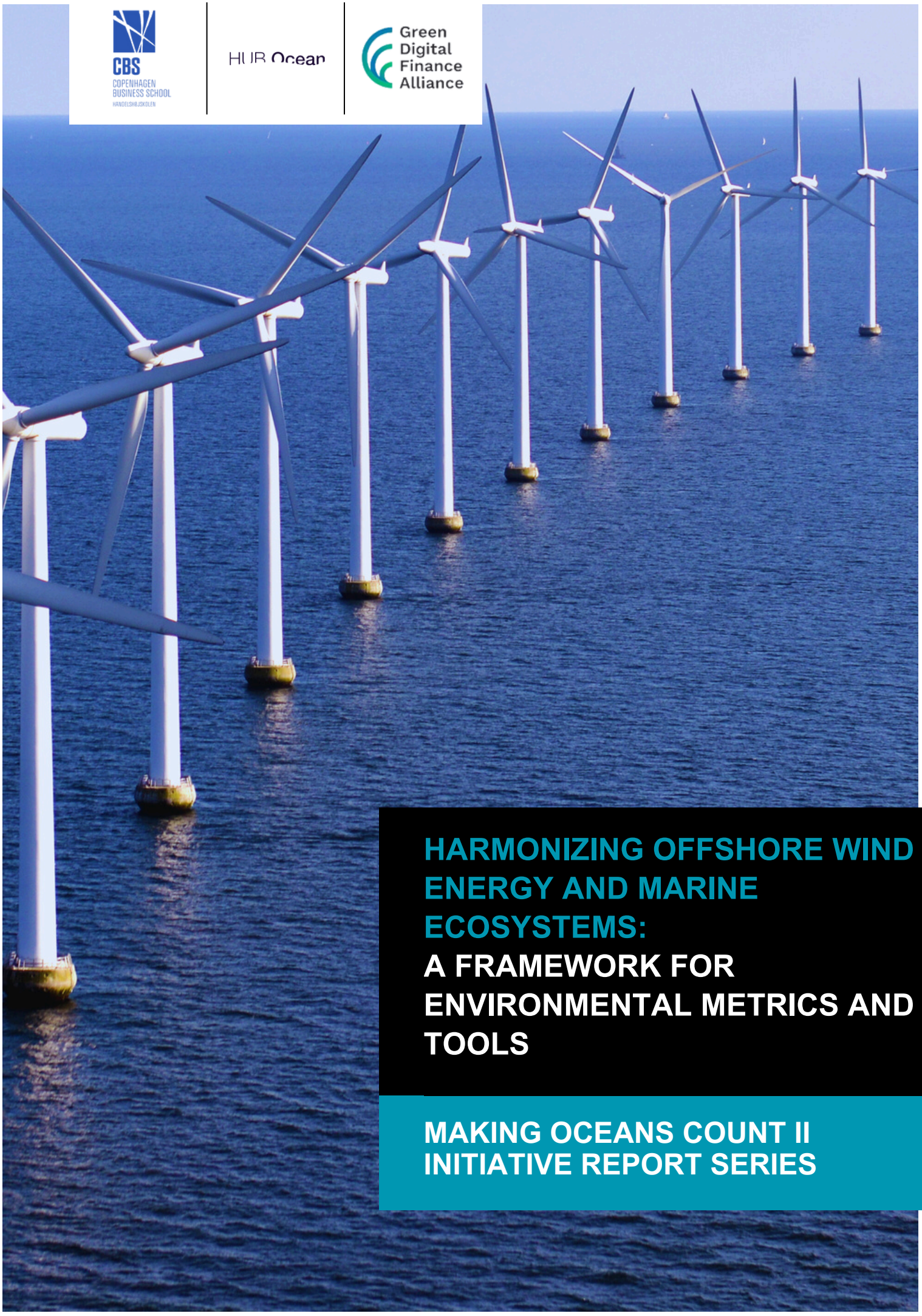

HARMONIZING OFFSHORE WIND ENERGY AND MARINE ECOSYSTEMS:
A FRAMEWORK FOR ENVIRONMENTAL METRICS AND TOOLS

MAKING OCEANS COUNT II INITIATIVE REPORT SERIES

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About the MOC II initiative

The initiative, supported by the VELUX FONDEN, has been implemented by a consortium comprising the Green Digital Finance Alliance, Copenhagen Business School, and Hub Ocean.

www.cbs.dk
www.greendigitalfinancealliance.org
www.hubocean.earth

THE MAKING OCEANS COUNT II INITIATIVE

The Making Oceans Count II (MOC II) project seeks to ensure that material marine ecosystem-related risks and opportunities are better integrated into the decision-making processes of key actors within the Nordic financial sector and the blue economy. Investors play a pivotal role in advancing the sustainability of marine environments, as well as protecting and restoring their biodiversity.

