Guidance on biodiversity cumulative impact assessment for wind and solar developments and associated infrastructure

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IUCN is pleased to acknowledge the support of its Framework Partners who provide core funding: Ministry of Foreign Affairs, Denmark; Ministry for Foreign Affairs, Finland; Government of France and the French Development Agency (AFD); Ministry of Environment, Republic of Korea; Ministry of the Environment, Climate and Sustainable Development, Grand Duchy of Luxembourg; the Norwegian Agency for Development Cooperation (Norad); the Swedish International Development Cooperation Agency (Sida); the Swiss Agency for Development and Cooperation (SDC); and the United States Department of State.

This publication has been made possible in part by funding from EDF Renouvelables, Électricité de France (EDF), Energias de Portugal (EDP), Eni S.p.A, Equinor ASA, Iberdrola Renovables International SAU, Shell International Petroleum Mij Bv – Holland, and Total SE.

Published by: IUCN, Gland, Switzerland and The Biodiversity Consultancy, Cambridge, UK

Produced by: IUCN Global Climate Change and Energy Transition Team and The Biodiversity Consultancy

Recommended citation: Bennun, L., Fletcher, C., Cook, A., Wilson, D., Jobson, B., Asante-Owusu, R., Dakmejian, A., Liu, Q. (2024). *Guidance on biodiversity cumulative impact assessment for wind and solar developments and associated infrastructure*. Gland, Switzerland: IUCN, and Cambridge, UK: The Biodiversity Consultancy

ISBN: 978-2-8317-2317-4 (PDF)

DOI: https://doi.org/10.2305/EHGE6100

Copy-editing and layout: Diwata Hunziker

Cover photo: Fishers working near wind turbines/Tran Le Tuan

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Executive summary

The stringent Paris Agreement target of limiting global warming to 2°C above pre-industrial levels by 2050 emphasises the necessity of urgent, rapid, and extensive renewable energy adoption to achieve this goal. In parallel, the recently adopted Kunming-Montreal Global Biodiversity Framework (KMGBF) has the overall vision of achieving full recovery of nature by 2050, and by 2030 aims to halt and reverse biodiversity loss to sustain a healthy planet, whilst delivering benefits essential for human well-being and economic prosperity for all people. These two intertwined global goals highlight that the transition to low-carbon energy cannot occur in isolation, nor in a vacuum – achieving them both requires combining efforts to reduce greenhouse gas (GHG) emissions with biodiversity conservation and ensuring they are mutually beneficial.

As wind and solar energy projects proliferate worldwide, policy makers, practitioners, and conservationists alike are recognising the need for timely strategic planning to inform licensing and regulatory systems and conservation approaches, and which can respond to the accelerating pace of the renewable energy transition. Key to this is balancing the reduction of GHG emissions with the need to minimise local biodiversity and human well-being impacts. The pace of the energy transition will require the renewable energy sector to both maximise development in current areas of favourable wind and solar resource and expand into many new areas. Competition for suitable and available areas will thus increase. Understanding cumulative impacts is therefore an important part of informing strategic, coherent, and efficient collective approaches to mitigation and ecological compensation. This includes spatial planning to support informed decisions about energy policies and the allocation and sustainable use of the available space (both on land and in the coastal/marine realm) and informing the potential trade-offs that might be necessary to support inclusive planning and a managed energy transition. This relates not only to project-level objectives and mitigation efforts, but also to achieving global and jurisdictional goals and targets for nature.

Cumulative impacts on biodiversity represent some of the most complex and urgent environmental, social, technical, and governance issues of today, which raise significant challenges at a cumulative scale as the renewable energy industry undergoes a rapid global expansion. Implementation remains problematic in practice, for practical reasons including (but not limited to): i) the frequent absence of government-led strategic planning and assessment (including absence of conservation targets and thresholds); ii) poor integration of cumulative impact assessment (CIA) into project environmental and social impact assessment (ESIA) and approvals processes; iii) lack of standardised methods for assessing cumulative impacts; iv) data availability and access to information (including data and information collected through monitoring at sites under construction and in the operational phase); v) and handling uncertainty. Conceptually, a fundamental challenge for CIA is that it is commonly implemented as an element of impact assessment and is framed in terms of damage limitation, or defining what constitutes 'acceptable loss' of biodiversity (i.e. how many of a species, or what extent of an ecosystem). This approach is now misaligned with global biodiversity goals (e.g. KMGBF) and jurisdictional targets, which are increasingly aspirational and framed around recovery and restoration.

These commonly encountered practical and conceptual barriers can prevent or hinder the assessment of cumulative impacts, and they are often exacerbated in emerging market contexts where enabling policy and regulations are emerging or yet to be developed. From the perspective of conservation and biodiversity outcomes, these challenges will become even more significant as wind and solar development scales up in countries and regions with emerging regulatory oversight and/or a limited biodiversity information base.

