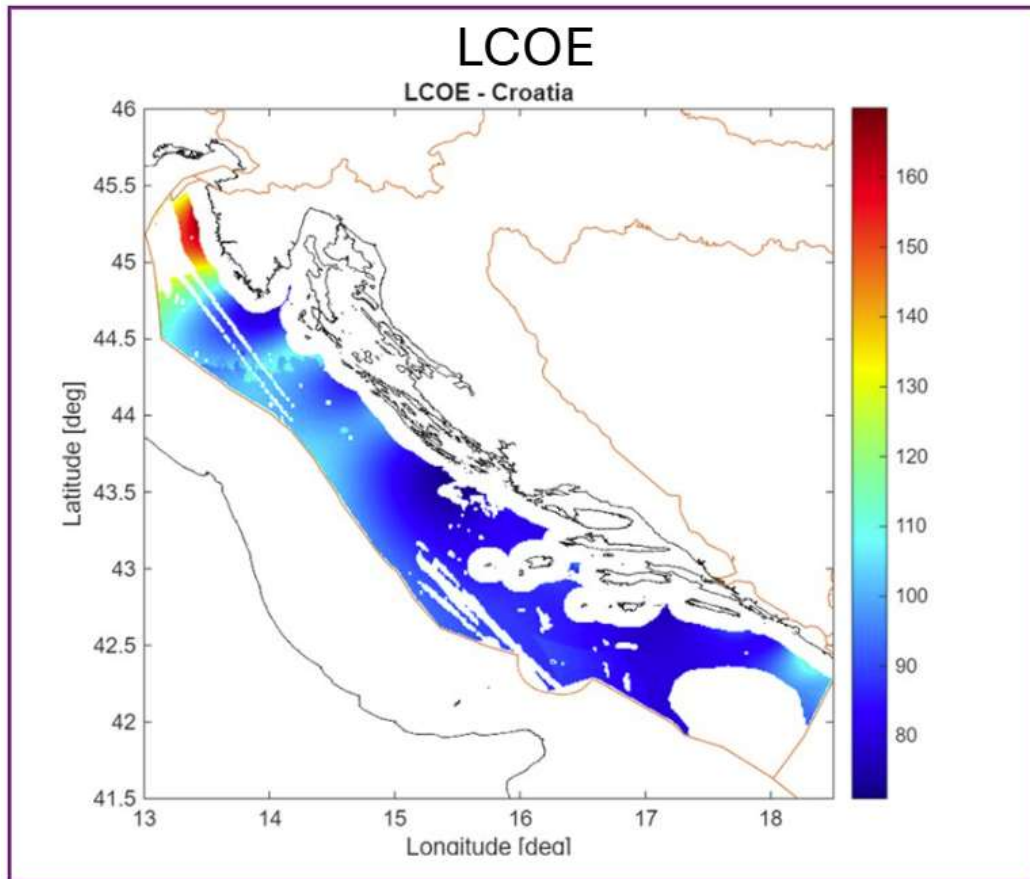


Figure 5: Levelized Cost of Energy from OWT's in Albania

The identification of suitable areas in Croatia was conducted using a tiered filtering approach to avoid "No-Go" zones while maximizing energy yield.

- Suitable Area: Approximately 30,647 km² has been identified as eligible for offshore wind development.
- Technical Potential: The estimated technical energy potential for the Croatian maritime zone is 83,00 TWh/year.
- Mean LCOE of 99,79 €/MWh and minimum of 71,02 €/MWh.
- Mean AEP of 2,78 and maximum of 4,37 TWh/y.
- Technological Mix: Due to the varying depths of the Adriatic, the case study evaluates both bottom-fixed foundations (concentrated in the shallower Northern Adriatic) and floating platforms (in the deeper Central and Southern Adriatic).



Croatia		
Technical Potential	83,00	TWh/y
Suitable Area	30647	Km ²
LCOE min (mean)	71,02 (99,79)	€/MWh
AEP max (mean)	4,37 (2,78)	TWh/y

Figure 6 provides the technical potential divided by LCOE ranges and by distance from shore. Almost all the potential is within a narrow band of 70-90 €/MWh, which makes the value uniform and competitive. This is also supported by the fact that the eligible points are all relatively close to shore, with distances in the range of 20-40 km.

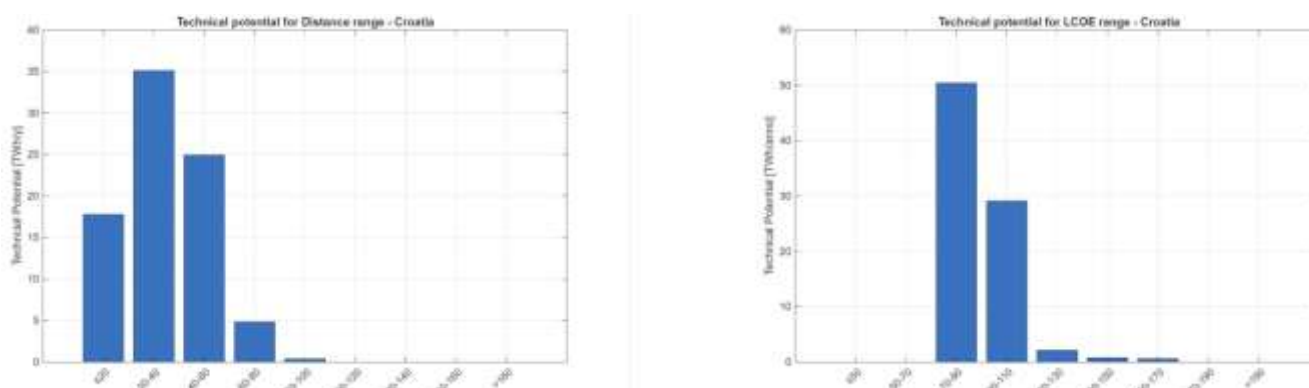


Figure 6: Technical potential for LCOE range (panel a) and Distance range (panel b) for the Croatia's Economic Exclusive Zone