The initiative, supported by the Danish VELUX FONDEN, is implemented by a consortium comprising Copenhagen Business School, the Green Digital Finance Alliance, and Hub Ocean. The project has also benefited from the active participation and insights of financial institutions and data providers from the Nordic region and internationally.

In its current phase, Making Oceans Count II, the project focuses on scoping and addressing the needs of the sustainable blue economy and finance. The long-term ambition is to leverage ocean-related data to develop insightful and actionable ocean (ESG) metrics tailored for investors and industries exposed to the marine environment.

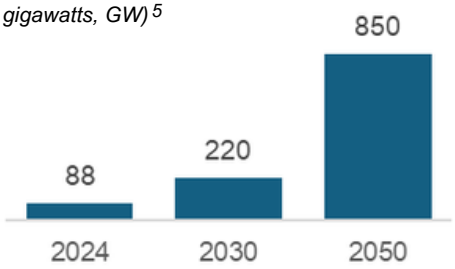
By aligning ocean data with the needs of financial and ocean-based industry decision-makers, the MOC initiative aspires to drive meaningful contributions toward a sustainable blue economy.

INTRODUCTION

Balancing Renewable Energy Growth and Environmental Sustainability

Over the last two decades, the offshore wind energy sector has evolved into a mature, competitive, and globally scalable industry.[1] It plays a pivotal role in the renewable energy landscape, offering significant growth potential while contributing to global decarbonization efforts.[2] Recognising its importance, many countries are actively expanding the scale and scope of offshore wind farms,[3] positioning offshore wind energy as a vital solution for a sustainable energy mix, including reducing greenhouse gas emissions and achieving international climate targets.[4]

Figure 1: Projected growth of global offshore wind capacity (in gigawatts, GW) [5]



Global offshore wind capacity may reach 850 GW by 2050 - a 10-fold increase.

As the number of offshore wind farms will increase, the environmental pressures and cumulative impacts posed by offshore wind farms will become more relevant, emphasizing the need for a balanced approach that considers their ecological impacts.[6]

Environmental considerations

Offshore wind farms impose environmental pressures on marine ecosystems during installation, operation, and decommissioning. Pressures are specific activities or processes that create stress on the environment, arising from human actions that affect ecosystems and species.[7] For the offshore wind sector, the marine pressures include in particular habitat disruption, including seabed disturbance, noise and water pollution, threats to marine wildlife, and greenhouse gas emissions.[6,8]

Impacts are the direct or indirect consequences of these pressures. They describe the outcomes that

pressures impose on natural systems, such as biodiversity loss, habitat degradation, ecosystem collapse, and climate change.[8] These impacts vary by region due to distinct ecological characteristics.[9]

Turbine installation can disturb benthic and coastal habitats (pressure), threatening sensitive and endangered species in biodiversity hotspots (impact). Activities such as artificial lighting and cable-laying (pressure) increase risks of entanglement, habitat degradation, and the displacement of native species (impact).[9] Additionally, noise from construction and turbine operation (pressure) poses a major threat to marine life (impact), which is already under pressure from overfishing, global warming, and acidification. This noise can disrupt behavior (pressure) and exacerbate existing environmental stresses (impact).[8]

Offshore wind farms create an artificial reef effect that impacts the entire food web. Turbine foundations provide new habitats, increasing biodiversity by attracting species that feed on rapidly colonizing fouling organisms. Over time, these structures form new ecosystems that transform the original environment (pressure). However, this can also facilitate the spread of non-native species, potentially outcompeting native ones (impact).[9,10]

Greenhouse gas emissions and other value chain-related pressures are indirectly linked to offshore wind farms through for example manufacturing, installation, demolition, and transportation. These life-cycle impacts, though often overlooked, are

significant and must be considered.[8]

Balancing ocean resource use with ecosystem protection is crucial.[6] Environmental risks and uncertainties pose non-technical barriers to offshore energy expansion, affecting consent processes and increasing costs.[11] Although legal frameworks aim to preserve ecosystems while exploiting marine resources,[6] updated and integrative scientific data is essential for understanding wind farm pressures and impacts and guiding informed planning.[11]

Challenges in linking nature-related risks to financial risks in offshore wind investments

The financial sector and renewable energy companies face significant challenges in addressing the relationship between offshore wind projects and natural ecosystems. Investors must understand how these projects rely on and affect natural capital, viewing and treating nature risks as both sustainability and financial risks (double materiality).[12]