Thus, a key aim of this guidance is to **reframe CIA to help support biodiversity conservation and the achievement of global biodiversity goals** (alongside climate and other societal development goals). This guidance is focused on biodiversity and wind and solar development, and is aimed primarily at government planners and project developers. However, since it is designed to help tackle some of the existing challenges of CIA, there is potentially broader applicability. It complements existing guidance on CIA by:

- outlining **pragmatic and scalable approaches** to implementation of CIA by government planners responsible for the renewable energy transition, and by wind and solar energy project developers, that:
  - are aligned with existing good practice (such as the mitigation hierarchy), whilst recognising that the timeframe to meet global and national climate targets is short;
  - show how the requirement for individual developers to assess multiple other projects or activities can be avoided; and
  - show how CIA can be better integrated into project-level ESIA, and what developers can do when there is not a government-level CIA to draw on.
- **facilitating an 'entry point' for government-led CIA**, showing how CIA can be approached even in data-poor contexts where the available biodiversity baseline information remains limited, especially where regulatory requirements are still emerging, and/or resources and capacity are limited (again recognising the urgency with respect to the transition);
- **signposting emerging technical methods** which show promise for improving CIA in wind and solar contexts, which governments and project developers may consider trialling or improving further.
- **summarising the key biodiversity features** where cumulative impact are likely to have the greatest effect, and so likely to be a focus of a CIA for wind and solar development and transmission infrastructure; and
- **highlighting priority areas that still need improvement** either through technical development or regional- or sector-scale collaboration.

The document outlines approaches for:

- **government-led CIA**: an approach for government planners to carry out at the appropriate strategic (e.g. national or regional) scale.
- **project-level CIA**: approaches for developers of wind and solar projects and associated infrastructure to undertake at the individual project level – one when there is a government-led CIA available to draw on, and a fallback approach when there is not.

These two scales are intrinsically linked. Ideally, the government-led CIA provides the framework within which project-level CIA is implemented. As part of this, government can establish guiding principles and minimum standards for CIA, including requirements for stakeholder engagement, technical methods, and data sharing between projects. Project level CIA, can then help fill any gaps in government-led CIA, leading to incremental improvements in it.

Lenders and investors could also benefit from the information and practical approaches described, as a potentially useful complement to the existing standards and guidance of financial institutions (depending on the specific project situation), or as part of broader enabling programmes to promote the renewable energy transition, supported by development finance institutions.

The approach to each step is detailed in the guidance herein, summarised as follows:

1) Set the spatial and temporal scales of CIA.

2) Identify valued environmental components (VECs) – the environmental and social attributes considered to be important in assessing risks – and trends in these VECs at an appropriate spatial scale.

3) Determine VEC conservation targets and impact thresholds.

4) Define an approach to apportioning allowable impacts on VECs.

Stakeholder engagement, and data sharing and dissemination, will be essential. Information on the technical methods that could be used to support CIA is provided. Expert knowledge is expected to comprise a substantial part of the approach. Determining an acceptable threshold level of impact, beyond which a biodiversity feature may undergo undesirable change, is often a challenging technical and political problem. There are many reasons why ecological thresholds are difficult to define, determine and standardise. Where information and resources allow, methods such as those outlined in Section 3 can be used to assess population- or ecosystem-level impacts and thresholds for individual VECs. In relatively data-poor situations, a practical way forward is to assign VECs (based on overall conservation targets and specific VEC characteristics) to a set of general categories with associated thresholds.

At the government level, the benefits of CIA include the ability to take a broad and holistic view and deliver conservation outcomes on a much larger scale than project-by-project assessment, by identifying national or regional conservation priorities and defining conservation targets/impact thresholds at that scale. Government-led CIA also supports more efficient, consistent, and expedited project-level permitting processes by aiding transparency and equitability between projects and enabling developers to integrate CIA and conservation priorities more easily into the project ESIA process from the beginning. Likewise, government-led CIA avoids the requirement for individual developers to assess other multiple projects or activities which is a common expectation and often beyond the ability of individual developers to achieve meaningfully.

The value of CIA to project developers includes providing confidence that receptors at high risk of cumulative impacts, and consequently material project impacts, are identified in a timely manner so that effective and efficient project design, mitigation and monitoring actions can be identified as early as possible. This can be expected to reduce the risk of needing to identify and implement additional mitigation requirements at late stages of project development or even operations, hence leading to increased investor confidence.

CIA also clearly sets potential project impacts within the context of other pressures on biodiversity and can guide effective collaborations with other project proponents and stakeholder partners (e.g. environmental NGOs, civil society) to implement collective mitigation, compensation, and monitoring actions at appropriate spatial scales.

When there is a government-led CIA to draw on, the outputs can be integrated directly into the project ESIA at the scoping stage and inform the subsequent process (e.g. establishing the baseline, informing impact assessment, and mitigation requirements). Projects should follow existing good practice for ESIA. In this guidance, it is assumed that existing government assessments are robust, up to date, have been developed in consultation with appropriate stakeholders and remain representative. It is not expected that individual developers should be required to validate the outcomes of government-led CIA, since the scope of a project-level ESIA baseline is unlikely to capture or represent the spatial scale of government-led CIA.[1]

In both cases, the project approaches are designed to be implemented during the ESIA scoping and baseline stages. They show how establishing the status of biodiversity features and defining thresholds for impact can help work around the challenge of having to evaluate impacts linked to other developments. Since developers working in the same landscape or seascape are likely to have the same (or many of the same) biodiversity priorities, there are opportunities for collaboration to identify relevant features and to set thresholds. An important outcome of project-level CIA and ESIA will be to facilitate data availability to feed into and inform government-level assessments.

