



Guiding Elements for Strengthening Cumulative Impact Assessment Regulations for Offshore Wind Energy

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Abstract

The multiple uses of marine space and the synergies among their effects require a systematic assessment of cumulative impacts, especially amid the growing blue economy and offshore wind expansion, which interact with existing human activities in an impacted seascape. Cumulative Impact Assessment (CIA) has become essential for systematically managing complex environmental interactions. Clear legal requirements for CIA are crucial to supporting better-informed decision-making, improving environmental governance, and fostering the implementation of CIA into practices. This study aims to compare the legal requirements related to CIA applied to the early planning and development phases of offshore wind energy (OWE) in the United Kingdom, the Netherlands, the United States, and Canada, offering guiding elements for designing or restructuring CIA regulations for offshore wind markets. We conducted a comprehensive scholarly and gray literature review to identify the key federal legislation related to CIA applied for OWE, which was then comparatively analysed using a set of core questions. The key findings are (1) Clear legislation is foundation to CIA practice; (2) Definition of cumulative impacts is key to guiding CIA implementation; (3) CIA requirements are crucial at various planning levels, from marine spatial planning to project-level assessments; (4) CIA regulations should consider collaboration, clear roles, and shared accountability among institutions and sectors; and (5) Stakeholder engagement and public consultation should be ensured throughout all the CIA steps. These elements may be used to support countries that have not yet adopted CIA, as well as those seeking to strengthen its implementation in offshore wind development.

Keywords Cumulative impacts · Environmental impact assessment · Marine and coastal environment · Marine and coastal management

Introduction

Offshore wind energy (OWE) is rapidly growing globally due to the expected shift to a low-carbon economy. While it offers climate benefits, it can also have a significant impact on marine biodiversity, fisheries, and coastal communities. Therefore, it is crucial to evaluate the environmental and social consequences of OWE expansion, along with other existing pressures and impacts in a region. Cumulative

impacts (or effects) are environmental changes caused by multiple interactions among human activities and natural processes that accumulate across space and time (CCME—Canadian Council of Ministers of the Environment (2014).

To assess these impacts, it is essential to understand how ecosystems respond to various disturbances caused by multiple stressors (Raoux et al. 2018), supported by principles and frameworks such as ecosystem-based management, integrated marine and coastal management, and the Sustainable Development Goals. In this context, the issues to be addressed regarding the expansion of OWE relate to ensuring its compatibility with the multiple uses of marine space (Schupp et al. 2021), including fishing, tourism, and oil and gas activities, while not jeopardizing biodiversity and the efforts to protect it. Managing incremental changes caused by continuum effects is considered the greatest challenge in marine management (Willstead et al. 2018a), calling for an assessment on how various activities and processes cumulatively impact the environment (Willstead

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et al. 2023). The lack of adequate assessment of cumulative impacts from offshore developments can severely impact sensitive species (Caine 2020).

Several countries have recognized the critical role of Cumulative Impact Assessment (CIA), also referred to as Cumulative Effect Assessment (CEA), in the strategic governance and management of coastal and marine ecosystems (Willstead et al. 2023). However, despite the increasing acknowledgment of cumulative impacts, challenges persist in leveraging its practice (Willstead et al. 2018b; Blakley and Russell 2022; Hollarsmith et al. 2022; Greaves and Parrott 2024), particularly in integrating CIA into policies and planning (Willstead et al. 2023). This may involve fragmented legislation and regulations, as well as policies that inadequately address cumulative impacts, along with a lack of guidance on assessing and managing these impacts (Davies et al. 2020; Olagunju et al. 2021).

Therefore, there is a pressing need for clearly defined policies and regulations that fully address cumulative impacts assessment to effectively reconcile environmental and socio-economic trade-offs (Kuempel et al. 2025). Clear and transparent requirements are needed to guide the effective implementation of CIA at both project and strategic levels (RenewableUK 2013), while regulatory and legislative frameworks play a pivotal role in integrating CIA into mainstream practices (Olagunju et al. 2021). Addressing these challenges requires concerted efforts from policymakers, practitioners, and stakeholders to develop cohesive strategies that improve the effectiveness of the CIA (Ma et al. 2012), based on sound scientific evidence.

Building on the recognition that understanding how requirements of cumulative effects are addressed in national EIA laws can facilitate implementation in other contexts and contribute to the development of international best practices (Nelson and Shirley 2023), and current CIA practices offer a valuable source of insight (Hague et al. 2022), this study aims to compare the legal requirements related to CIA applied to the early planning and development phases of OWE in the United Kingdom, the Netherlands, the United States and Canada, offering guiding elements for designing or reframing CIA regulations related to offshore wind markets. The chosen countries have either established OWE projects or are actively planning their development, ensuring relevance to the study's focus. They have also demonstrated concerns about cumulative impacts on marine and coastal environments, particularly related to interactions with other sectors. This paper is organized into six sections. Next section (Section “Cumulative Impact Assessment and Its Relevance to the Offshore Wind Energy Sector”) provides an overview of CIA and its importance in the context of offshore wind energy. The details of the research methods are presented next (Section “Method”). Section “Regulation Review” presents the results of the

regulatory review of CIA requirements in each selected country. The comparative analysis and the identification of guiding elements of CIA legislation, which may be valuable to other contexts, are addressed in Section “Comparative Analysis and Discussions on Guiding Elements of CIA Legislation”. Finally, Section “Conclusion” synthesises the guiding elements identified for strengthening CIA regulatory frameworks and suggests future research opportunities.

Cumulative Impact Assessment and Its Relevance to the Offshore Wind Energy Sector

Cumulative impacts are increasingly discussed in various countries, especially in jurisdictions with advanced marine management policies and legal frameworks at both the project and strategic levels, such as the European Union and the United Kingdom (Declerck et al. 2023; Willstead et al. 2023).

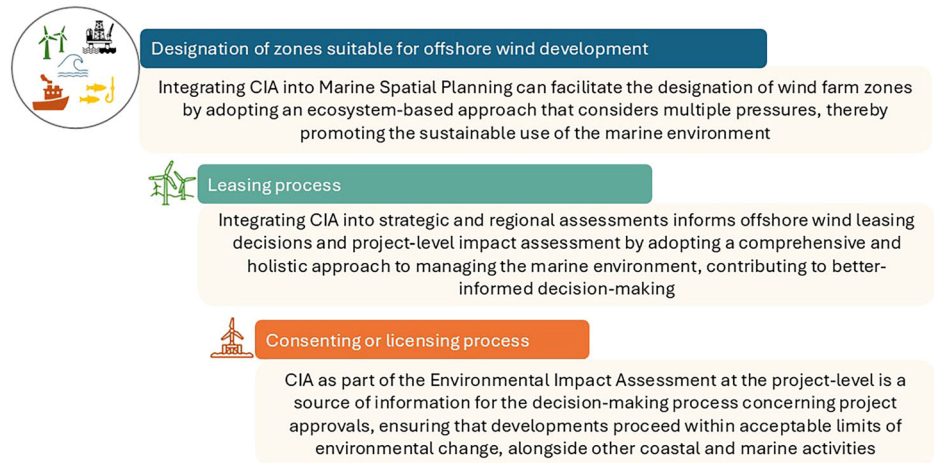
As cumulative impacts gain prominence in regulatory and planning discussions, CIA has become a vital tool for systematically addressing these complex interactions by establishing and evaluating connections among multiple activities that have various effects on different ecosystem components (Judd et al. 2015). By integrating CIA into decision-making, especially in regions with a high concentration of OWE developments, authorities can make better-informed choices by alleviating significant cumulative effects (Ma et al. 2009; Connelly 2011; IFC - International Finance Corporation (2013) and improving sectoral or regional planning (Harriman and Noble 2008).

Given the complexity of understanding cumulative effects, incorporating their assessment into spatial planning and environmental studies is crucial (Hernandez et al. 2021), particularly when multiple overlapping activities jeopardize ecosystem functions (Stephenson et al. 2019). Various CIA approaches can be applied at both project and strategic levels, each serving different roles and deliverables (Harriman and Noble 2008; Kaveney et al. 2015; Sinclair et al. 2022; Sánchez 2023). In addition to assessing challenges, the long-term monitoring of cumulative impacts remains a complex task in the context of OWE, as the identification of appropriate indicators necessitates consideration of ecological processes at broader spatial and temporal scales (Rezaei et al. 2023).