Financial institutions and companies are increasingly expected to incorporate marine and biodiversity considerations into decision-making, with sustainable ocean investment metrics gaining importance.[13,14] However, many struggle to access actionable data to evaluate and manage ocean-related impacts, as translating public primary data into investment- and project-relevant insights remains a key challenge. Limited corporate disclosures and access to asset-level and site specific data, particularly geolocated data and environmental metrics, further complicate the assessment of companies' contributions to ocean pressures and their impact on marine ecosystems.[13]

Therefore, a well-defined ESG framework is crucial for addressing these challenges, as it provides a structured approach to assessing sustainability-related risks and opportunities. In this context, ESG criteria serve as a foundation for integrating environmental, social, and governance considerations into corporate strategy and investment decision-making.[15] This report specifically focuses on the environmental dimension of ESG criteria, emphasizing the need for robust environmental metrics. Based on the criteria outlined here, environmental metrics will be developed within the MOC II initiative for offshore wind farms to enhance the evaluation of ocean-related impacts and support sustainable investment practices. The primary objective of these metrics will be to accurately reflect a firm's performance concerning specific ESG criteria,[16] ensuring a comprehensive assessment of its environmental impact and sustainability practices.

EXTERNAL CONTEXT

Addressing Key Industry Challenges, Growth Drivers, and Regulatory Standards for Advancing Ocean-Related Environmental Metrics

Industry assessment

The offshore wind industry is highly capital-intensive, driven by technological innovation, and operates within a complex regulatory framework. Significant upfront investments limit market access to large, financially robust firms, though falling renewable energy costs are opening doors.[1,17] Advancements like efficient turbines and floating platforms enable market expansion, but companies slow to adopt such innovations risk losing competitiveness.[4,18]

Government support, such as subsidies and revenue-stabilizing frameworks like Contracts for Difference, is a key growth driver, though future cuts could threaten projects.[4,19] Meeting environmental metrics enhances investment appeal, as offshore wind is critical to decarbonization.[20] However, global supply chains reliant on international components face risks from geopolitical or logistical disruptions.[21]

Regulatory challenges and environmental concerns further shape the industry. Strict permitting processes, marine ecosystem impacts, and fisheries-related public resistance can delay projects and increase costs, making proactive stakeholder engagement vital.[4, 22]

In summary, the offshore wind sector offers growth opportunities through innovation, government support, and environmental investments but faces hurdles from high costs, regulatory complexities, and supply chain vulnerabilities. Success depends on firms' ability to adapt and lead in the global clean energy transition.

Regulatory basis

To develop ocean-related environmental metrics for the offshore wind industry within the MOC II initiative, relevant regulations and voluntary standards must be considered. This includes adhering to legal requirements and integrating industry-specific sustainability standards from the EU, alongside globally recognized frameworks, to ensure international applicability.

The combination of binding regulations and voluntary standards creates a sense of urgency for industry players and financial institutions, as they must rapidly adapt to meet emerging expectations. Capturing Impacts, Risks, and Opportunities (IROs) associated with marine ecosystems is essential for regulatory compliance and sustainability alignment. This integrated approach enables the development of transparent environmental criteria that promote informed decision-making, guide investments, and support the sustainable use of marine resources.

The evolving regulatory landscape, as detailed in Table 1, highlights the critical need for proactive compliance measures and the adoption of forward-thinking strategies. As new mandates emerge, stakeholders must stay ahead by embedding sustainability into core business practices, ensuring competitiveness and fostering trust among investors and regulators alike.

Table 1: Non-exhaustive list of ocean-related regulations and standards relevant for EU investors