1 It is important that the data used for government-led and project-level CIA should be coherent For example, developers may, if they wish, be able to verify VEC trajectories at the spatial scale of government-led CIA, using desk-based approaches.

Acknowledgements

The following have made contributions to the contents of this publications as participants of the IUCN Promoting Nature-friendly Renewable Energy Developments project:

Reviewers and contributors
Tris Allinson (BirdLife International); Audrey Bard (Equinor); Joyce Boekestijn (Shell); Guillaume Capdevielle (Total SE); Melanie Dages (EDF Renewables); Astrid Delaporte-Sprengers (Total SE); Steven Dickinson (Total SE); Gustavo Estrada (Eni); Alessandro Frangi (EDF Renewables); Monica Fundingsland (Equinor); Ben Jobson (TBC); Agathe Jouneau (EDF Renewables); Marine Julliand (Total SE); Peter Marcus Kolderup Greve (Equinor); Magdalena Kos (Eni); Larissa Leitch (Shell); Adele Mayol (Total SE); Bruce McKenney (The Nature Conservancy); Thomas Merzi (Total SE); Marta Morichini (ENI); Rhiannon Niven (BirdLife International); Pedroni Paola Maria (Eni); Magali Pollard (Total SE); Howard Rosenbaum (Wildlife Conservation Society); Jose Rubio (Fauna & Flora International); Eldina Salkanovic (Shell); Libby Sandbrook (Fauna & Flora International); Ariane Thenaday (Total SE); Claire Varret (EDF); Hafren Williams (Fauna & Flora International); Margherita Zapelloni (Eni Plenitude).

Peer reviewers
Edward Willsteed (Associate Director, Howell Marine Consulting); Cris Hein (Senior Project Leader-Environmental Portfolio, National Renewable Energy Laboratory)

Disclaimer
BirdLife International chose not to receive funding for its contribution to this project, as per their Working with Business Framework.

Acronyms

AA	Appropriate assessment
ABM	Agent-based models
BSI	British Standards Institution
CBD	Convention on Biological Diversity
CE	Cumulative exposure
CEA	Cumulative effects assessment
CEAM	Cumulative effects assessment and management
CEM	Commission on Ecosystem Management
CI	Cumulative impact(s)
CIA	Cumulative impact assessment
CIU	Counterfactual of Impacted to Unimpacted Population
CSP	Concentrated solar power
CSRD	Corporate Sustainability Reporting Directive
DECC	Department of Energy and Climate Change (UK)*
DFI	Development Finance Institution
EFRAG	European Financial Reporting Advisory Group
EIA	Environmental impact assessment
EMMP	Environmental Management and Monitoring Plan
ESG	Environmental, social, and governance
ESIA	Environmental and social Impact assessment
ESRS	European Sustainability Reporting Standard
EU	European Union
GHG	Greenhouse gas
GIIP	Good International Industry Practice
GPS	Global Positioning System
GRI	Global Reporting Initiative
GW	Gigawatt
HRA	Habitat regulations assessment
IBA	Important Bird and Biodiversity Area
IDEA	Investigate, discuss, estimate and aggregate
IFC	International Finance Corporation
IMEC	Impact mitigation and ecological compensation
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
KBA	Key Biodiversity Area
KMGBF	Kunming-Montreal Global Biodiversity Framework
LEAP	Locate, evaluate, assess, prioritise
LSE	Likely significant effect
MSB	Migratory soaring birds
MSP	Marine Spatial Planning
MW	Megawatt
NFRD	Non-Financial Reporting Directive
NGO	Non-governmental organisation
ORCT	Overberg Renosterveld Conservation Trust
PBR	Potential biological removal
PV	Photovoltaic
PVA	Population viability analysis
RCIA	Rapid cumulative impact assessment
REDZ	Renewable Energy Development Zone
SABAA	South Africa Bat Assessment Association
SBTi	Science Based Targets Initiative
SBTN	Science Based Targets Network
SDG	Sustainable Development Goal
SDM	Species Distribution Modelling
SDOD	Shutdown on demand
SEA	Strategic environmental assessment
SESA	Strategic environmental and social assessment
SNCB	Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage
SPA	Special protection area
SSSI	Site of Special Scientific Interest
TNFD	Taskforce on Nature-related Financial Disclosures
USAID	United States Agency for International Development
VEC	Valued environmental component**
WWF	World Wildlife Fund
WWP	Wind power project

* Became part of the Department for Business, Energy and Industrial Strategy in July 2016.
** Also referred to as valued environmental and social component(s).