To ensure social acceptance and ecological preservation—key goals of the SPOWIND project—the following constraints were applied in the Croatian context:

- **Natura 2000 and National Parks:** The identified suitable area strictly avoids core protected zones such as National Parks Kornati, Mljet, and Brijuni, as well as the Lastovsko otočje Nature Park.
- **Tourism and Visibility:** A buffer zone of 15–20 km from the coastline was analyzed to minimize the visual impact on Croatia’s high-value coastal tourism sector, particularly near major destination hubs.
- **Maritime Traffic:** Key navigation routes connecting the ports of Rijeka, Zadar, and Split were excluded to maintain maritime safety.





The Croatia case study provides a "rational way" to balance energy demands with environmental protection. By identifying over 30,000 km² of suitable space, it demonstrates that Croatia can play a significant role in the Mediterranean's transition to a low-carbon future without compromising its unique natural heritage or maritime economy.



6.3. Case study- Cyprus

The Cyprus case study investigates the offshore wind potential in the Eastern Mediterranean, a region characterized by deep waters and a highly consistent wind regime driven by the Etesian (Meltemi) winds. Due to the abrupt bathymetric gradients close to the coastline, offshore wind development in Cyprus is primarily suited for floating technologies. The wind conditions offshore Cyprus are particularly favorable in terms of consistency and seasonal alignment with electricity demand:

Wind Resources: Mean wind speeds offshore are generally above the technical threshold required for commercial offshore wind deployment, supporting stable capacity factors throughout the year.

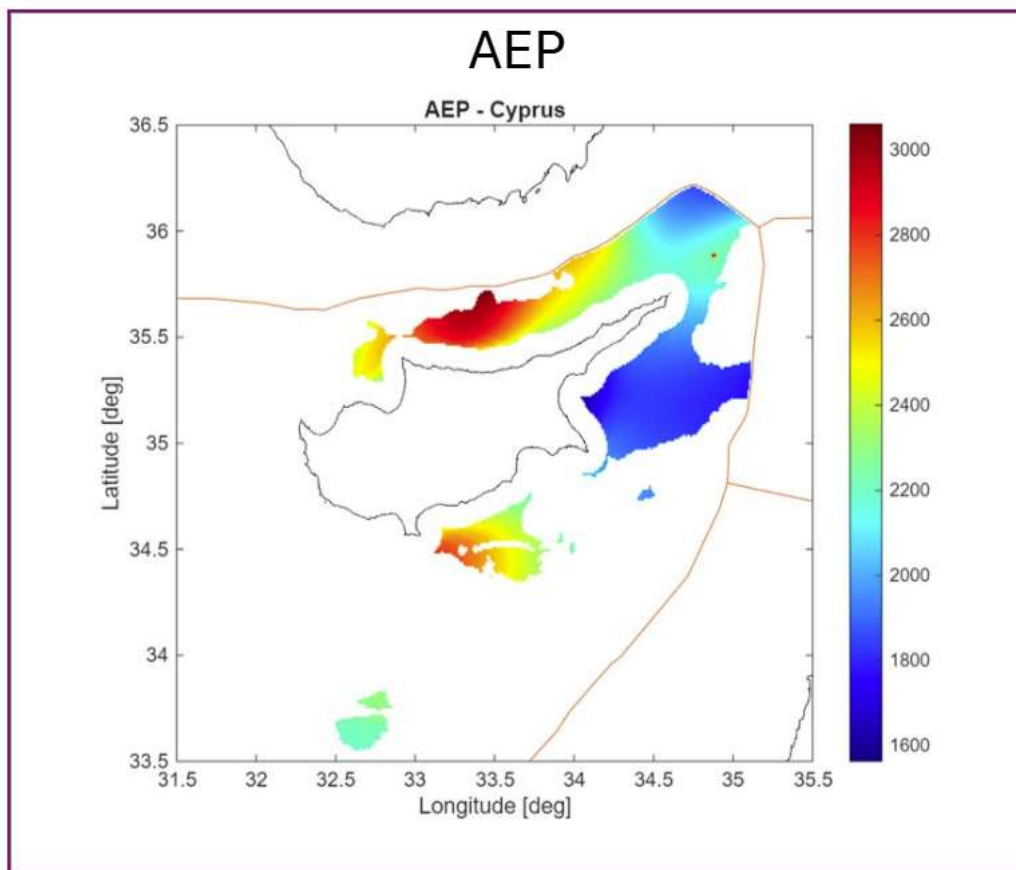


Figure 7: OWT annual energy production (AEP) in Cyprus

Directional Stability: The predominance of persistent wind directions reduces wake losses and facilitates optimized array layouts for floating wind farms.