Regulations/Standards	Compliance	Issuer	Description
Corporate Sustainability Reporting Directive (CSRD)[23]	**Mandatory**	EU	Requires companies to **disclose ESG information** to increase transparency and accountability. Relevant reporting standards include European Sustainability Reporting Standards (**ESRS) E1-E5** for **climate change, marine resources, and biodiversity**. Emphasizes **double materiality assessment**.
EU Taxonomy[24]	**Mandatory**	EU	**Classification system** for environmentally sustainable economic activities **to direct investments**. Relevant sections include Annex I and II, requiring adherence to the **'Do No Significant Harm'** DNSH **principle**, promoting marine biodiversity protection.
Sustainable Finance Disclosure Regulation (SFDR) [25]	**Mandatory**	EU	Mandates **financial market participants** to **disclose integration of sustainability risks**. Covers Articles 6, 8, and 9, focusing on adverse impacts on marine ecosystems and biodiversity.
Marine Strategy Framework Directive (MSFD) [26]	**Mandatory**	EU	**Defines objectives for marine environment protection**. Includes descriptors for good environmental status. Addresses biodiversity, seafloor integrity, pollution, and marine litter.
Renewable Energy Directive (RED) [27]	**Mandatory**	EU	Sets **binding targets for renewable energy expansion**. Focuses on sustainable practices and the integration of renewable energies.
Taskforce on Nature-related Financial Disclosures (TNFD)[28]	**Voluntary**	Independent	Framework for **disclosing nature-related risks and opportunities**. Focuses on biodiversity and ecosystem degradation, including marine impacts.
Global Reporting Initiative (GRI)[29]	**Voluntary**	Independent	Provides a **global standard for ESG reporting**. Relevant standards include GRI 101, 303, 305, and 306, covering biodiversity, emissions, and marine habitat protection.
International Financial Reporting Standards (IFRS S1[30] **and S2**[31] **)**	**Voluntary**	Independent	Framework for **sustainability-related financial reporting**. IFRS **S1** covers **material sustainability risks**, while IFRS **S2** focuses on **climate-related disclosures**.
Sustainability Accounting Standards Board (SASB) [32]	**Voluntary**	Independent	**Industry-specific standards** for wind energy sector. Includes metrics on biodiversity, GHG emissions, and waste management.
United Nations Sustainable Development Goals (SDGs)[33]	**Voluntary**	United Nations	**Global framework for sustainable development**. Key goals include SDG 6, 7,12, 13, and 14, focusing on marine ecosystem protection and renewable energy promotion.
Global Biodiversity Framework (GBF) [34]	**Voluntary**	Independent	**Sets global biodiversity protection targets**. Relevant goals include spatial planning, pollution reduction, and sustainable marine ecosystem management.
United Nations Sustainable Ocean Principles (UN SOP) [35]	**Voluntary**	United Nations	**Framework for responsible ocean-related practices**. Emphasizes ocean health, governance, and stakeholder collaboration.
Science based Target for Nature (SBTN)[36]	**Voluntary**	Independent	**Framework for science-based targets** on biodiversity, freshwater, land, ocean, and climate, aligning corporate strategies with global sustainability goals.