Glossary

Cumulative Exposure	The proportion of a population potentially exposed to renewable energy infrastructure. (Goodale et al., 2019)
Cumulative Effects Assessment	See Annex I – Definitions from literature
Cumulative Effects Assessment and Management	See Annex I – Definitions from literature
Cumulative impact(s)	Variously defined in the literature and by government agencies and financial institutions as impacts that can result from the successive, incremental, and/or combined effects of an action, in combination with other relevant past, present, and reasonably foreseeable future actions, including individually minor but collectively significant actions taking place over a period of time, and focused on features and impacts that are generally recognized as important based on scientific considerations and/or concerns from directly affected local communities. See Box 2 and Annex I.
Cumulative Impact Assessment	See Annex I
Ecological threshold	The point at which a relatively small change in external conditions causes a rapid change in an ecosystem. When an ecological threshold has been passed, the ecosystem may no longer be able to return to its state by means of its inherent resilience (IPBES, 2019)
Ecosystem integrity	Considered to be the degree to which an ecosystem's characteristics reflect its natural range of variation (Carter et al., 2019; Nicholson et al., 2021). Characteristics include ecosystem condition (with components of composition, structure and function) and connectivity
Effect	An effect is a change as a result or consequence of an action or another cause. An effect is not necessarily an impact unless it affects a component of the environment in a significant or substantial way, as deemed by society (Blakley, 2021). The terms 'effect' and 'impact' are often used synonymously in the literature and the community of practice.
Kunming-Montreal Global Biodiversity Framework	This framework was adopted during COP 15 following a four-year consultation and negotiation process. It sets out a suite of goals and targets for overall biodiversity outcomes by 2030 and 2050. The framework aims to put nature on a path to recovery, halting biodiversity loss and reversing it through ecosystem and species restoration
Good International Industry Practice	Defined as the exercise of professional skill, diligence, prudence, and foresight that would reasonably be expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally or regionally (IFC, 2012)
Investigate, Discuss, Estimate and Aggregate	Defined as a structured elicitation protocol modified from the well-established Delphi procedure (Hsu & Sandford, 2007) and was designed to derive judgements of quantitative and probabilistic estimates (Courtney Jones et al., 2023)

IDEAcology	An interface created specifically for the IDEA protocol, designed to facilitate managing an IDEA elicitation, the process prior to statistical analysis (Courtney Jones et al., 2023)
Impact	An effect becomes an impact when it affects a component of the environment in a significant or substantial way, as deemed by society (Blakley, 2021). The terms 'effect' and 'impact' are often used synonymously in the literature and the community of practice.
Likely significant effect	Any effect that may reasonably be predicted as a consequence of the plan or project that may affect the conservation objectives of the features for which a site was designated.
Mitigation hierarchy	A widely used tool that guides users towards limiting as far as possible the negative impacts on biodiversity from development projects. It emphasises best-practice of avoiding and minimising any negative impacts, and then restoring sites no longer used by a project, before finally considering offsetting residual impacts (TBC, 2024)
Natura 2000	"A network of protected areas covering Europe's most valuable and threatened species and habitats. It is the largest coordinated network of protected areas in the world, extending across all 27 EU Member States, both on land and at sea. The sites within Natura 2000 are designated under the Birds and the Habitats Directives" (EEA, 2023)
Nature positive	There is no single agreed definition for this concept, and several are in use. In line with the KMGBF, the Nature Positive Initiative defines it as 'halt and reverse nature loss by 2030 on a 2020 baseline, and achieve full recovery by 2050.' According to the United Kingdom Council for Sustainable Business, "a nature-positive approach puts nature and biodiversity gain at the heart of decision-making and design. It goes beyond reducing and mitigating negative impacts on nature as it is a proactive and restorative approach focused on conservation, regeneration, and growth" (zu Ermgassen et al., 2022, p. 3) (see Box 1).
Potential biological removal	A measure of the number of individuals that can be removed from a population annually by human-induced mortality whilst retaining a viable population (Wade, 1998)
Species Distribution Modelling	Quantitative modelling approach that relates known locations of species occurrences to environmental covariates (e.g. altitude, temperature, precipitation, land cover) that may influence or define habitat potential photovoltaic
Tipping point	A set of conditions of an ecological or social system where further perturbation will cause rapid change and prevent the system from returning to its former state (IPBES, 2019).
Valued environmental component	Defined as environmental and social attributes considered to be important in assessing risks (IFC, 2013). They are the receptors considered important by governments, project proponents, the public or other stakeholders, based on cultural values or scientific concerns (Hegmann et al., 1999)

Inspecting or repairing solar cells on solar farms. Photo: EmmaStock

1 Introduction

1 The renewable energy transition

The need to transition to a lower carbon, nature-safe, renewable energy-based economy is more urgent than ever (WWF & BCG, 2023; WWF & TBC, 2023). The Paris Agreement[2] sets a stringent target of limiting global warming to 2°C above pre-industrial levels by 2050,[3] emphasising the necessity of urgent, rapid, and extensive renewable energy adoption to achieve such target. Delays in implementing low-carbon energy solutions as part of the transition from fossil fuels to renewable energy will severely hinder progress towards this goal.

In parallel, the recently adopted Kunming-Montreal Global Biodiversity Framework[4] (KMGBF) sets an overall vision of achieving full recovery of nature by 2050, and aims to halt and reverse biodiversity loss by 2030 to sustain a healthy planet, whilst delivering benefits essential for human well-being and economic prosperity for all people (Box 1).