Figure 7 illustrates the spatial distribution of Annual Energy Production (AEP) within the Cypriot Exclusive Economic Zone, highlighting areas with high production potential concentrated mainly in the southern and eastern offshore blocks. These regions benefit from strong and steady wind



conditions while maintaining sufficient distance from the coastline to minimize visual impact.

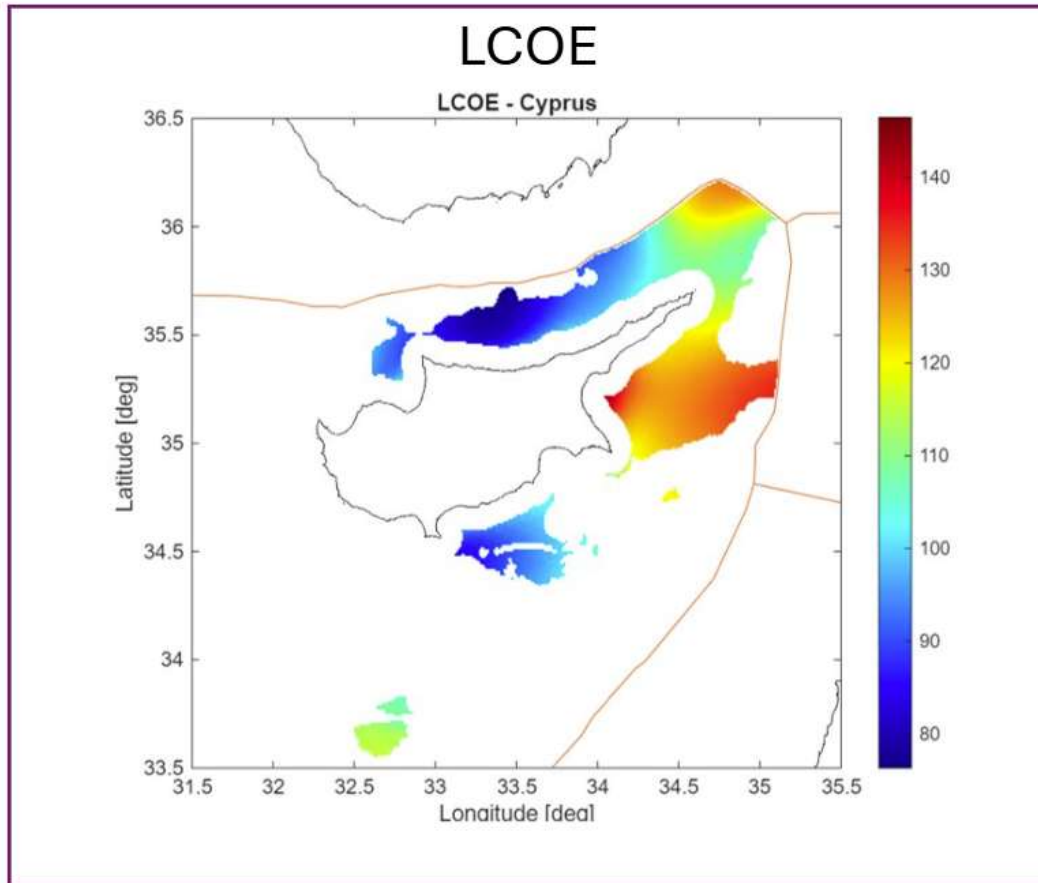


Figure 8: Levelised Cost of Energy from OWTs in Cyprus

The techno-economic assessment performed using the SPOWIND WebGIS tool evaluates the cost-effectiveness of floating offshore wind solutions. Figure 8 presents the spatial distribution of the Levelised Cost of Energy (LCOE), showing a minimum value of 76.3 and a mean of 110.3 €/MWh, with higher costs generally associated with increased distance from shore and deeper water depths.

Cyprus		
Technical Potential	34,19	TWh/y
Suitable Area	15408	Km ²





LCOE min (mean)	76,3 (110,3)	€/MWh
AEP max (mean)	3,06 (2,2)	TWh/y

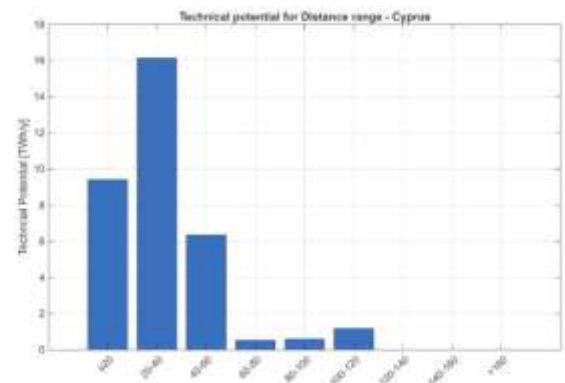
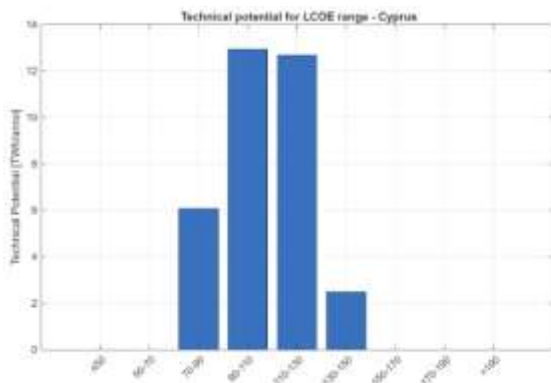


Figure 9: Technical potential for LCOE range (panel a) and Distance range (panel b) for the Cyprus' Economic Exclusive Zone

Figure 9 provides the technical potential divided by LCOE ranges and by distance from shore. It is possible to notice that the potential slice near the minimum represents a small part of the total.