Cumulative impacts are especially pronounced when “different phases of OWF¹ development, happening simultaneously in an area, each have different pressures and impacts on the environment over different periods of time”

¹ Offshore wind farm.

Fig. 1 Main contributions of Cumulative Impact Assessment (CIA) to the early planning and development stages in the offshore wind energy sector.
Source: Prepared by the authors



(Nordic Energy Research 2022, p. 42). These impacts are often overlooked when assessing only a single wind farm (Köller et al. 2006). As an example of cumulative impacts of OWE, Berkenhagen et al. (2010) pointed out that the fisheries industry can be impacted by decreased opportunities to catch valuable species when several wind farms are proposed in the same region. Another potential cumulative impact arises from noise generated by pile driving at multiple wind farms, which can affect marine mammals at the population level (Bailey et al. 2014). Additionally, during decommissioning, increased vessel traffic and underwater noise can further contribute to cumulative disturbances affecting marine mammal populations (Hall et al. 2022). Other offshore and coastal activities must also be considered, as they contribute to cumulative impacts (Renewable UK 2013).

Given these cumulative impacts, early and comprehensive planning is essential for the OWE sector. The CIA's contributions to early planning may benefit the sector in different ways (Fig. 1), influencing the decision-making process, as discussed by Ferguson et al. (2024). It can be integrated into marine spatial plans, particularly by identifying areas with high pressures and sensitive ecosystems (Hammar et al. 2020), therefore supporting the achievement of Good Environmental Status (Kirkfeldt and Andersen 2021). In addition, CIA can support the definition of areas for the leasing process, and the development phase, which involves environmental approval and licensing procedures.

Method

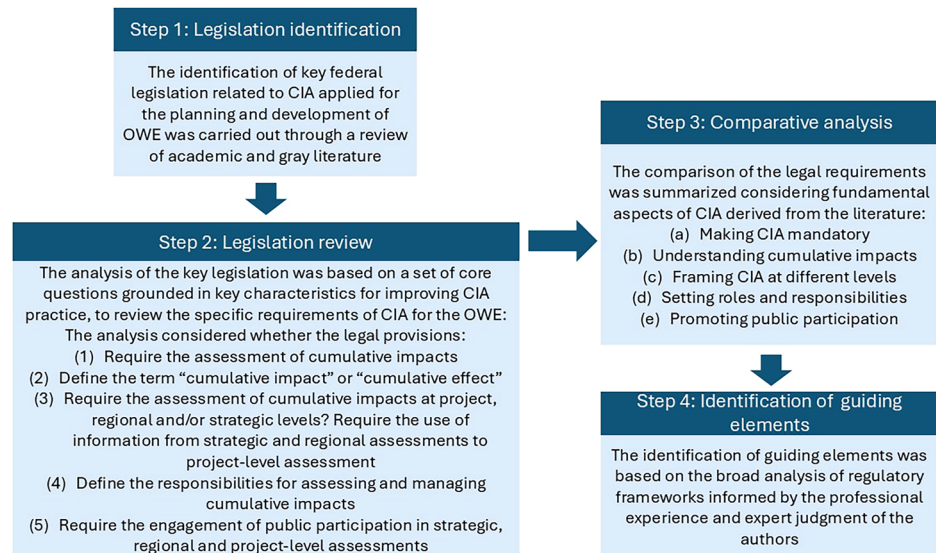
The comparative analysis of the CIA legal requirements involved in the planning and development of OWE in selected countries aimed to serve as a potential guiding resource for policymakers and regulatory bodies seeking to create, adapt, or refine their frameworks in alignment with

the evolving landscape of CIA implementation related to OWE.

The countries were selected considering (i) existing or planned OWE projects; (ii) concerns regarding the cumulative impacts on the coastal and marine environment from OWE projects; (iii) history of legal requirements to consider cumulative impacts; (iv) availability and accessibility of academic and grey literature; and (v) prior knowledge and experience in EIA systems of the authors. These criteria were applied based on preliminary scans of available literature, legal documents, and institutional frameworks across several countries. This selection does not imply that the chosen countries have the best practices, nor does it encompass all countries that meet these criteria. The selection was also influenced by the availability of information in scientific and technical literature and public documents related to CIA. The selected countries were the United Kingdom, the Netherlands, the United States of America, and Canada, as detailed below.

The **United Kingdom (UK)** significantly contributes to the world's installed offshore wind capacity (14.7 GW), being the largest offshore wind market in Europe and the second largest in the world (GWEC—Global Wind Energy Council (2024). The assessment of cumulative impacts has been required since 1985 under *European Directive 85/337/EEC*. Currently, with the United Kingdom outside the European Union, *The Town and Country Planning (Environmental Impact Assessment) Regulations 2017* require the need to consider the accumulation of effects with other existing and/or approved projects. Concerns about embracing a comprehensive marine management strategy that incorporates cumulative effects derived from human activities, such as offshore wind projects, has a potential to increase in UK waters, especially due to the adoption of national planning policies (Willstead et al. 2018b; Declerck et al. 2023), as well as considering the requirements for project approvals, with the significance of CIA growing for

Fig. 2 Steps for the comparative analysis of legal requirements for Cumulative Impact Assessment (CIA) in the offshore wind energy (OWE) sector in the selected countries and the identification of key guiding elements for designing or restructuring CIA regulation. Source: Prepared by the authors



renewable energy developments (Masden et al. 2015). In addition, there is a specific guideline for cumulative impact assessment in offshore wind farms (RenewableUK 2013).

The **Netherlands** is the fourth largest producer of offshore wind energy in the world, and the third in Europe, with 4.8 GW installed and 1.9 GW of new capacity commissioned in 2023, being the largest market in Europe considering new additions (GWEC - Global Wind Energy Council (2024). The requirement to consider cumulative effects in combination with other plans and projects has been established since the 1998 *Nature Conservation Act*. Additionally, recognizing the importance of evaluating cumulative impacts in future decisions regarding offshore wind energy, as mentioned in the 2016–2021 North Sea Policy Document for the Dutch sector, the tool Framework for Assessing Ecological and Cumulative Effects was created to evaluate the potential cumulative impacts on species populations.

The **United States** is the only market with offshore wind development in operation in the Americas. There is an expectation of a significant and rapid increase in offshore and onshore wind energy to achieve the carbon emission reduction targets with the Inflation Reduction Act of 2022. In 2023, the total installation was 42 MW (GWEC - Global Wind Energy Council (2024). The assessment of cumulative impacts under the 1969 *National Environmental Policy Act* (NEPA) documents was first required by the Council on Environmental Quality (CEQ) regulations in 1978, which inspired similar requirements in several other countries, including CIA. Concerns regarding the rapid growth of the offshore wind sector on the South and North Outer Continental Shelf have led to the development of a cumulative impacts scenario framework intended for use in NEPA analyses (BOEM—Bureau of Ocean Energy Management

(2019); BOEM—Bureau of Ocean Energy Management (2020).

Canada is an emerging player in the offshore wind sector. The country has the longest coastline globally, with a technical potential of 9.3 TW². A new legislative framework for offshore renewable energy was introduced in 2023 (Bill C-49)³. The assessment of cumulative impacts is a requirement for future projects since the *Canadian Environmental Assessment Act*, which came into force in 1995. Although the offshore wind energy sector is still in the initial phases, the country has a historical and meaningful CIA practice that can be reflected in the planning and development of OWE. Currently, the progress of the OWE is mainly focused on Nova Scotia and Newfoundland and Labrador provinces, with the development of Regional Assessments in each province to inform future planning, licensing processes, and impact assessments, considering cumulative impacts⁴.

The comparative analysis of the legal requirements was conducted in four steps (Fig. 2), inspired by the methodological approach applied by similar comparative studies (e.g. Loza and Fidélis 2022; Nelson and Shirley 2023). These steps are detailed below, which supported the discussion of the findings for improving CIA regulation applied to the OWE sector.

² Source: https://gwec.net/wp-content/uploads/2021/06/Canada_Offshore-Wind-Technical-Potential_GWEC-OREAC.pdf. Accessed 18 Jan. 2024.

³ Source: <https://www.parl.ca/documentviewer/en/44-1/bill/C-49/second-reading>. Accessed 23 May 2024.

⁴ Available at: <https://iaac-aeic.gc.ca/050/evaluations/proj/83514?culture=en-CA> and <https://iaac-aeic.gc.ca/050/evaluations/proj/84343?culture=en-CA>.