These global climate and nature goals highlight that the transition to low-carbon energy cannot occur in isolation, nor in a vacuum – achieving them both requires combining efforts to reduce greenhouse gas (GHG) emissions with biodiversity conservation and ensuring they are mutually beneficial (action on climate is not necessarily inherently good for biodiversity (Dunne, 2022). Further, access to energy remains a critical challenge in many countries, subjecting many people to a life of poverty. Addressing this challenge through the rapid deployment of renewable energy is paramount – in 2023 at the halfway point for achieving the 2030 Sustainable Development Goals (SDGs) the world is currently not on track to achieve SDG 7 – ensuring access to affordable, reliable, sustainable and modern energy for all (IEA, 2023a; Roser, 2020; World Bank, 2023). All of this implies the need to transform the way societies are operating to address the current biodiversity and ecosystem collapse and work towards a just and nature-positive future.[5]

Renewable energy is now the least cost option in the power sector (REN21, 2019). Over 60 countries now generate more than 10% of their electricity from wind and solar (Ember, 2023), and renewable energy is expected to overtake coal as the largest source of global electricity generation by early 2025 (IEA, 2022a). Over the period 2022 to 2027, renewable energy capacity is expected to grow by 2,400 gigawatts (GW)[6] – equalling the entire installed capacity of China today, and to account for more than 90% of global electricity capacity expansion (IEA, 2022a). Overall, renewables are set to contribute up to 80% of new power capacity by 2050 (mostly from solar PV) (IEA, 2022b). However, while large-scale decarbonisation of global power infrastructure is essential to meeting climate goals, it must not happen at the expense of nature (Gasparatos et al., 2017; TNC, 2021), especially as this would likely reduce the efficacy of decarbonisation efforts.

2 https://unfccc.int/process-and-meetings/the-paris-agreement
3 To achieve the Paris Agreement goal, greenhouse gas (GHG) emissions must peak before 2025 at the latest and decline 43% by 2030. However, global GHG emissions continue to increase, for various reasons (IPCC, 2023a)
4 https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf
5 Note that the KMGBF does not specifically include the term 'nature positive', and there is no single agreed definition for this concept – several are in use (for example, zu Ermgassen et al., 2022). IUCN is developing a quantitative methodology to help companies, governments and civil society assess opportunities and risks, set targets, measure progress and deliver nature-positive impacts (IUCN, 2022).
6 1 GW, or 1 billion watts, is enough to power approximately 333 x 3 MW utility scale wind turbines, or around 3.125 million x 320 watt photovoltaic panels, or about 100 million LED light bulbs (Rumph, 2022). For context, the United States consumed 3,995 GW in 2022 (Stein, 2023).

Box 1

Global goals for biodiversity

In December 2022, global goals for biodiversity were adopted via the Kunming-Montreal Global Biodiversity Framework (KMGBF) (CBD, 2022). This historic intergovernmental agreement is also an explicit call to action for the private sector, requiring all sectors of society to contribute towards its delivery (Booth et al., 2023). The key elements of the KMGBF are four long-term goals to achieve the 2050 vision, that "by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people," including 23 action-oriented global targets to achieve the 2030 mission – in short, "to take urgent action to halt and reverse biodiversity loss to put nature on a path to recovery" (CBD, 2022).

Goal A addresses biodiversity outcomes and includes elements to enhance ecosystem area and integrity, restore species populations and prevent extinctions, and safeguard genetic diversity.

Targets for 2030 address threat reduction and restoration, sustainably meeting people's needs, and means of implementation. Threat-reduction and restoration targets are especially relevant in the roll out and expansion of renewable energy development globally. These include targets related to: inclusive spatial planning and halting loss of high biodiversity importance areas (**Target 1**); effective restoration of at least 30% of degraded areas of ecosystems (**Target 2**); effective conservation and management of at least 30% of land and sea (**Target 3**); and urgent action to halt extinctions and ensure conservation and recovery of species (**Target 4**). These global targets have implications for targets and thresholds for biodiversity features in Cumulative Impact Assessments (CIA) (see Section 3.3.3).

Target 14 calls for governments to integrate biodiversity across all policies and plans, including strategic environmental assessments and environmental impact assessments, at all levels of government and across all sectors, "progressively aligning all relevant public and private activities, and fiscal and financial flows" (CBD, 2022, p. 11) with the KMGBF. CIA, as an input to inclusive spatial planning, is an important tool for meeting this target as well as Target 1.

Target 15 requires government to take measures that ensure businesses assess and disclose their biodiversity-related risks, dependencies and impacts, along value chains and across portfolios, "in order to progressively reduce negative impacts on biodiversity, increase positive impacts, reduce biodiversity-related risks to business and financial institutions, and promote actions to ensure sustainable patterns of production" (CBD, 2022, p. 11).

The 'nature positive' concept

In parallel with the KMGBF, the 'nature positive' concept is emerging as an inclusive and ambitious 'rallying call' that aligns with the KMGBF (Booth et al., 2023). 'Nature' is often used as shorthand for biodiversity, but it is a broader concept that also encompasses non-living components, such as climate, air, soil and water. Conservation and business forums are increasingly converging on the nature positive concept (zu Ermgassen et al., 2022) to achieve the 2030 and 2050 goals of the KMGBF and to drive transformative change in the relationship between business and nature. There is no single agreed definition for the term, and several are in use. In line with the KMGBF, the Nature Positive Initiative defines it as "halt and reverse nature loss by 2030 on a 2020 baseline, and achieve full recovery by 2050" (NPI, n.d.). The UK

continued→

Box 1 (continued)


Photo: © Ricardo Tomé/TBC

Council for Sustainable Business says "a nature-positive approach puts nature and biodiversity gain at the heart of decision-making and design. It goes)beyond reducing and mitigating negative impacts on nature as it is a proactive and restorative approach focused on conservation, regeneration, and growth" (zu Ermgassen et al., 2022, p. 3). Although debate continues on what 'nature positive' means for business (Milner-Gulland, 2022; zu Ermgassen et al., 2022), it is generally viewed as a broad societal goal to which businesses and civil society can contribute, rather than a specific project or organisational-level objective.