After applying environmental, navigational, and technical constraints, the following results were obtained for the Cyprus case study:

Suitable Area: Approximately 15,408 km² identified as eligible for offshore wind deployment.

Technical Potential: An estimated energy yield of 34.19 TWh/year.

Mean LCOE of 110.3 €/MWh and minimum of 76.3 €/MWh.

Mean AEP of 2.2 TWh/y and maximum of 3.06 TWh/y.

Dominant Technology: Floating offshore wind platforms, due to the prevailing deep-water conditions.

The Cyprus case study demonstrates the strategic relevance of floating offshore wind in the Levantine Basin, confirming that despite higher costs compared to bottom-fixed solutions, the high wind consistency and large available offshore areas provide a solid foundation for long-term offshore wind development.



6.4. Case study- Italy

The Italy case study represents one of the most significant contributions within the SPOWIND project, due to the extensive maritime space available and the wide range of bathymetric conditions across the Adriatic, Ionian, and Tyrrhenian Seas. Italy exhibits the largest offshore wind technical potential among the analyzed countries.

The wind resource offshore Italy shows substantial spatial variability but overall strong potential:

Wind Resources: High mean wind speeds are observed in several offshore corridors, particularly in the southern Adriatic and Ionian Seas, supporting high annual energy yields.

Technological Diversity: The coexistence of shallow and deep waters allows for the deployment of both bottom-fixed and floating offshore wind technologies.

Figure 10 presents the spatial distribution of Annual Energy Production (AEP) across the Italian maritime zones, highlighting extensive high-productivity areas offshore, particularly where deep-water floating solutions can exploit stronger and more persistent winds.

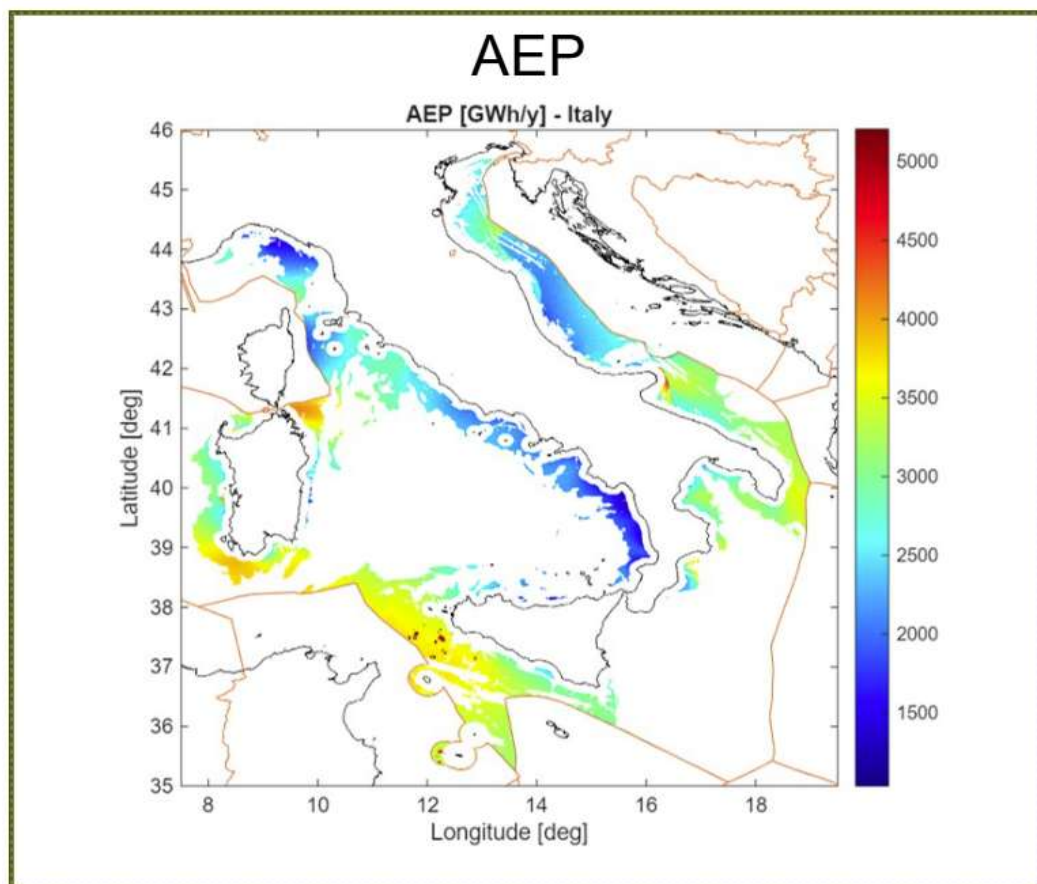


Figure 10: OWT annual energy production (AEP) in Italy

The economic performance of offshore wind in Italy is evaluated through the LCOE mapping shown in Figure 11. The results indicate competitive cost levels, with minimum LCOE values reaching approximately 57.75 €/MWh and a mean value of 92.49 €/MWh. Lower LCOE values are generally associated with areas closer to shore or with favorable grid connection opportunities.