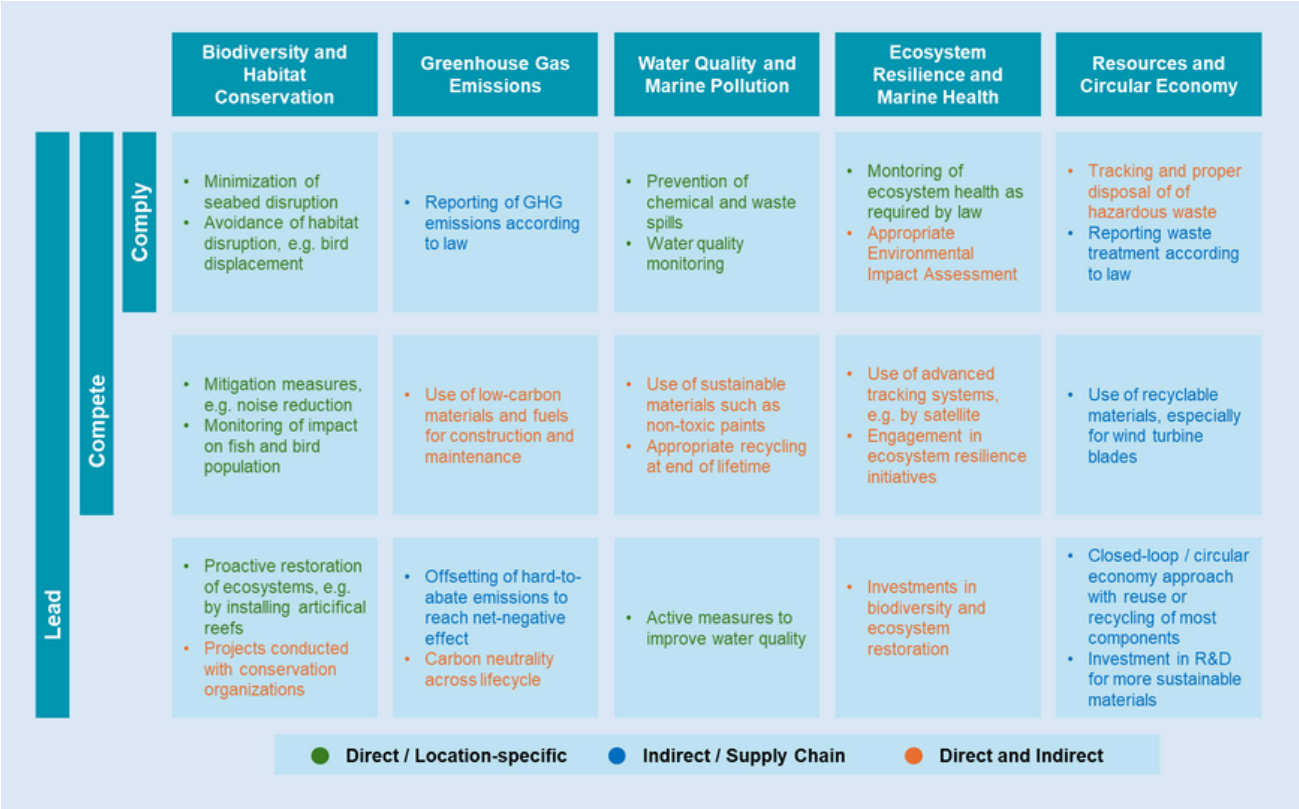
POTENTIAL PATHWAYS FOR BLUE ECONOMY INVESTORS

Environmental Criteria and Tools for Offshore Wind Farms and Developers

Environmental criteria

The environmental criteria, developed through a literature review, focus on the impact of offshore wind farms on ocean ecosystems and compliance with relevant regulations. Using a double materiality approach aligned with the CSRD,[23] 44 criteria were identified to assess ecosystem pressures and impacts during construction, operation, and decommissioning, alongside associated risks and opportunities. These criteria were organized into a matrix (Illustration 1) to ensure alignment with standards.

Illustration 1: Matrix of relevant environmental criteria for offshore wind



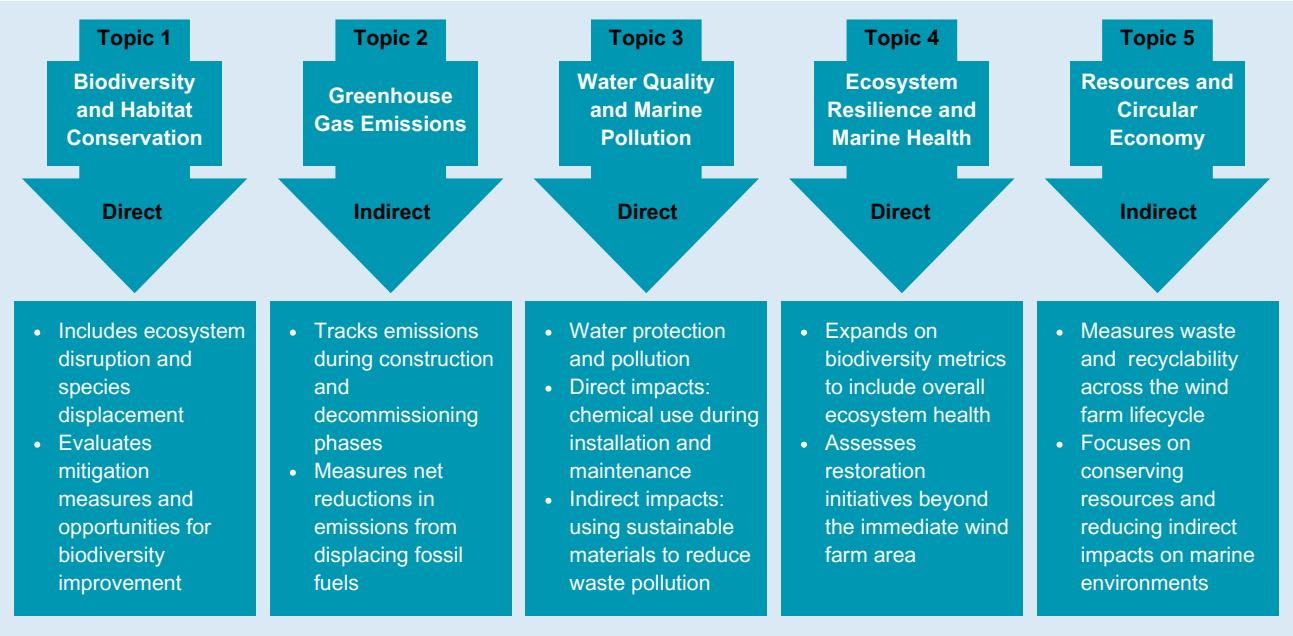
The criteria emphasize systemic change rather than isolated goals, promoting sustainable structures (e.g., circular manufacturing) and aligning with the mitigation hierarchy.[37] The criteria are structured into three ambition levels (Illustration 2):