The idea of 'nature positive' emerges from the urgent need to conserve and restore nature, with widespread recognition of the pace at which species and ecosystems are disappearing and the scale of risk this poses to business and society (Dasgupta, 2021; IPBES, 2022; WWF, 2022). Nature positive moves beyond traditional corporate approaches, such as no net loss (NNL) or net positive impact (NPI) of biodiversity, in three main ways (TBC, 2022): i) a broader scope, encompassing all of a company's value chain and integrating all of nature; ii) clearer alignment with global goals – requiring absolute improvements in the state of nature, not just slowing down its loss; and iii) emphasis on both mainstreaming nature in corporate structures and processes, and broader, transformational systems change that goes beyond any single company.

The KMGBF does not include the term 'nature positive' but embeds this purpose and clear direction for the journey towards collective action for biodiversity. It also signposts increasing stakeholder expectations for the role of business in supporting efforts to halt and reverse biodiversity loss, including in the text of Target 15 (TBC, 2023). The IUCN Commission on Ecosystem Management (CEM), through the Impact Mitigation and Ecological Compensation Thematic Group (IMEC) has developed a technical paper, 'Nature positive for business, Developing a common approach' (Baggaley et al. 2023), to provide businesses with a better understanding of approaches that can contribute to the global goal of nature positive.

Application of the mitigation hierarchy is central to a 'nature positive' approach (Maron et al., 2023). This means strongly prioritising impact avoidance and minimisation, whether at project, landscape or systems levels. To meet the KMGBF and 'nature positive' goals for nature recovery, further conservation actions will also then be needed to obtain an overall net gain of biodiversity.

Contributed by: The Biodiversity Consultancy

As wind and solar energy projects proliferate worldwide, policy makers, practitioners, and conservationists alike are recognising the need for timely strategic planning to inform licensing and regulatory systems and conservation approaches, which can respond to the accelerating pace of the renewable energy transition. Key to this is balancing the reduction of GHG emissions with the need to minimise local biodiversity and human well-being impacts. The pace of the energy transition will require the wind and solar sectors to both maximise development in current areas of favourable resource and expand into many new areas. Competition for suitable and available areas will thus increase, emphasising the importance of early government-led strategic spatial planning and assessment (Box 2). It is also worth noting that the regulatory landscape for nature and biodiversity reporting and target setting is advancing rapidly across different jurisdictions in response to the growing trend towards 'mainstreaming' biodiversity into corporate decision-making (Box 3).

Hence, understanding and managing potential cumulative impacts (see Section 1.2) on biodiversity in meaningful and practical ways will be key to a renewable energy transition that supports both climate and nature goals. It is therefore essential to meaningfully assess the potential cumulative impacts of development alongside multiple different global/national goals and targets, to be able to make informed decisions about energy policies and the allocation and sustainable use of the available space, both on land and in the coastal/marine realm, as well as informing the potential trade-offs that might be necessary to support inclusive planning and a managed energy transition.

1.2 Terminology

Whilst there is no single agreed definition for the terms 'cumulative impact', this guidance aligns with the definitions in the literature and used by government agencies and financial institutions (see Annex I), which generally acknowledge that cumulative impacts can result from **successive, incremental, and/or combined effects of an action** (e.g. a development project):

- acting in combination with other relevant past, present, and reasonably foreseeable future actions;[7]
- including individually minor but collectively significant actions taking place over a period of time; and/or
- focused on features and impacts that are generally recognised as important, based on scientific considerations and/or concerns from directly affected local communities.[8]

Some definitions state what types of impacts contribute to cumulative impacts, and others do not (Foley et al., 2017). The terms 'cumulative effects' (CE) and 'cumulative effects assessment' (CEA) are also used and are generally interchangeable with cumulative impacts and CIA (Blakley, 2021; Roudgarmi, 2018; Seitz et al., 2011). There is a distinction between 'effect' and 'impact', whereby an effect is not necessarily an impact unless it affects a component of the environment in a significant or substantial way, as deemed by society (Blakley, 2021). The expanded term 'cumulative effects assessment and management' (CEAM) captures the need for mitigation and management (Canter & Ross, 2010).

In Europe, the term 'in combination assessment' is used with specific respect to the Habitats Directive (EU, 1992) and the requirement to understand the potential for a project to have adverse significant effects on the integrity of sites in the Natura 2000 network (European Commission, n.d.) (Case study 1; EU, 1992 in combination assessment). The CSRD[9] on material sustainability impacts, risks and opportunities (ESRS 4)[10] does not specifically refer to cumulative impacts, but it refers to

7 WBG ESS1 (World Bank, 2017) also adds "unplanned but predictable activities enabled by the project that may occur later or at a different location". IFC PS1 (IFC, 2012a) limits activities for consideration to those existing, planned or reasonably defined at the time the risks and impacts identification process is conducted.