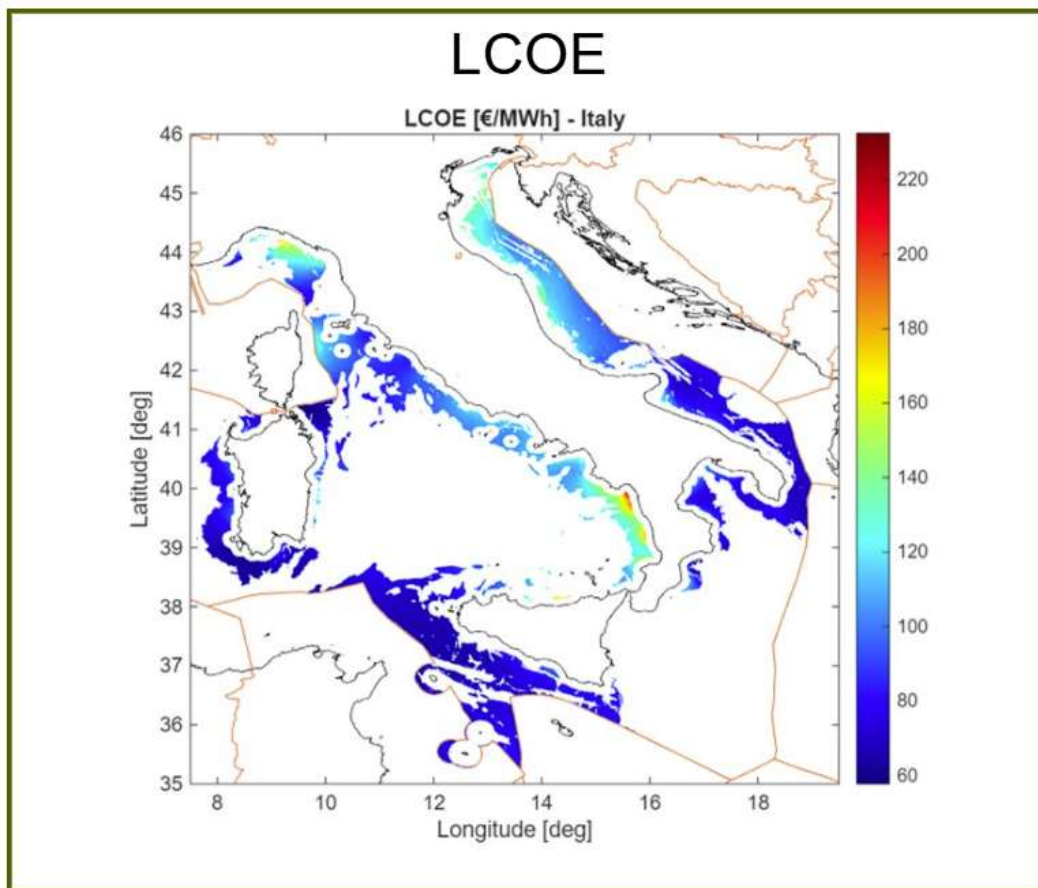


Figure 11: Levelised Cost of Energy from OWTs in Italy.

Figure 12 provides the technical potential divided by LCOE ranges and by distance from shore. A good slice of the total is between the mean and the lower LCOE value enhancing opportunity for these technologies.

The application of the integrated spatial planning methodology yields the following key indicators for Italy:

Suitable Area: Approximately 149,160 km² identified as suitable for offshore wind development.

Technical Potential: An estimated offshore wind potential of 431.26 TWh/year.

Mean LCOE of 92.49 €/MWh and minimum of 57.75 €/MWh.

Mean AEP of 2.90 TWh/y and maximum of 5.20 TWh/y.



Dominant Technologies: A combination of bottom-fixed turbines in shallower areas and floating platforms in deeper offshore zones.

Italy		
Technical Potential	431,26	TWh/y
Suitable Area	149'160	Km ²
LCOE min (mean)	57,75 (92,49)	€/MWh
AEP max - mean	5,20 (2,90)	TWh/y

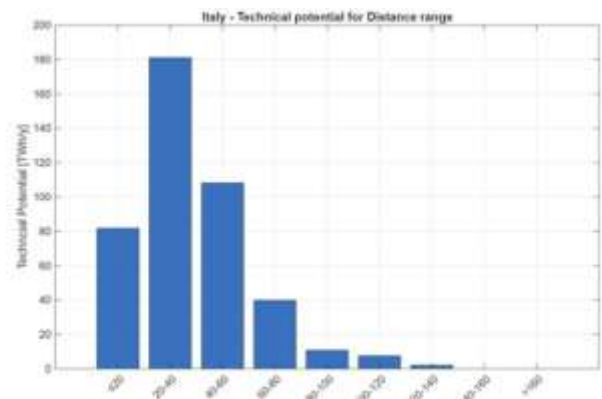
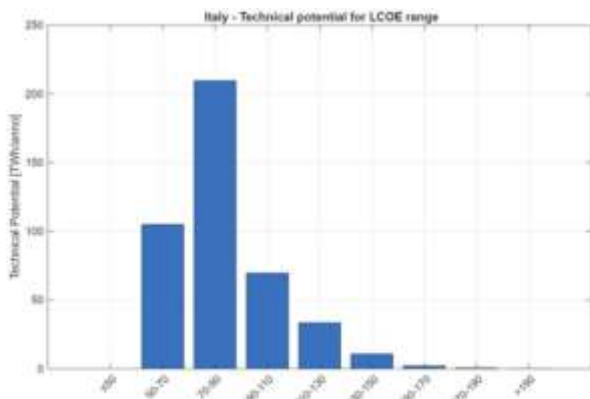


Figure 12: Technical potential for LCOE range (panel a) and Distance range (panel b) for the Italy's Economic Exclusive Zone

The Italian case study highlights the strategic role of offshore wind in supporting national decarbonization goals. The large available area, combined with competitive cost levels, confirms Italy as a key candidate for large-scale offshore wind deployment in the Mediterranean basin.