Legislation identification

The identification of legislation for analysis was primarily guided by a review of academic literature related to the planning and development of OWE at the national level in the target countries. The review focused on documents that mention and/or discuss legal requirements related to CIA in these countries, specifically applied to offshore wind farms or marine renewable energies, such as Willsteed et al. (2023) and Hollarsmith et al. (2022). The Scopus and ScienceDirect databases were used to gather the academic literature.

In addition, a gray literature review was conducted by examining available documents on the websites of government agencies responsible for approving OWE projects. These agencies were identified through literature discussing the regulatory framework for OWE (e.g., Vasconcelos et al. 2022 and GWEC - Global Wind Energy Council (2024)). The search for legislation was concentrated exclusively on key national laws related to marine spatial planning, as well as laws establishing requirements for EIA at the strategic (for plans, programs, and policies), regional (for the assessment of specific areas), and project (for project approvals) levels that apply to the planning and development of the OWE sector. This approach provided a more comprehensive view of the regulatory landscape, as the offshore industry is primarily regulated at the national level in the chosen countries, creating a standardized regulatory system that ensures uniformity among sub-national jurisdictions.

Sub-national legislation and non-statutory regulations (such as ministerial orders, normative instructions, and resolutions issued by the Executive with legal force), as well as technical guidelines associated with the reviewed legislation were not considered, as they fall outside the main objective of this study. The decision to focus on primary legislation and not conduct an in-depth search in legal portals may have implications for the scope of the findings. Some specific requirements for CIA may be present in supplementary regulations or operational guidelines that were not captured in this review. However, we believe that the analyzed instruments provide a representative overview of the regulatory landscape and are sufficient to meet the study’s objectives. Future research could expand this analysis to include subordinate regulations and specific sectoral policies that also influence CIA practices.

Legislation review

The review of key legislation was conducted using a set of core questions, grounded in key characteristics identified in the literature as essential for improving CIA practice, drawing on current CIA practice and recommendations (Table 1). The main goal was to understand how different regulators are addressing the specific requirements related to

Table 1 Core questions for analyzing Cumulative Impact Assessment (CIA) requirements, based on key characteristics for improving CIA in the early planning and development of the offshore wind sector in selected countries (EIA, Environmental Impact Assessment)

Core questions	Key characteristics of CIA	Supporting references
(1) Do the legal provisions require the assessment of cumulative impacts?	<i>Making CIA mandatory:</i> need for clear legislation and statutory authorities to implement CIA effectively	Masden et al. (2010); Wämbäck and Hilding-Rydevik (2009); Folkesson et al. (2013)
(2) Do the legal provisions define the term “cumulative impact” or “cumulative effect”?	<i>Understanding cumulative impacts:</i> the presentation of a definition of cumulative impacts in a regulatory context will support its straightforward application at the different planning levels and will avoid an uncertain regulatory environment	Broderick et al. (2018); Masden et al. (2010)
(3) Do the legal provisions require the assessment of cumulative impacts at project, regional and/or strategic levels? Do the legal provisions require the use of information from strategic and regional assessments to project-level assessment?	<i>Framing CIA at different levels:</i> CIA is adaptable to various planning stages, such as strategic and regional assessments, and under EIA at the project-level. The tier from strategic and regional assessments to project-level can influence the decision-making process of projects approval, besides the identification of issues or trends of regional relevance and cumulative significance, as well as thresholds and limits to be respected	Blakley and Noble (2021) Gunn and Noble (2009) Halpern et al. (2008a) Willsteed et al. (2018b)
(4) Do the legal provisions define the responsibilities for assessing and managing cumulative impacts?	<i>Setting roles and responsibilities:</i> the establishment of roles and responsibilities are key in any legislation to ensure the CIA implementation	Sinclair et al. (2017) IFC - International Finance Corporation (2013)
(5) Do the legal provisions require the engagement of public participation in strategic, regional and project-level assessments?	<i>Promoting public participation:</i> the earlier engagement of stakeholders is considered vital in all forms of environmental impact assessment to better address issues of concern related to cumulative impacts, increasing transparency and effectively influencing on decision-making	Hammar et al. (2020) Fidler and Noble (2013)

Source: Prepared by the authors

the CIA for OWE during the planning and development of the sector. Each legislation identified (Step 1) was first searched by considering the following words related to cumulative impacts: ‘cumulative’, ‘combined’, ‘combination’, ‘synergistic’, and ‘accumulation’⁵. After searching for the terms, the context in which they were used was carefully analyzed to respond to the defined core questions. The answers to these questions were organized by country to facilitate a more comprehensive comparative analysis.

Comparative analysis

The comparative analysis of CIA legal requirements was organized considering the characteristics for improving CIA practice listed in Table 1, derived from the literature review, to identify similarities and differences between the selected countries. The analysis was intended to show variations in the legal landscape, providing insights for identifying guiding elements that may influence policymakers and promote dialogue on harmonizing legal requirements on CIA for the offshore wind sector.

Identification of guiding elements

The identification of guiding elements for designing or reframing CIA regulation was based on a comprehensive analysis of the regulatory frameworks, grounded on the existing literature on fundamental characteristics of CIA, informed by the professional experience and expert judgment of the authors. We have selected elements that highlight key features of these systems, aligning with the issues explored in the methods. The insights presented are generalizations drawn from current practice (Morrison-Saunders et al. 2003)—in this context, recent norms—focusing on identifying elements from mature EIA systems that could be transferable or adaptable to other contexts. In doing so, we aimed to contribute to a broader discussion on strengthening CIA implementation in both emerging and well-established regulatory frameworks for the OWE sector. We acknowledge that the review has limitations and could be improved by interviewing experts knowledgeable of the jurisdiction where they work. Even so, we recognize that the surveyed requirements fulfill the study’s aim, and the guiding elements will be useful to direct future studies with greater depth on key points of interest.

Regulation Review

The legal requirements related to the CIA in key national legislation concerning marine spatial planning and EIA at

strategic, regional, and project levels for the OWE sector are outlined by each selected country based on the set of core questions defined for the regulation review (Table 1). Figure 3 summarizes the CIA’s adopted legal requirements during the early planning and development stages of the OWE sector.

The United Kingdom

Several legislations in the United Kingdom require the consideration of cumulative impacts in the early planning, leasing, and project approval process of offshore wind development, enacted by the United Kingdom Government and the Devolved Administration⁶ (Kofahl and Northrup 2023).

Under marine planning, the *Marine and Coast Access Act 2009* regulates the sustainable use of the coastal and marine space in the UK, integrating marine planning, environmental protection and licensing process, with no explicit mention of cumulative impacts, as the *Marine Act (Northern Ireland) 2013* and the *Marine (Scotland) Act 2010*.

The Marine Management Organisation (MMO)—a non-departmental public body—is responsible for developing marine plans in England, while in Scotland, Wales and Northern Ireland government departments have this role⁷.

Regarding the leasing process, the Strategic Environmental Assessment (SEA) has been applied to inform future licensing round decisions for offshore energy development⁸. The instrument is governed by the *Environmental Assessment of Plans and Programmes Regulations 2004* in England, which requires the consideration of “the cumulative nature of the effects” (Schedule 1, s. 2(b)) when determining the likely significance of effects of a plan or programme. Environmental reports should also consider “cumulative and synergistic effects” (Schedule 2, s. 6). The related legislation in Wales, Northern Ireland, and Scotland⁹ provides the same requirements. The regulations state the

⁶ Devolved Administrations govern specific matters in Northern Ireland, Scotland and Wales.

⁷ Marine Scotland, Marine and Fisheries Division of Welsh Government, and the Department for Agriculture, Environment and Rural Affairs (DAERA), respectively.

⁸ In 2003, a SEA was undertaken to support site leases for offshore wind farms in three strategic regions off the coasts of England and Wales. In 2023, a SEA was conducted by the Department of Enterprise, Trade and Investment for the development of offshore wind and marine renewable energy in Northern Ireland to support the identification of locations for future developments. In Scotland, the Sectoral Marine Plan for Offshore Wind Energy (2020) was subject to SEA, to assess the draft plan option areas potentially suitable for wind energy generation.

⁹ *Environmental Assessment of Plans and Programmes (Wales) Regulations 2004*, *Environmental Assessment of Plans and Programmes Regulations (Northern Ireland) 2004* and *Environmental Assessment (Scotland) Act 2005*.