8 Termed 'Affected Communities' in IFC PS1 (IFC, 2012a) and WBG ESS1 (World Bank, 2017).

9 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464

10 https://www.efrag.org/lab6

Box 2

Relationship between cumulative impact assessment and strategic spatial planning and assessment

CIA is a component of, and not synonymous with, wider strategic spatial planning and assessment processes like Strategic Environmental Assessment (SEA) or Marine Spatial Planning (MSP) (see Bennun et al., 2024). SEA is a systematic process for incorporating environmental and social considerations across different levels of strategic decision-making (the plan, programme, and policy levels) as early as possible, with a high degree of government ownership (EU, 2017). It is not a single approach, but a family of approaches on a continuum from impact analysis to institutional assessment (Coutinho et al., 2019). MSP is defined as a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that usually have been specified through a political process (Ehler & Douvere, 2009).

Both SEA and MSP are usually government-led processes for exploring future development scenarios and influencing and rationalising the organisation and future spatial distribution of different activities. The aim is to balance development with the need to protect the environment and achieve social and economic objectives in a transparent way, based on managing trade-offs between environmental, economic, and social constraints (Blakley & Noble, 2021; Ehler & Douvere, 2009; Partidario, 2012). Significant biodiversity impacts can often be avoided entirely by placing renewable energy developments in areas of low biodiversity value, such as previously converted sites (e.g. agricultural lands and other types of modified habitat). Avoidance at the early planning stage is the most effective and lowest cost mitigation measure available to governments and developers.

Hence, the important role of CIA to identify biodiversity priorities and understand conservation goals/targets for them, which then feeds into strategic planning and assessment – alongside multiple other considerations. CIA is a key input into strategic planning and assessment, and it must be linked to these processes (Figure 1). This is one key reason why it is beneficial to reframe CIA away from an impact assessment approach that attempts to define how much loss is acceptable, towards a conservation-oriented approach that helps plan to align with global and jurisdictional biodiversity goals/targets (see Section 2.1). Government-led CIA may take place at the landscape, national, or international (e.g. regional or flyway) levels, but it will not be effective if delinked from robust planning, target-setting, and implementation processes.

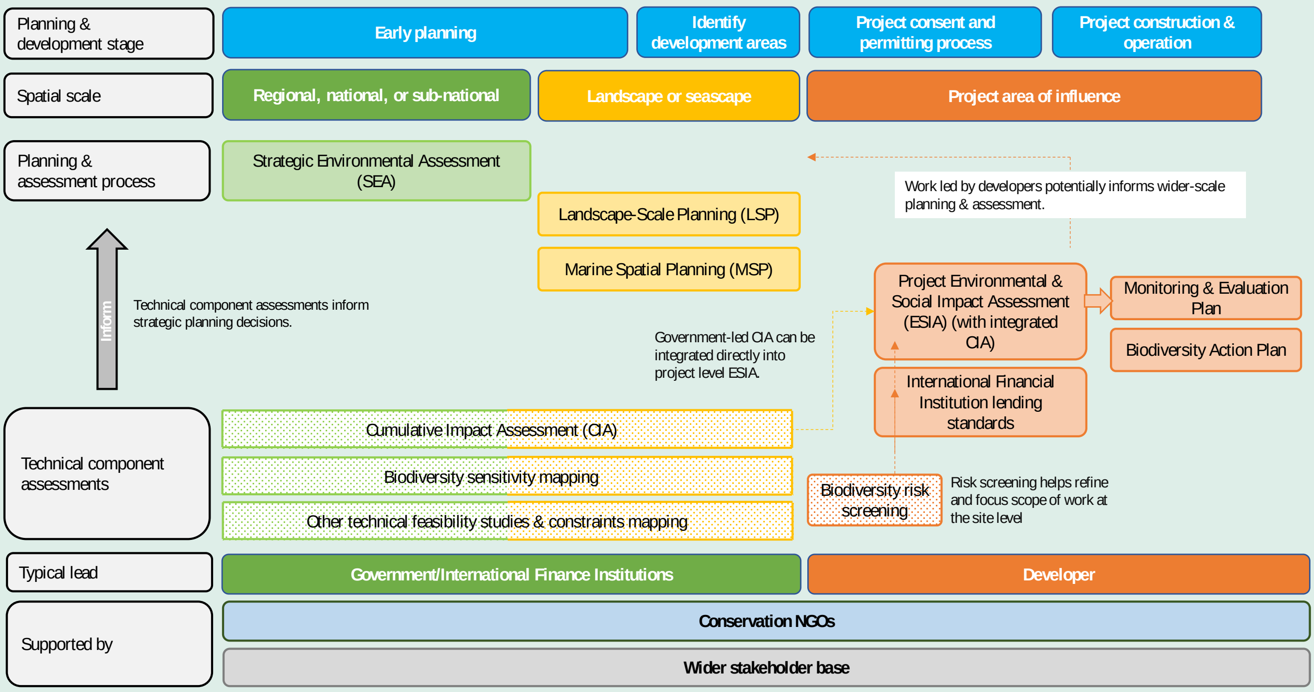

Figure 1 Overarching existing spatial planning processes and key technical component assessments *Source: Authors.*

Note: This is a simplified figure of processes and assessments that in practice involve significant feedback and adaptive response. Some are highlighted in the figure.