6.5. Case study- Montenegro

The Montenegro case study focuses on a relatively small but strategically relevant offshore area in the Southern Adriatic. The narrow continental shelf and rapidly increasing water depths make floating offshore wind the most suitable technological option for this region.

The offshore wind resource in Montenegro is influenced by Adriatic wind systems, offering favorable conditions for energy production:



Wind Resources: Offshore areas exhibit sufficient wind speeds to ensure technical feasibility, particularly beyond the nearshore zone.

Spatial Constraints: The limited extent of the maritime area requires careful optimization to balance energy yield, environmental protection, and distance to shore. Figure 13 shows the spatial distribution of Annual Energy Production (AEP) within the Montenegrin Exclusive Economic Zone. The highest production values are concentrated in deeper offshore regions where floating platforms can be deployed efficiently.

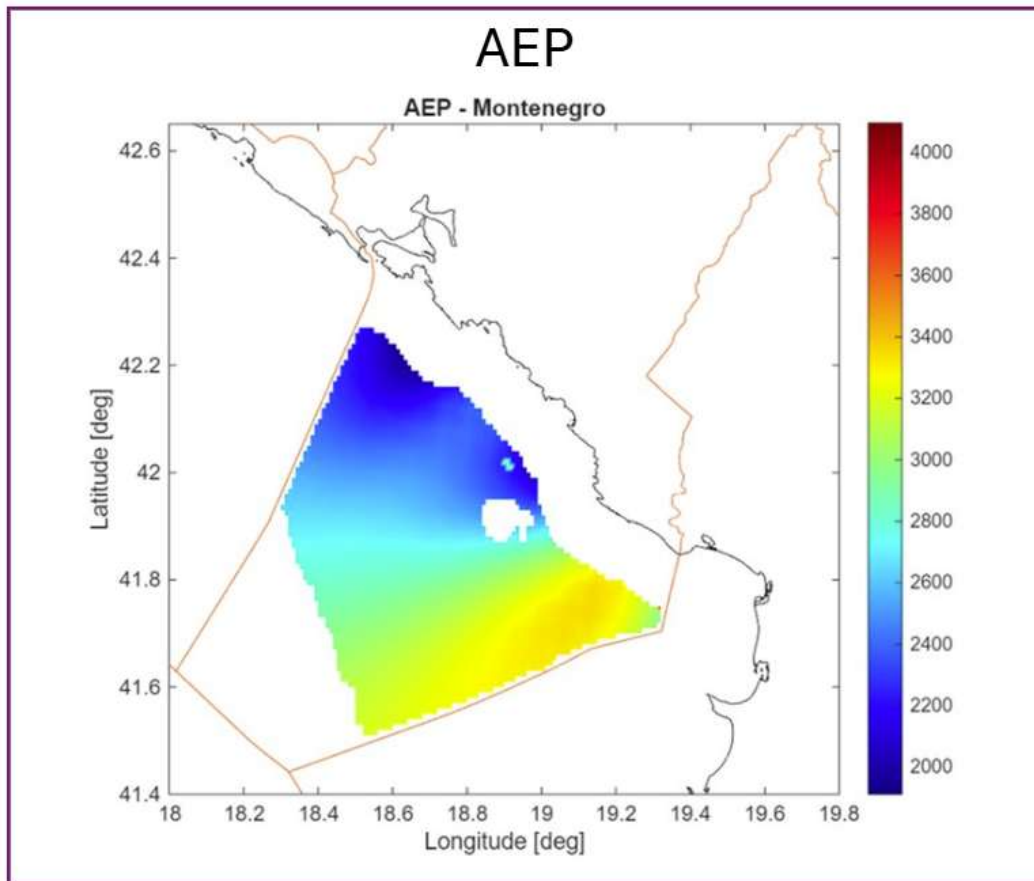


Figure 13: OWT annual energy production (AEP) in Montenegro

The economic assessment, illustrated in Figure 14, indicates LCOE minimum value of approximately 69.6 €/MWh and a mean of 88.48 €/MWh. These results suggest a relatively competitive cost structure, supported by moderate distances from shore and favorable wind conditions.

Figure 12 provides the technical potential divided by LCOE ranges and by distance from shore. A good slice of the total is between the mean and the lower LCOE value enhancing

opportunity for these technologies.

The resulting indicators for the Montenegro case study are summarized as follows:

Suitable Area: Approximately 4,349 km² identified as eligible for offshore wind development.

Technical Potential: An estimated energy yield of 12.18 TWh/year.

Mean LCOE of 88.48 €/MWh and minimum of 69.6 €/MWh.

Mean AEP of 2.73 TWh/y and maximum of 4.1 TWh/y.