Illustration 2: Ambition levels

Ambition level	Mitigation hierarchy	Description
Comply	Avoid and minimize harm	• Focuses on criteria necessary for **legal compliance** • Includes principles like the EU Taxonomy's "do no significant harm" • Covers standards for material negative impacts and risks, as defined by frameworks such as ESRS and GRI
Compete	Achieves reductions	• Builds on compliance criteria by addressing risks and opportunities **beyond legal requirements** • Enables substantial contributions aligned with the EU Taxonomy • Supports alignment with EU Taxonomy investments and enhances industry competitiveness
Lead	Includes conservation and restoration efforts	• Incorporates compliance and competitive criteria while setting **new sustainability benchmarks** for "positive nature impacts" • Reflects systemic change and aligns with the GBF • Encourages innovative sustainability practices and positions companies as industry leaders through positive deviance

The environmental criteria are categorized into five topics:

Illustration 3: Topics



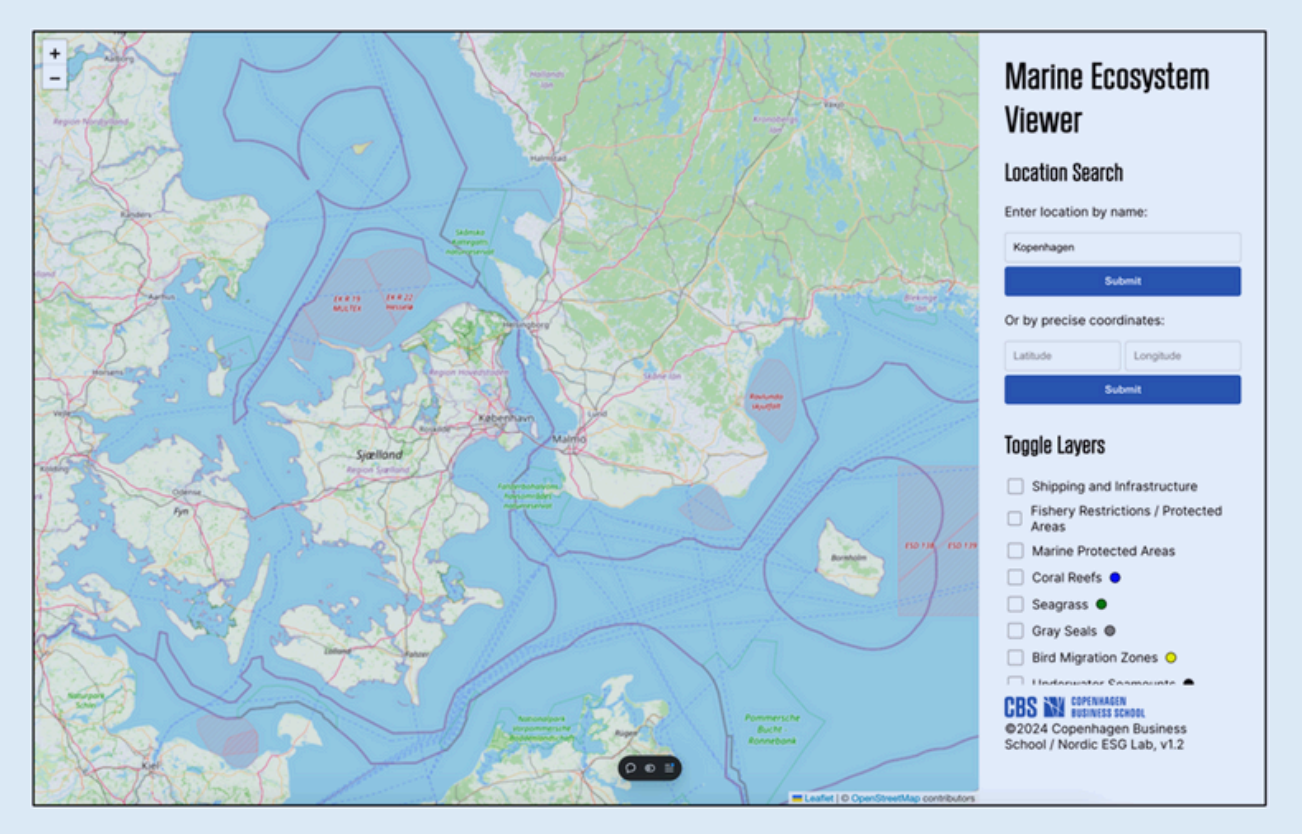
Topics 1, 3, and 4 prioritize location-specific (direct) factors, while Topics 2 and 5 address indirect impacts across the value chain. These categories align with ESRS environmental topics, regulatory requirements, and investor expectations, ensuring comprehensive coverage of offshore wind farm environmental pressures, impacts, and opportunities.

Rather than providing direct quantifiable measurements, these criteria establish a structured framework that ensures alignment with existing standards while facilitating a systematic understanding of environmental interactions. As part of the MOC II initiative, this framework will be instrumental in the further development of quantifiable metrics, ultimately enabling a more robust and data-driven approach to evaluating offshore wind energy's environmental footprint.