⁵ The Netherlands’ laws were translated into English using the automatic translation tool of the Microsoft Edge browser.

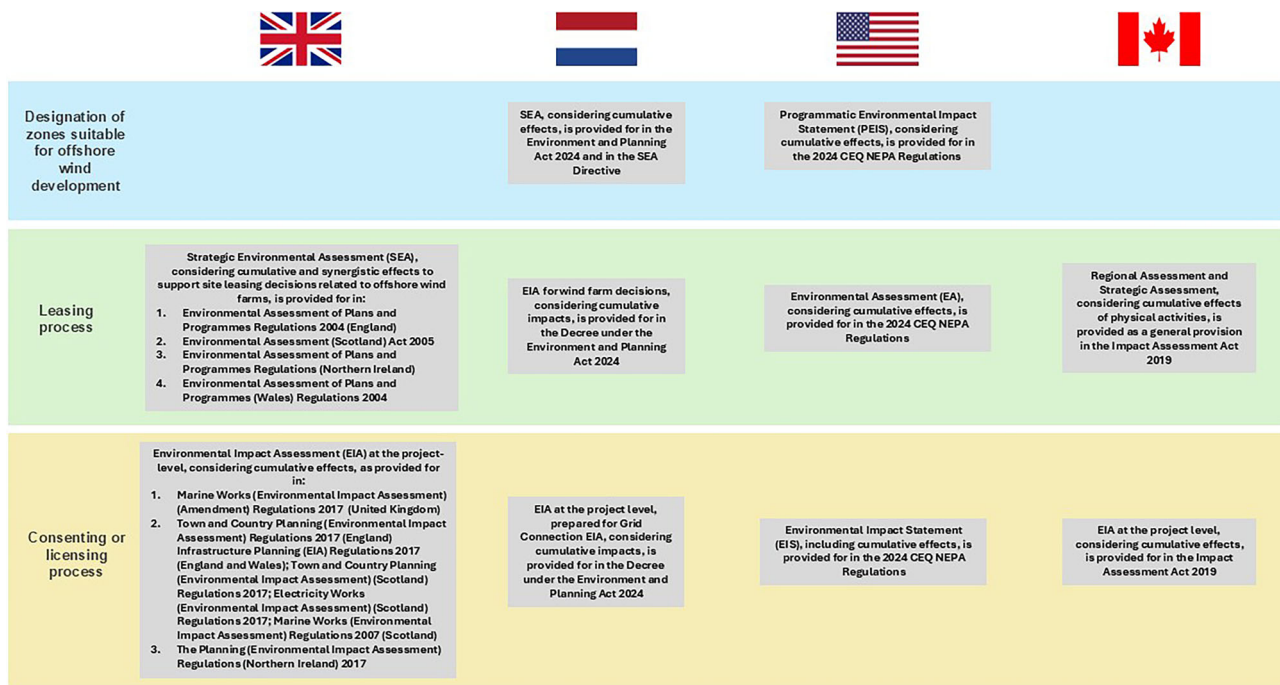


Fig. 3 Cumulative Impact Assessment (CIA) legal requirements applied in the context of offshore wind energy in the United Kingdom, the Netherlands, the United States, and Canada. Source: Prepared by the authors

need to ensure that consultation bodies and public consultees have been given an effective opportunity to express their opinion on the relevant documents. The responsible authorities for preparing the SEA related to offshore energy are the Department for Energy Security and Net Zero and Marine Scotland.

Concerning the consenting process in inshore and onshore waters, the MMO is responsible for projects up to 100 MW in England and Wales. In contrast, the Planning Inspectorate is responsible for projects classified as Nationally Significant Infrastructure Projects (NSIPs). Local planning authorities are statutory consultees in the process, without any responsibility for decisions. In Northern Ireland, the Department for Agriculture, Environment and Rural Affairs is responsible for consenting offshore wind projects within 12 nautical miles off the coast. Beyond this limit, the MMO is the authority responsible for consenting to such projects.

The applicable legislation for offshore projects encompasses several pieces of legislation. In England, the *Town and Country Planning (Environmental Impact Assessment) Regulations 2017* require the consideration of “the cumulation of the impact with the impact of other existing and/or approved development” as one of the criteria for project screening (Schedule 3, s. 3(g)). Additionally, Environmental Statements must address “the cumulation of effects with other existing and/or approved projects, taking into account any existing environmental problems relating to

areas of particular environmental importance likely to be affected or the use of natural resources” (Schedule 4, s. 5(e)).

The *Infrastructure Planning (EIA) Regulations 2017* (England, Wales and Scotland for limited purposes), which implements the EIA Directive procedures in the context of NSIPs¹⁰, the *Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017*¹¹ and the *Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017*¹²—also present the need of considering cumulative impacts in both the screening process and the preparation of Environmental Statements. The same requirements are provided by the *Marine Works (Environmental Impact Assessment) (Amendment) Regulations 2017* and the *Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017*, which apply to projects requiring a marine licence. All the above-mentioned legislation states that the results of other relevant assessments must be considered both in the screening phase and when preparing the environmental report.

The local planning authorities are responsible for onshore elements (and offshore up to 50 MW) while

¹⁰ Applied to offshore wind projects (including its elements, such as cabling and onshore and offshore substations) with a capacity of more than 100 megawatts (England) or more than 350 megawatts (Wales).

¹¹ Applied to offshore wind projects and onshore elements related up to 50 MW.

¹² Applied to projects that exceed 50 MW.

offshore projects over 50 MW are consented to by the Marine Directorate—Licensing Operations Team. The developer/applicant is responsible for preparing an Environmental Statement of a proposed development, which should involve competent experts, as well as for monitoring impacts.

Public participation is crucial in the environmental impact assessment process across all the legislation mentioned. Environmental impact reports must be publicly accessible, allowing stakeholders to engage in the decision-making process. Responsible authorities are required to consider public feedback before reaching a final decision.

Finally, the *UK-National Policy Statement*¹³ for *Renewable Energy Infrastructure (EN-3)* recognizes the importance of assessing and reducing cumulative effects of offshore wind, especially considering the offshore-onshore transmission infrastructure; the need to define mitigation and compensation measures collaboratively when several developers are likely to have cumulative impacts; and highlights valued components to be considered when assessing cumulative impacts (as birds and marine mammals). Moreover, when the Rochdale Envelope¹⁴ approach is employed, cumulative impacts should also be assessed, especially when establishing the worst-case scenario. None of the aforementioned legislation defines cumulative impacts.

The Netherlands

In the Netherlands, cumulative impacts are required—implicitly and explicitly—at the early planning stage of the OWE, in the designation of wind energy, besides the wind farm site decisions.

The designation of offshore wind farm areas is part of the North Sea Programme, which outlines the spatial planning for the Dutch North Sea. The latest North Sea Programme (2022–2027) includes a spatial development strategy for the Dutch North Sea, addressing knowledge gaps about the effects of human activities on the ecosystem, including cumulative impacts, and emphasizing the need for tackling (cumulative) impacts of all human activities in areas of concern. The responsible authority for developing the North Sea Programme is the Dutch Ministry of Infrastructure and Water Management, with the support of the Interdepartmental Directors' Consultative Body North Sea¹⁵. The

Programme was subjected to the *Water Act*, which transposed the obligations of the *Maritime Spatial Planning Directive* (MSPD—Directive 2014/89/EU) and the *Marine Strategy Framework Directive* (MSFD—Directive 2008/56/EC) (Government of the Netherlands 2022).

The MSPD requires that marine spatial plans consider the various and significant pressures on marine waters, ecosystems, and resources—“in the marine waters, ecosystems and marine resources are subject to significant pressures” (s. 13). The MSFD states the need for marine strategies “apply an ecosystem-based approach to the management of human activities, ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of good environmental status” (art. 3, s. 3). It also determines that an assessment in marine waters should include an analysis of the predominant pressures and impacts, covering the main cumulative and synergetic effects (art.8, s. 1). The *Water Act* was replaced by the new *Environment and Planning Act 2024*, which emphasizes that a maritime spatial plan should be adopted as referred to by the MSPD.