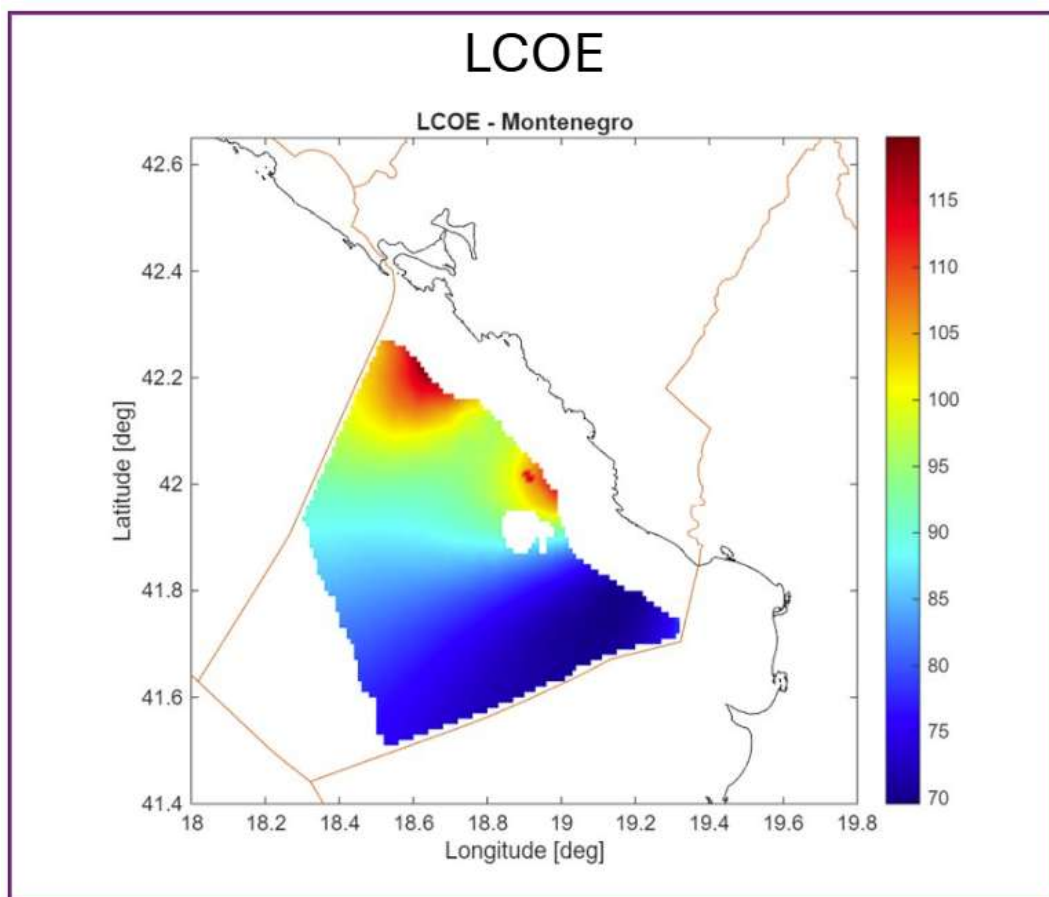


Figure 14: Levelised Cost of Energy from OWTs in Montenegro

Dominant Technology: Floating offshore wind platforms, due to the prevailing deep-water bathymetry.



Montenegro		
Technical Potential	12,18	TWh/y
Suitable Area	4349	Km ²
LCOE min (mean)	69,6 (88,48)	€/MWh
AEP max (mean)	4,1 (2,73)	TWh/y

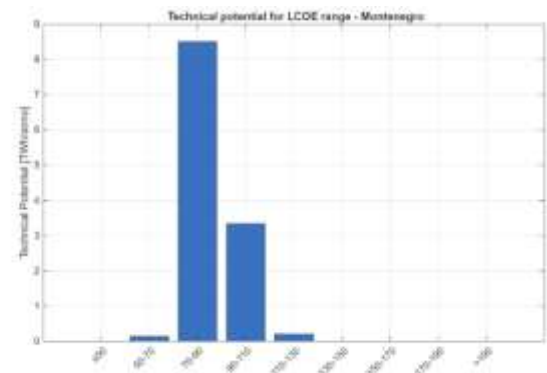
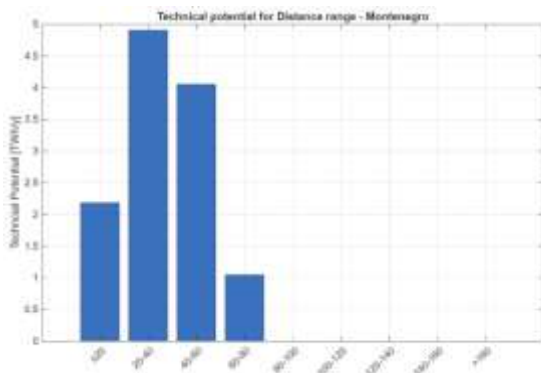


Figure 15: Technical potential for LCOE range (panel a) and Distance range (panel b) for the Montenegro's Economic Exclusive Zone

Despite its relatively limited spatial extent, the Montenegro case study demonstrates that offshore wind can contribute meaningfully to the national and regional energy mix, particularly when integrated into a broader Adriatic offshore wind strategy.