Prototype ecosystem map

An ecosystem map was developed by the CBS project work to help financial investors and stakeholders identify location-specific metrics. The tool allows users to explore qualitative geolocated environmental data to assess potential pressures and negative environmental impacts of offshore wind farms. It features a global map of proposed development areas and surrounding ocean regions, overlaid with data visualizing ocean ecosystems, flora and fauna, and infrastructure.

Illustration 4: Prototype ecosystem map (Link: https://ocean-ecosystem-risk-viewer.vercel.app/)



Data for the prototype layers were sourced from the UNEP WCMC's Ocean Data Viewer, which provides datasets on marine and terrestrial ecosystems, such as marine mammal occurrences, coral reefs, and seagrass. Additional layers include bird migration corridors, fishery exclusions, and marine protected areas. Infrastructure and shipping lane data were integrated from OpenStreetMap and OpenSeaMap projects. These layers were combined into a geo-information system that allows users to search by location or GPS coordinates and select relevant data layers.

The Ocean Viewer will complement the metrics to be developed based on the designed environmental criteria, enabling detailed site analysis through visualized geolocated data on infrastructure, environmental restrictions, and biodiversity. This analysis supports metric selection specific to each site while highlighting potential risks for systematic assessment. Together, the ecosystem map and environmental metrics will form a strong foundation for informed decision-making and risk assessment in offshore wind farm planning and implementation.

INTEGRATING ENVIRONMENTAL SUSTAINABILITY INTO DECISION-MAKING

Stakeholder Feedback, Prototyping and Regulatory alignment

Five interviews with three industry experts (Ørsted and two anonymous firms) and two academics (a Professor at University of Hamburg (UHH) and Sustainability Reporting Technical Expert Group (SRB) member of European Financial Reporting Advisory Group (EFRAG), and a Professor at DTU Aqua) provided positive and constructive feedback on on both the environmental criteria and prototype ecosystem map.

Stakeholder feedback on the environmental criteria

Table 2 summarizes stakeholder feedback on the environmental criteria. Several stakeholders appreciated the comprehensiveness of the matrix in addressing the critical environmental pressures and impacts of offshore wind farms. Each comment is categorized by topic and marked as included, planned for future updates, or not applicable (n/a). Key insights on the criteria include:

Table 2: Stakeholder feedback on environmental criteria

Topic	Who	Statement	Included
Relevance and feasibility	Global infrastructure fund (anonymous)	"You are using the same taxonomy as we would (…). It's **easy to understand** and it follows **industry logic**"	**Yes**
Local and value chain perspectives	Global infrastructure fund (anonymous)	Suggested viewing **greenhouse gas emissions** and **waste disposal** from both local and value chain perspectives.	**Yes**
Alignment with standards	Professor Alexander Bassen, UHH (SRB member EFRAG)	Emphasized **aligning metric [environmental criteria] wording with sector-specific standards and regulations** to simplify compliance.	**Yes**
Species interactions	Professor Jens Petersen, DTU Aqua	Recommended adding **metrics for species interactions with infrastructure**, such as artificial reefs promoting biodiversity or introducing invasive species.	**Not yet**; proposed for future updates
Ambition at "lead" level	Professor Jens Petersen, DTU Aqua & Cat Hemmingsen, Biodiversity Advisor, Ørsted	Advocated for **greater ambition at the "lead" level** and stressed the need for **regular and timely updates** to metrics.	**Partially**; updates included
Prevention of superficial compliance	Cat Hemmingsen, Biodiversity Advisor, Ørsted	Highlighted the need to ensure companies **cannot "buy their way out" of compliance**, avoiding superficial compliance.	n/a

Use in investment decisions	Global infrastructure fund (anonymous)	Mentioned that they could use the matrix as **input in decision-making** for OWP investments. Suggested adding positive impact measures alongside a risk score grading system.	n/a

Stakeholder feedback on the prototype ecosystem map

Table 3 summarizes stakeholder feedback on the ecosystem map prototype. Similar to the feedback on the environmental criteria, the prototype of the ecosystem map received positive feedback. Each comment is categorized by topic and marked as included, planned for future updates, or not applicable (n/a).