Another instrument required under the *Environment and Planning Act 2024* is the EIA for plans or programmes¹⁶. The Act and its regulatory Decree do not explicitly mention considering cumulative impacts when preparing an EIA for plans and programmes. Instead, the EIA should comply with the SEA Directive, which requires consideration of cumulative impacts during both the screening phase and when preparing the environmental report.

There is a mention of considering the “existing environmental problems relevant to the plan or programme, in particular in the context of the particular problems in areas where the importance of protecting the environment plays an important role” (s. 11.1, art. 11.3(1)(d)).

The Act highlights that the competent authority may use “other environmental impact assessment if they comply with the requirements set out in or pursuant to this Requirements” (s. 16.4, § 16.4.1, art. 16.37(b)(1°) to avoid overlap of EIA for a plan or programme. The Minister of Economic Affairs and Climate Policy is the competent authority responsible for preparing an EIA for a plan or programme and for implementing monitoring measures.

In addition, EIA is applied for each wind farm site decision, which must be completed prior to the auction

¹³ National Policy Statements are planning documents that define the government's objectives towards the development of NSIPs.

¹⁴ The *Rochdale Envelope* approach is employed when some details of a proposed development have not been confirmed when the application is submitted.

¹⁵ Source: https://maritime-spatial-planning.ec.europa.eu/media/document/Netherlands_countryprofile. Accessed 16 Jul. 2024.

¹⁶ A SEA on North Sea Energy (SEANSE) was carried out to develop a Common Environmental Assessment Framework for renewable energy to support the implementation of marine spatial plans, focusing on cumulative effects of large scale wind farms. In addition, a SEA will be conducted for the North Sea Programme revision, considering the cumulative effects for each farm zone determined, where possible. The ecological effects will be determined by using the valued ecosystem components and indicators through the cumulative ecological impact study.

stage, that must be developed under the *Environment and Planning Act 2024* and the *Offshore Wind Energy Act 2015*. The pre-auction EIA is overseen by the Netherlands Enterprise Agency (RVO) and forms the basis for the tender requirements, including mitigation measures. Furthermore, TenneT, the national electricity transmission system operator, conducts an EIA for the energy transmission infrastructure. The winning developers must present studies to demonstrate that their project complies with the environmental conditions established by the pre-auction EIA. If necessary, additional studies may be required. The Act outlines EIA requirements for projects that comply with the EIA Directive. The *Environmental Decree* defines that when describing the potentially significant environmental effects of the project, it should consider “the cumulation of impacts with other existing or approved projects, whereby take into account all the existing environmental problems of areas that are of particular environmental importance and may be affected by the project, or with the use of natural resources” (s. 11.2, art. 11.18(1)(e)). In addition, it is also stated that another EIA can be used if set out in or pursuant to the requirements, and when “the project is described in that environmental impact report” (s. 16.4, § 16.4.2, art. 16.48). The developer is responsible for monitoring measures. The Act indicates that the General Administrative Law Act applies to the EIA process regarding public involvement. This legislation outlines the necessary steps for interested parties to express their opinions to the administrative body regarding an application.

The Act and its regulatory Decree further state that the competent authority shall provide the Netherlands Commission for Environmental Assessment (NCEA) with the opportunity to advise the EIA regarding plans, programs, or projects. The NCEA plays a significant role in the EIA process by drafting compulsory or voluntary advisory reports for the government concerning environmental assessment scope (optional) and quality of environmental assessments, that can contribute to the transparency and accountability of environmental decision-making. The advice on the environmental impact report of a project is mandatory, while it is voluntary for planning EIA or a programme. These reports may be opened to public comments, particularly in cases where a project generates controversy¹⁷. None of the legislation applied to the development of offshore wind farms defined cumulative impacts.

The United States

In the United States, cumulative impacts are required for both programmatic (strategic) and project assessments,

including conducting environmental reviews at early planning stages of offshore wind development in the planning and leasing stages¹⁸, as well as at the project level for project approval. Under the marine spatial planning, the *Ocean Act 2000*, which establishes a commission to make recommendations for coordinated and comprehensive national ocean policy that will promote sustainable use of the ocean and its resources, does not explicitly mention the need to consider cumulative impacts in ocean management. The National Oceanic and Atmospheric Administration (NOAA) is responsible for conducting coastal and marine spatial initiatives.

The environmental review process at both the strategic and project levels related to the OWE is led by the Bureau of Ocean Energy Management (BOEM), an agency of the U.S. Department of the Interior, which is the responsible authority for overseeing offshore renewable energy development in federal waters. The proponent is responsible for monitoring during and after the construction phase.

The environmental reviews must comply with NEPA and implementing CEQ Regulations (40 CFR Parts 1500–1508)¹⁹. The first CEQ regulation for implementing NEPA (1978) required the assessment of cumulative effects of an action along with other proposed actions, both at the project and strategic levels and defined cumulative impacts. The *2024 CEQ NEPA Implementing Regulations Revisions Phase 2* also considers the need to consider cumulative effects, which are defined as “the effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions regardless of what agency (Federal or non-Federal) or person undertakes the action”. In addition, “cumulative effects can result from action with individually minor but collectively significant effects taking place over a period of time” (40 CFR Parts 1508.1(i)(3)).

For a broader analytical level, programmatic reviews can be conducted under NEPA, which can be based on a Programmatic Environmental Impact Statement (PEIS). A PEIS was conducted to assess alternative uses of renewable energy in the Outer Continental Shelf²⁰. Additionally, a PEIS may be undertaken for a regional analysis that considers the development of multiple offshore wind projects within a lease area or across multiple lease areas, assessing the environmental effects and potential programmatic mitigation and monitoring measures for future wind energy

¹⁸ The offshore wind development involves four stages: planning, leasing, site assessment and construction and operations.

¹⁹ Important to note that pursuant to Executive Order 14154 of February 21, 2025, BOEM may amend its NEPA implementing procedures.

²⁰ Available at: <https://www.boem.gov/renewable-energy/guide-ocs-alternative-energy-final-programmatic-environmental-impact-statement-eis>. Accessed 17 Jul. 2024.

¹⁷ Source: <https://www.commissiener.nl/english/our-services>.

development, as in the cases of the California Offshore Wind PEIS²¹ and the New York Bight PEIS²². Furthermore, an Environmental Assessment is prepared to support the leasing process within wind energy areas of competitive interest by determining whether the issuance of leases and approval of site assessment plans in specific areas would have a significant effect on the environment (BOEM—Bureau of Ocean Energy Management (2025). Finally, an Environmental Impact Statement (EIS) is prepared to inform a decision regarding a project's Construction and Operations Plan, which outlines all planned facilities related to construction, commercial operations, and decommissioning of a project.

The 2024 *CEQ Regulations* also emphasize that “where an existing environmental impact statement, environmental assessment, or programmatic environmental document is relevant to a later proposed action, agencies may employ tiering” (40 CFR Parts 1501.11(b)). Tiering is suitable for moving from broader assessments to narrower ones or from early-stage assessments to later ones, allowing agencies to concentrate on current issues and exclude those that have already been resolved or are no longer relevant.

NEPA regulations require public participation when preparing programmatic assessments, EAs, and EISs. This participation should be promoted and facilitated in the decision-making process, encompassing meaningful engagement with communities throughout the NEPA process. Potentially affected Federal, State, Tribal, and local governments can act as cooperating agencies. Engagement should begin early, during the scoping phase, and continue through various opportunities after the environmental assessment is prepared, consistent with the different types of assessments.

Canada

In Canada, diverse marine activities should be considered for developing marine spatial plans that balance ecological health with human activities. In addition, cumulative effects should be considered for strategic, regional, and project-level assessments.

Marine spatial plans are being developed for five areas across the country to identify both suitable and unsuitable locations for various marine activities²³. These plans are

founded on the *Oceans Act* of 1996, which mandates “the development and implementation of plans for the integrated management of all activities or measures affecting estuaries, coastal waters, and marine waters that form part of Canada or in which Canada has rights under international law” (s. 31), but does not present an explicit requirement for cumulative impacts. Fisheries and Oceans Canada, a federal institution, leads the marine spatial planning process in partnership with other provincial and territorial governments, while engaging affected Indigenous organizations, coastal communities, and other stakeholders.