4. Conclusions

The SPOWIND project has successfully demonstrated that the integration of Marine Spatial Planning (MSP) with advanced geospatial modeling is essential for the sustainable growth of offshore wind (OFW) energy in the Mediterranean and Adriatic basins. Through the development and validation of the WebGIS tool, the project has transitioned from a theoretical methodology to a practical framework capable of guiding large-scale investment and policy decisions.

The synthesis of findings from the six partner regions—Italy, Croatia, Albania, Montenegro, Cyprus, and Greece—reveals a significant technical potential for renewable energy that can be





realized while maintaining ecological integrity and social harmony.

The case studies conducted across the partner regions—Italy, Croatia, Albania, Montenegro, Cyprus, and Greece—reveal a substantial and diverse technical potential for offshore wind.

- **Large-Scale Energy Generation:** The project identified significant technical potentials, ranging from 431.26 TWh/y in Italy to 22.15 TWh/y in Albania, illustrating that the Mediterranean can play a decisive role in the European Union’s decarbonization targets.
- **Cost Competitiveness:** The techno-economic assessments indicate that while offshore wind currently faces higher construction costs, the Levelised Cost of Energy (LCOE) is becoming increasingly competitive. Minimum LCOE values as low as 57.75 €/MWh in Italy and 71.02 €/MWh in Croatia suggest that strategic site selection can significantly mitigate the financial drawbacks of offshore deployment.
- **Technological Adaptation:** The abrupt depth variations of the Mediterranean necessitate a dual approach, utilizing bottom-fixed technology for shallower shelves (e.g., Albania) and floating platforms for deeper offshore zones (e.g., Greece and Italy).

The following table summarizes the key spatial and economic indicators across the project areas, highlighting the diverse technical potential identified by the WebGIS tool:

Country	Suitable Area (Km ²)	Technical Potential (TWh/y)	Min LCOE (€/MWh)	Dominant Technology
Italy	149,160	431.26	57.75	Floating / Fixed
Greece	118,520	382.40	62.10	Floating
Croatia	30,647	134.19	71.02	Fixed / Floating
Cyprus	12,450	45.10	85.30	Floating
Montenegro	4,349	12.18	69.60	Floating
Albania	5,820	22.15	89.00	Bottom-fixed

A core achievement of the SPOWIND methodology is the operationalization of an Ecosystem-Based Maritime Spatial Planning (EB-MSP) approach. By strictly excluding Natura 2000 sites and core protected zones (e.g., National Parks Kornati and Mljet), the project ensures that the transition to a low-carbon future does not compromise marine biodiversity. This process prioritizes the preservation of biodiversity by establishing clear exclusion zones and buffers around high-value ecological sites:





- **Environmental Stewardship:** By strictly excluding Natura 2000 sites and National Parks (e.g., Kornati, Mljet) from the suitable areas, the WebGIS tool ensures that energy production does not come at the expense of marine biodiversity or sensitive habitats.
- **Conflict Mitigation:** The tool effectively rationalizes the use of marine space by detecting and avoiding overlaps with existing maritime activities such as shipping lanes, traditional fishing grounds, and underwater cultural heritage.
- **Landscape Preservation:** The use of visual impact buffers (typically 10–20 km from the shore) addresses the critical need for social acceptance, protecting the aesthetic value of the coastline which is vital for the Mediterranean’s tourism-based economies.

To effectively categorize maritime space, the methodology applies specific buffers that determine the suitability of a given cell. These constraints balance energy goals with societal and environmental priorities.

Environmental Category	Constraint Type	Standard Buffer / Rationale
National & Nature Parks	Hard Exclusion	100% Exclusion from the legal boundaries of the park.
Natura 2000 Sites	High-Priority Avoidance	Avoidance "as much as possible" to ensure maximum sustainability.
Coastal Buffer	Soft Constraint	Typically, 10–20 km from the shore to minimize visual impact and protect coastal tourism.
Wildlife Corridors	Mitigation	Analysis of migration paths to ensure minimal conflict with avian and marine mammal populations.

While the WebGIS tool provides an automated initial identification of suitable areas, it does not replace the mandatory legal procedures required for project approval. Every identified site must undergo:

- **Environmental Impact Assessment (EIA):** A site-specific study to evaluate potential disturbances to local marine life.
- **Appropriate Assessment:** A dedicated evaluation of the impact on Natura 2000 sites, conducted according to current national and EU legislation.

By integrating these environmental data layers, the SPOWIND project ensures a "rational use of marine space" that balances the urgent need for decarbonization with the long-term protection





of Mediterranean ecosystems.

To move from planning to implementation, the project highlights three critical areas for future development:

- **Infrastructure Synergy:** Future investments must prioritize upgrading port capacities (e.g., Ravenna, Split, or Limassol) and reinforcing onshore electrical grids to handle the transmission of large-scale offshore power.
- **Technological Versatility:** The Mediterranean's steep bathymetry requires continued focus on floating offshore wind platforms, which represent most of the identified technical potential in deep-water regions.
- **Transboundary Collaboration:** As energy infrastructure and environmental impacts cross national borders, regional energy security will depend on hybrid projects and shared grid connections between partner countries.

In conclusion, the SPOWIND WebGIS tool serves as a vital decision-support system for the Integrated Maritime Policy (IMP). It provides a scientifically grounded roadmap for Mediterranean countries to harness their vast wind resources, ensuring that the transition to renewable energy is both economically sound and ecologically responsible.





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