Table 3: Stakeholder feedback prototype ecosystem map

Topic	Who	Statement	Included
Layered filters ease data collection	Cat Hemmingsen, Biodiversity Advisor, Ørsted	Commented on the prototype's layered filters, stating: "Especially in a **site selection planning phase**, it would be **beneficial** to have it in one place (…). I think it would be one **used in** a **risk screening**."	**Yes**
Integration of infrastructure and environment	Wind energy consultancy (anonymous)	**Appreciated** the **integration of infrastructure and environmental considerations**, saying: "This is something I haven't seen before".	**Yes**
Use in investment decisions	Global infrastructure fund (anonymous)	Mentioned that they could use the matrix and prototype as **input in decision-making** for offshore wind projects investments. Suggested **adding positive impact measures** alongside a **risk score grading system**. Acknowledged the **challenge** of the required extensive **data collection**.	n/a
Regional specificity of tool	Professor Jens Petersen, DTU Aqua	Stressed the need for **region-specific adaptation**, as "the maritime spatial planning in other countries is not identical". Recommended **including country-specific maps** for future research.	**Not yet**; proposed for future updates
Challenges of quantifying environmental risks	Wind energy consultancy (anonymous)	Highlighted the **difficulty of quantifying environmental risks** due to differing opinions and interpretations, emphasizing a **lack of industry benchmarks**.	n/a
Regular data updates	Wind energy consultancy (anonymous)	Emphasized the **importance of regular updates** to ensure the tool's relevance and quality in the evolving industry.	n/a

Managerial implications

Financial investors and industry stakeholders can leverage this type of prototype and approach – developed based on environmental criteria – to inform decision-making across all phases of offshore wind projects. At the initial stage, the location-specific map helps identify existing infrastructure, regulatory restrictions, and the potential impact on local flora and fauna. Based on these insights, relevant components of the matrix can be applied and fit-for-purpose metrics can be adopted. While most "comply" criteria are universally applicable, "compete" and "lead" criteria may vary depending on the location. Once the appropriate criteria are selected, the necessary data points can be determined.

Stakeholder feedback underscores the value of ESG criteria and ecosystem mapping in assessing ocean-related risks and opportunities, thereby enhancing decision-making processes. Adopting environmental metrics aligned with the identified criteria and prototype is strongly recommended to improve project planning, risk assessment, and regulatory

compliance. In the short term, these tools streamline project planning and approval processes, while in the long term, they support the integration of key sustainability metrics into operations.

Although financial investments in data collection, analytical tools, and continuous updates are required, there is a growing willingness among stakeholders to invest in biodiversity metrics, recognizing their increasing significance.

Additionally, organizational adjustments – such as training employees or hiring environmental and data experts – are essential to effectively implement and manage these sustainability initiatives.

Regulatory integration of metrics

Environmental metrics help companies meet mandatory requirements, particularly under the CSRD.

The environmental criteria, developed in alignment with the ESRS framework and other regulations, form the foundation for the metrics within the MOC II initiative. As these metrics will be built upon these criteria, they will facilitate efficient management and reporting of ocean-related environmental data. Illustration 5 demonstrates how each criterion aligns with specific ESRS requirements. For instance, the criterion “Energy Use” under CO2 emissions meets ESRS E1 (“Climate Change”) disclosure requirement E1-5, paragraph 35.[38]

The metrics’ alignment with CSRD ensures compliance with regulations, supports strategic decision-making, and reduces risks while driving positive environmental and economic outcomes.

Investors gain transparency and alignment with the EU Taxonomy and SFDR, strengthening the offshore wind industry’s position and advancing global sustainability goals.

Additionally, Environmental Impact Assessments (EIAs), mandatory for offshore wind parks in countries like Denmark, evaluate a project’s environmental impacts on nature, soil, water, air, and cultural heritage.[39] Conducted before tendering, EIAs optimize planning by covering offshore areas, cable routes, and land connections.

As ESG frameworks continue to evolve, they have the potential to complement data collection efforts for EIA process by aligning with regulatory and impact assessment requirements. While EIA has historically served as a foundational tool for assessing and evaluating environmental impacts, there is increasing discussion on how the EIA community can engage with the financial sector to highlight the value of EIA-based knowledge in sustainable finance.[40] This evolving interaction and interoperability of tools may open pathways for ESG metrics to enhance data availability for impact assessments over project life-cycles including cumulative impacts, thereby supporting compliance efforts and broader sustainability goals.

Illustration 5: Alignment with ESRS requirements

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
Biodiversity and Habitat Conservation	**Greenhouse Gas Emissions**	**Water Quality and Marine Pollution**	**Ecosystem Resilience and Marine Health**	**Resources and Circular Economy**
Complies with **ESRS E3 and E4**, addressing habitats, species displacement, and biodiversity measures	Aligns with **ESRS E1** by assessing life cycle emissions and net carbon intensity	Supports **ESRS E2, E3, and E5**	Matches **ESRS E4** standards	Addresses **ESRS E5** by focusing on circularity, recycling, and waste minimization

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