The *Impact Assessment Act 2019* (IAA) is the primary legislative framework governing the impact assessment process in Canada. The Act includes a general provision that underscores the importance of considering the “cumulative effects of physical activities” in the administration of the law (s. 6(2)). Regional assessments are encouraged by the IAA to understand the effects of existing or future physical activities carried out in a region that is entirely on federal lands (s. 92). Regional assessments are the primary ongoing instrument used to inform future wind planning and licensing processes, along with recommendations for offshore wind licensing areas and future impact assessments of offshore wind projects²⁴. They aim to comprehend the impacts of major resource development initiatives and programs, while also outlining the preferred course of action and setting conditions for project proponents (Blakley et al. 2020). The IAA also recognizes the importance of Strategic Assessments in assessing federal “policy, plan or program—proposed or existing—that is relevant to conducting impact assessments” (s. 95(1)(a)). A committee or the Impact Assessment Agency of Canada (the Agency) carries out the Regional Assessment and Strategic Assessments. Both assessments must ensure that meaningful opportunities for public participation are guaranteed, ensuring information is accessible to the public.

The approval of offshore wind projects—with 10 or more turbines or an expansion—is subjected to the IAA, which establishes that an impact assessment of a project under approval must consider “any cumulative effects that are likely to result from the designated project in combination with other physical activities that have been or will be carried out” (s. 22(1)(a)(ii)). While the Act does not include a formal definition of cumulative effects, this provision offers a clear and operational interpretation within the regulatory context. In addition, it should also consider any Regional or Strategic Assessment carried out (s. 22(1)(p)).

²¹ Available at: <https://www.boem.gov/renewable-energy/state-activities/california-offshore-wind-programmatic-environmental-impact>. Accessed 16 Jun 2025.

²² As the case of the New York Bight Programmatic Environmental Impact Statement, available at: <https://www.boem.gov/renewable-energy/state-activities/new-york-bight-final-programmatic-environmental-impact-statement>. Accessed 17 Jul. 2024.

²³ Source: <https://www.dfo-mpo.gc.ca/oceans/planning-planification/reas-aies/index-eng.html>.

²⁴ Two Regional Assessments of Offshore Wind Development are being conducted in Nova Scotia (<https://iaac-aeic.gc.ca/050/evaluations/proj/83514?culture=en-CA>) and Newfoundland and Labrador (<https://iaac-aeic.gc.ca/050/evaluations/proj/84343?culture=en-CA>).

Project proponents, including individuals, federal authorities, governments, or organizations, are responsible for preparing an impact assessment of a designated project, as well as developing and implementing follow-up and monitoring programs. Public involvement starts early with consultations involving Indigenous communities and members of the public who may be affected by the project to identify major concerns. Similarly, the Agency must ensure meaningful public participation during the project's impact assessment.

Comparative Analysis and Discussions on Guiding Elements of CIA Legislation

The analysis of similarities and differences in the CIA legal requirements applied during the early planning and development phases of the OWE sector across selected countries is structured around five key characteristics of CIA (Table 2): i) making CIA mandatory; ii) understanding cumulative impacts; iii) framing CIA at different levels; iv) setting roles and responsibilities; and v) promoting public participation. These results provide the foundation for discussing the guiding elements of CIA legislation, which may guide policymakers in various jurisdictions to enhance the adoption and harmonization of CIA practices for the planning and development of OWE.

Making CIA mandatory

The legislation reviewed across the four countries reveals that cumulative impact requirements are both explicitly and implicitly integrated into legal frameworks. Legislation plays a pivotal role in shaping the practice of CIA for offshore wind energy projects, with strict legislative requirements identified as a significant factor in promoting the effective implementation and development of these assessments (Folkesson et al. 2013).

Although legislation alone is unlikely to provide a complete solution for addressing cumulative environmental change (Nelson and Shirley 2023), establishing minimum standards for assessing cumulative impacts does not necessarily require extensive legal frameworks.

Clear statutory authorities are essential for overseeing and enforcing CIA requirements. Instead of relying on complex or overly detailed regulations, concise legal frameworks that prioritize clear guidelines, define responsibilities, and establish effective mechanisms for CIA application can be highly effective (Masden et al. 2010).

The focus should be on ensuring that laws address the most critical issues in a practical and adaptable manner, allowing for flexibility as environmental management needs evolve (Wärnäck and Hilding-Rydevik 2009). This

approach reinforces the importance of formalized, mandatory CIA requirements as an essential step in disseminating international best practices and ensuring strong environmental governance (Nelson and Shirley 2023).

Voluntary CIA studies in the marine context, while not required by the legal framework, are likely to have limited capacity to engage the multiple stakeholders involved in a heavily utilized marine environment, thereby significantly reducing their chances of influencing decision-making. It is crucial to recognize that political shifts and changes in government priorities can greatly impact regulatory frameworks, potentially leading to inconsistent enforcement and disruptions in the continuity of CIA practices. Consequently, a stable and transparent legal framework is essential to ensure the effectiveness and consistency of CIA processes amidst shifting governmental priorities.

The main finding related to CIA being mandatory is that clear and concise legislation, rather than overly complex or extensive frameworks, plays a vital role in shaping effective CIA practices, particularly in rapidly evolving sectors such as offshore wind energy. While legislation alone is not a complete solution for cumulative impacts, maintaining formalized CIA requirements within regulatory processes is essential because it can facilitate the sharing of international best practices and enhance the consistency of assessments.

Understanding cumulative impacts

Only the CEQ NEPA regulations provide a formal definition of cumulative impacts, which encompass effects from past, present, and future activities. In marine planning, some legal frameworks emphasize the need to consider all activities collectively or account for significant pressures that affect coastal and marine waters. Additionally, certain legislation explicitly acknowledges cumulative, additive, and synergistic (in-combination) effects. Overall, the legal frameworks recognize the importance of assessing the impacts of other activities, which may include both existing and/or future developments.

The absence of a clear and appropriate definition regarding cumulative impacts can create a regulatory environment marked by uncertainty and confusion (Masden et al. 2010). This lack of clarity can hinder effective decision-making processes and obstruct stakeholders' understanding of the implications of cumulative impacts on environmental and social systems. Additionally, the variation in requirements and definitions may result in differing expectations concerning EIA content (Nelson and Shirley 2023). In this context, Judd et al. (2015) emphasized that, regardless of the terminology used, it is crucial to focus on the combination and interaction of pressures affecting environmental features. Thus, providing a definition based

Table 2 Summary of the comparative analysis of Cumulative Impact Assessment (CIA) legal requirements across the selected country, considering key characteristics for improving CIA practice

Key characteristics of CIA	The United Kingdom	The Netherlands	The United States	Canada
Making CIA mandatory	Cumulative impacts are required implicitly and explicitly	Cumulative impacts are required implicitly and explicitly	Cumulative effects are required explicitly for both programmatic and project assessments	Cumulative impacts are required implicitly and explicitly
Understanding cumulative impacts	There is no legal definition	There is no legal definition	The effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions regardless of what agency (Federal or non-Federal) or person undertakes the action ^a	There is no legal definition
Framing CIA at different levels	Cumulative impacts should be integrated into the marine planning, regional, strategic and project assessments. Other relevant assessment should be considered in the screening phase and when preparing environmental reports of projects	Cumulative impact assessment should be integrated into the spatial development strategy and the Environmental Impact Assessment for plans, programmes and projects. The use of other Environmental Impact Assessment is possible when required	Cumulative effect assessment should be integrated into programmatic and project-level assessments. The process of considering information from broader assessment to narrower ones is established	Cumulative effect assessment should be integrated into regional, strategic assessment and project-level assessment. Impact assessment of projects should consider any relevant Regional Assessment or Strategic Assessment
Setting roles and responsibilities	Plans and programs assessment: national authority Project assessment: project proponents	Plans or programs assessment: national authority Project assessment: national authority for site decision; proponents for project-level studies to operationalize and demonstrate compliance with pre-auction EIA conditions	Programmatic assessments: federal authority Project assessment: federal authority	Regional assessment and strategic assessment: committee or federal agency Project assessment: project proponents
Promoting public participation	Public participation should be ensured in the Environmental Impact Assessment process of plans, programs and projects	Public involvement should promote opportunities for interested parties to provide their opinion related to an application	Public participation must be promoted and facilitated when preparing programmatic assessments, Environmental Assessments, and Environmental Impact Statements. It should begin in the scoping phase	Public participation should be ensured in strategic, regional and project assessments

^aThe regulatory definition by CEQ Regulations applies to all types of projects, just to offshore wind farms

Source: Prepared by the authors

on scientific findings may help standardize CIA practices (Foley et al. 2017).

Consequently, it is essential to provide a well-defined concept of cumulative impacts within a regulatory framework. By establishing a clear definition, regulatory bodies can promote a more straightforward application of CIA across various planning levels, ensuring that all stakeholders share a common understanding and set of expectations (Broderick et al. 2018).

An interesting aspect of the UK's approach is its consideration of cumulative effects when preparing environmental reports, particularly during the screening phase of a plan, programme, or project. The provisions for cumulative effects can significantly influence whether a project requires an EIA, thereby broadening its scope and enhancing public participation. Additionally, accounting for cumulative impacts can affect the type of environmental assessment needed during scoping. In the post-EIA phase, cumulative effects are crucial for monitoring and managing the environmental impacts of a project. Authorities can establish more effective monitoring programs that track not only the direct impacts of a project but also its cumulative effects over time (Nelson and Shirley 2023).

Although it falls outside our scope, it is essential to note the need for clear technical guidance that outlines expectations, methods, and implementation requirements (Olagunju et al. (2021). The associated technical guidance on the requirements for orienting CIA practice is one of the recommendations to improve this practice (Natural England 2014; Broderick et al. 2018; Dibo et al. 2018). Hague et al. (2022) emphasized that CIA practice should meet legislative requirements while remaining flexible enough to adapt to new knowledge and promote effective cross-industry cumulative assessments.

Several technical guidelines have been prepared to orient CIA practices at the project level, particularly in the United Kingdom, Canada, and the United States (Natural England 2014). For offshore wind farms, we highlight the guidance developed by BOEM, which establishes a common cumulative impact scenario framework for preparing Environmental Assessments and EISs. This framework provides information on cause-and-effect relationships between renewable energy projects and affected resources, as well as other types of actions (BOEM—Bureau of Ocean Energy Management (2019); BOEM—Bureau of Ocean Energy Management (2020). Furthermore, RenewableUK (2013) offers several solutions for addressing the challenges associated with the cumulative impacts of offshore wind farms. Additionally, the guidelines put forth by Willstead et al. (2018b, p. 2342) to incorporate an ecological perspective into project-led CIAs can aid in the preparation of guidance in emerging markets. It is important to note that to enhance CIA practices, technical guidelines must be updated to

reflect new scientific knowledge and best practices (Antwi et al. 2024).

The main finding is that a lack of clarity can lead to regulatory uncertainty and obstruct decision-making. Clear definitions are crucial for effective environmental regulation, whether in legal or technical sources, improving consistency and effectiveness of CIA practice. Incorporating cumulative effects from screening to follow-up emphasizes the importance of addressing impacts across all project phases development.

Framing CIA at different levels

CIA is integrated at multiple levels, including marine planning, regional, strategic, and project assessments. Project EIAs should account for relevant broader assessments, ensure a tiered approach, and support the assessment of cumulative impacts. In the Netherlands, existing EIAs for plans or programs may be used to assess new ones. Similarly, at the project level, an existing EIA can be used if it complies with regulations and adequately describes the project.

Based on the findings, CIA is applied for project approval, focusing on the assessment of the combined impacts of several activities within the context of regulatory approval of proposals, as well as SEA-driven approaches related to the proactive planning of a sector or region, with various purposes and deliverables (Harriman and Noble 2008). Although CIA should be applied at different spatial scales to implement ecosystem-based management principles in marine management (Judd et al. 2015), previous experiences with CIA at various levels may face challenges related to integrating frameworks by connecting data, modeling, and monitoring approaches (Declerck et al. 2023).

CIA plays a vital role in addressing anthropogenic drivers linked to global climate change, which significantly contribute to the cumulative impact on offshore ecosystems (Halpern et al. 2008a). Policies related to Marine Spatial Planning emphasise the need for an integrated assessment of pressures arising from multiple sources and uses in specific regions. Integrating CIA into MSP supports the adoption of an ecosystem approach for the sustainable use of the marine environment (Halpern et al. 2008b; Bergström et al. 2019) and facilitates strategic decision-making by identifying areas with high and low concerns regarding cumulative impacts from pressures in particular locations, especially taking into account seascape connectivity (Jonsson et al. 2021). This approach limits additional pressures on specific areas of concern and enhances transparency in planning decisions (Hammar et al. 2020). Various studies have explored the role and implementation of CIA in MSP, as well as methods to quantify and manage cumulative impacts

on the marine ecosystem, assisting governments and stakeholders, particularly in regions with intense usage and significant cumulative impact concerns (Fernandes et al. 2017; Bonnevie et al. 2020; Hammar et al. 2020; Choi et al. 2021). Concerns related to OWE can be addressed, such as the need to assess potential cumulative effects related to noise and vibration on sensitive receptors (HM Government 2011), along with other impacts of human activities on marine mammals and migrating birds (Government of the Netherlands 2022), contributing to a more detailed assessment in subsequent levels of evaluation.

CIA at strategic and regional levels can support the leasing process of the offshore wind sector by adopting a strategic mindset at this decision window (Gunn and Noble 2009). The strategic and regional assessments can offer meaningful context for assessing cumulative impacts (Olajunju et al. 2021). Under Strategic Environmental Assessment, CIA supports the establishment of thresholds for future projects, besides providing clear recommendations of mitigation measures to be adopted (Dalal-Clayton and Scott-Brown (2024). Regional assessments can incorporate broad spatial and temporal scales, including the multiple pressures that influence conditions, which contribute to regional marine management (Willstead et al. 2018b). Additionally, there exists an opportunity to effectively influence the decision-making process and advance toward project-level approval (Blakley and Noble 2021). This also involves identifying issues or trends of regional relevance and cumulative significance and recognizing the thresholds and limits that must be maintained (Gunn and Noble 2009) earlier in the planning process (Cooper and Sheate 2004). Other outcomes of regional assessments, which inform and improve project impact assessments and regional management, are also discussed by Bonnell (2025). Approaches for rebalancing the CIA at the project-level, supported by a multi-stakeholder regional assessment, are discussed by Joseph et al. (2023).

One regional initiative to be highlighted specifically developed for OWE is the Framework for Assessing Ecological and Cumulative Effects (FAECE, Dutch: Kader Ecologie & Cumulatie), developed by the Rijkswaterstaat, which is used to identify, describe, and assess cumulative ecological effects of decisions on future planned wind farms. The KEC provides an analysis of whether future planned wind farms align with an acceptable ecological level, outlines provisions for sharing mitigation measures, and identifies species considered critical and those near in an acceptable ecological level, provisions on how the mitigation measures can be shared, and the species considered critical and near the acceptable ecological level of impact. It is applied when preparing environmental impact assessments and appropriate assessments for site decisions, besides when designating new areas for the sector

(Rijkswaterstaat 2022) and other planning decisions related to offshore wind farm development (such as strategic planning documents). The framework is based on the DPSIR method (Gari et al. 2015) and is planned to be regularly updated.

Finally, EIA at the project level is fundamental for offshore wind project approvals, which should include the assessment of cumulative impacts (World Bank Group 2021). CIA practices at the project level continue to pose challenges under EIA (Foley et al. 2017; Sinclair et al. 2017; Dibo et al. 2018; Roudgarmi 2018; Hegmann 2021; Blakley and Russell 2022). In particular, offshore wind farms face shortcomings in adequately identifying and assessing cumulative impacts, especially concerning pathways of impacts and the future conditions of valued components and uncertainties. Nonetheless, it is essential to strengthen CIA at the project level, as it serves as the primary source of information for the decision-making process, offering a high degree of detail about the environment (Willstead et al. 2018b).

The main finding about applying CIA at different levels shows that, despite CIA being crucial from marine planning to project assessments, each approach delivers a specific outcome. At the project level, CIA focuses on analyzing combined impacts, while at the strategic level, it supports planning. The integration of approaches in CIA at several planning levels, although desired, can be challenging for supporting tiered decision-making.

Setting roles and responsibilities

CIA involves multiple actors, including government agencies, third parties, and affected communities, each playing a distinct role in assessing and managing cumulative impacts (IFC—International Finance Corporation (2013). Clearly defining roles and responsibilities in legislation is essential for ensuring effective CIA implementation (Sinclair et al. 2017). National authorities are generally responsible for preparing marine spatial plans and conducting strategic and regional assessments. Project proponents manage the assessment and monitoring at the project level in the United Kingdom and Canada. In contrast, BOEM, which oversees offshore wind project approvals in federal waters in the United States, is responsible for preparing the PEIS, EA and EIS, while proponents handle monitoring. In the Netherlands, the RVO is responsible for an EIA for a wind farm decision, and the tender winner is responsible for detailing specific project requirements and monitoring.

A key discussion point is that while project proponents often face challenges in conducting CIA, competent authorities can sometimes streamline the process by leading environmental reviews and establishing standardized procedures. Standardization can lead to more predictable

outcomes, reduce the time required for assessments, and improve the overall quality of environmental reviews by ensuring consistent terminology and methods, albeit context-specific issues can be overlooked (Fonseca et al. 2020). Additionally, authorities may receive support from other agencies to identify projects and plans in areas of concern, facilitating the identification of other actions capable of contributing to cumulative impacts (Prahler et al. 2014).

The “One Stop Shop” system is internationally recognized as a best practice for reducing time and costs in the approval of offshore wind development projects (González et al. 2020; Vasconcelos et al. 2022), promoting collaboration between governments and other stakeholders. In this regard, CIA could benefit from this type of initiative to support not only project approval but also monitoring cumulative impacts.

Dibo et al. (2018), based on stakeholder perspectives, argued that all actors involved in project-level CIA should assume greater responsibility. Shared responsibility among stakeholders may be a more effective approach for managing cumulative impacts and adopting mitigation strategies (Sunderland 2021). RenewableUK (2013) also emphasizes the benefits of collaboratively identifying and managing cumulative impacts related to OWE development, especially in data collection and modeling.

To support the assessment and monitoring of cumulative impacts, establishing a shared regional baseline, alongside site-specific studies conducted by developers with higher resolution, offers opportunities to improve practices at both the project and regional levels, as discussed by Willstead et al. (2017). Moreover, baseline monitoring is essential to support data-driven decision-making (Tedeschi et al. 2025).

By sharing data from previously constructed projects, stakeholders in the consenting process can gain a better understanding of potential cumulative impacts. One approach could be offshore developers paying a fee to access this repository and being required to contribute their monitoring data, thereby promoting collaboration with statutory consultees to ensure comprehensive data collection. This approach aims to transfer costs from individual data collection efforts to a collective system, ultimately facilitating large-scale data gathering while providing developers access to vital information (Caine 2020).

On the other hand, government agencies play a crucial role in creating publicly accessible databases with standardized protocols to enhance data quality and availability to facilitate CIA (Neri et al. 2016). Additionally, publicly available data platforms, also known as *clearinghouses*, are vital for storing and sharing environmental information. These centralized systems offer access to EIS and related documents, aiding agencies, consultants, and the public in assessing cumulative impacts. Moreover, data-sharing

initiatives enhance access to authoritative data, including marine-specific information (Prahler et al. 2014). This is particularly important in countries where project proponents are responsible for conducting environmental studies, including CIA.

Declerck et al. (2023) demonstrated that, in the case of CIAs required at various levels of MSP, SEA, and project-level EIA, a framework involving data requirements, modeling approaches, and shared monitoring strategies may be necessary to support a proper, holistic, and ecosystem-based assessment of cumulative impacts. In the United States, BOEM collaborates with the National Oceanic and Atmospheric Administration (NOAA), which provides baseline data and analysis on ocean conditions, marine resources, fisheries operations, and research and monitoring of offshore wind energy impacts²⁵. Similarly, in Canada, Fisheries and Oceans Canada supports programs and research to enhance the understanding of cumulative effects (Clarke et al. 2022).

In this way, effective CIA assessment and management highlight the importance of a collaborative approach with clearly defined roles and responsibilities among project proponents, government authorities, and affected communities. Ensuring access to high-quality data and commitment to shared accountability strengthen environmental assessments and support informed decision-making.

Promoting public participation

Public participation is a cornerstone of the EIA process and is required across different levels of planning, from strategic to project assessments, in most countries. Ensuring public involvement provides interested parties with opportunities to express their opinions, especially during the scoping phase, when community input can guide the direction of assessments. However, public participation in the scoping phase is not widely required. Practices, such as participatory funding in Canada, can significantly improve public participation.

The practice of public participation in MSP reinforces the guiding principle of promoting the inclusive participation of stakeholders in the MSP process (UNESCO-IOC, European Commission 2021; Quesada-Silva et al. 2019), aiding in the identification of interactions among stakeholders and their cumulative impacts (Flannery et al. 2018) as well as the most affected resources and components.

CIA tools enable the assessment of various policy scenarios and planning decisions, involving planners and practitioners in addressing complex information while enhancing transparency (Hammar et al. 2020). Continuous

²⁵ Source: <https://www.fisheries.noaa.gov/topic/offshore-wind-energy>.

engagement of affected communities and the public is key to assessing and managing cumulative impacts.

Opportunities for participation should be promoted in all CIA steps, especially in scoping, impact significance determination, and management of cumulative impacts (IFC - International Finance Corporation (2013). Stakeholder engagement at the strategic level is crucial in the process, but it involves how stakeholders are truly engaged and their effective influence on decision-making (Fidler and Noble 2013). Special attention should be given to stakeholder engagement and public consultation, as these are fundamental to identifying and addressing cumulative concerns at the project-level, especially local stakeholders, which can reduce local objections (World Bank Group 2021).

The main findings highlighted the importance of encouraging meaningful engagement at every stage, from screening to follow-up, at strategic, regional, and project levels. Communities can play a more meaningful role in planning decisions and help ensure environmental management is inclusive and well-informed.

Conclusion

CIA for offshore projects has been implemented in several countries, aiming at capturing the effects of multiple activities on marine ecosystem components. A review of established regulatory practices for assessing cumulative impacts in certain countries was conducted with the expectation that it could be applied to guide the development of future regulations in both emerging and mature offshore wind markets.

The comparative analysis shows that while all assessed countries incorporate CIA into their legal frameworks to varying degrees, key differences remain in terms of definitions, levels of application, institutional responsibilities, public participation, and tiered assessment. The key findings from this review for advancing CIA regulation are: (1) Clear legislation is foundational to effective CIA, as it ensures consistency and can foster best practices; (2) Definition of cumulative impacts is key to guiding CIA implementation for effective environmental regulation, enhancing both consistency and efficacy; (3) CIA requirements are crucial at various planning levels, from marine planning to project assessments, promoting better informed decision-making, although integrating CIA approaches at different levels can be challenging for supporting tiered decision-making; (4) CIA regulations should consider collaboration, clear roles, and shared accountability among institutions and sectors; and (5) Stakeholder engagement and public consultation should be ensured throughout all the CIA steps.

CIA can be regarded as a public policy innovation in various contexts. It is critical for responsibly advancing marine uses, including OWE. To frame new systems in contexts where CIA is not regulated, comparing the existing practice can identify guiding elements to be considered. The practice of CIA is quite diverse, but it is increasingly recognized as essential in areas with intensive or conflicting uses. Therefore, even in well-established systems, each jurisdiction could consider fit-for-purpose amendments to enhance their practice.

Ultimately, successfully implementing CIA in the offshore wind sector will contribute to the long-term sustainability of marine ecosystems and ensure perennial economic activity. This will require balancing a greater renewable energy supply with protecting environmental health and biodiversity. Conciliating both objectives requires that policymakers and legislators develop clear and enforceable CIA requirements adaptable to their national contexts while focusing on ecological integrity and stakeholder inclusiveness.

Future research could explore sub-national legislation and sub-legal regulations, as well as the content of technical guidelines, to provide a more detailed assessment of the guiding elements of CIA discussed in this study. These regulatory layers play a crucial role in shaping how cumulative impact considerations are operationalized in practice, offering additional mechanisms beyond national legislation. Investigating these frameworks could provide valuable insights into how CIA principles are applied in decision-making at various governance levels. Furthermore, research could analyze how CIA implementation aligns with both regulatory requirements and technical guidelines content. This could aid in identifying potential compliance gaps, assessing the effectiveness of existing legislative instruments, and uncovering opportunities for enhancing CIA practices.

Data availability

No datasets were generated or analysed during the current study.

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Author contributions APAD led the conception, design, and writing of the manuscript. JSG and CGD provided substantial inputs and revisions. AT and LES contributed to the revision and editing.

Compliance with ethical standards

Conflict of interest The authors declare no competing interests.

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