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Box 3

The emerging reporting and disclosure landscapes

A shift towards 'nature-positive thinking' (Box 1) by corporates has also been supported by the development of regulatory, such as the EU Corporate Sustainability Reporting Directive (CSRD), and voluntary standards (such as the Science-based Targets Network (SBTN) and the Taskforce for Nature-related Financial Disclosures (TNFD) (White et al., 2023).

CSRD is an EU environmental, social, and governance (ESG) legislative act that extends the reporting scope of the existing Non-Financial Reporting Directive (NFRD). The goal of the CSRD is to provide transparency that will help investors, analysts, consumers, and other stakeholders better evaluate EU companies' sustainability performance as well as the related business impacts and risks. Companies subject to CSRD report according to European Sustainability Reporting Standards (ESRS), prepared by EFRAG (European Financial Reporting Advisory Group). The ESRS are a set of rules for what information companies should disclose, and when and how they should do it. There are general requirements (ESRS 1) and disclosures (ESRS 2) for every company, and ESG topical standards split into Social and Environmental Standards, including ESRS 4 on biodiversity and ecosystems.

SBTN is a global coalition of NGOs, business associations, consultancies, leading scientists, and sustainability experts focused on setting the standard for ambitious corporate action on nature, translated into science-based targets for nature. These build on the existing Science Based Targets initiative (SBTi) which is already helped businesses to set GHG emissions reductions targets. SBTN's (2024, p. 11) current target-setting process for nature is divided into five steps: i) assess; ii) interpret and prioritise; iii) measure, set, and disclose targets; iv) act; and v) track. A guidance document is available from SBTN (2024).

TNFD builds on the Taskforce for Climate-related Financial Disclosures (TCFD) Framework. It is a global, market-led, science-based initiative with a mission to support businesses and financial institutions to integrate nature into their decision-making processes. through the identification, management, and disclosure of nature-related risks, opportunities, impacts, and dependencies. Guidance to do so is compiled in the TNFD Framework, containing disclosure recommendations, the Locate-Evaluate-Assess-Prioritise (LEAP) approach, and additional guidance for assessing, reporting, and acting. The LEAP guidance notes that consideration of external factors is also relevant for impacts because they could interact with a company's impact drivers to create cumulative impacts, or tipping points (see Sections 1.2 and 3.3.3).

TNFD aims to align with other existing frameworks, including SBTN and the EU ESRS, as well as the Global Reporting Initiative (GRI). TNFD and SBTN have released joint guidance for target-setting, outlining how both fit together and where targets sit in the TNFD framework. TNFD sector guidance is also in development, including for electric utilities and power generation, and metals and mining. Impacts within the scope of the TNFD framework include: i) direct changes in the state of nature caused by a business activity with a direct causal link; ii) indirect changes in the state of nature caused by business activities with an indirect causal link; and/or iii) cumulative changes in the state of nature (direct or indirect) that occur due to the interaction of activities of different actors operating in a landscape or freshwater/marine area.

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planetary boundaries (Stockholm Resilience Centre, n.d.) and the use of ecological thresholds[11] aligned with planetary boundaries and the KMGBF (Box 1) – both of which imply the need for CIA.

This guidance uses the terms 'cumulative impact' and 'cumulative impact assessment' as equivalent to 'cumulative effects' or 'cumulative effects assessment', respectively.

1.3 The importance of cumulative impacts for wind and solar development

Cumulative impacts on biodiversity represent some of the most complex and urgent environmental, social, technical, and governance issues of today (Blakley, 2021) (see Annex III for a summary of key potential impacts on biodiversity from wind and solar development and associated infrastructure). The reasons for this include:

- The individual impacts of a single development can combine with other developments or activities of the same type, or a range of different types, and overwhelm the ability of the receiving environment to absorb change (Blakley, 2021).
- Impacts can occur and combine at the same time, accumulate incrementally or successively, or act synergistically and unpredictably (Masden et al., 2010).
- When impacts accumulate gradually, they can be difficult to detect (Blakley, 2021).
- Individual impacts of a single development with multiple components can also combine and accumulate, such as an offshore wind farm with infrastructure in the marine realm (e.g. turbines), the intertidal/coastal zone (e.g. export cable landfall and grid connection), and onshore (e.g. substation and transmission infrastructure). If impacts are considered separately, their full effect in combination may not be obvious.
- Even project-level impacts that are individually minor or moderate (and thus often not assessed further) can be collectively significant for a receptor that is already in a compromised state (Blakley, 2021; Olagunju & Gunn, 2013; Roudgarmi, 2018; Thérivel & Ross, 2007).

These complexities raise significant challenges at a cumulative scale as the wind and solar sectors undergo a rapid global expansion. Applying the mitigation hierarchy remains central to good practice (Annex II; Bennun et al., 2021). Constraints on site suitability, whether due to physical limitations on site suitability, the need to be close to areas of energy demand, or social and economic considerations, often lead to a spatial clustering of sites. Where these sites overlap with the ranges or migratory routes of vulnerable species, the likelihood of a significant adverse impact may increase. Good baseline biodiversity data is necessary to identify sites where such an impact is likely. However, there are disparities in the availability of this baseline data, with many of the most data-limited species present in emerging markets (Proença et al., 2017), where wind and solar developments are often expanding most rapidly. In some instances, inferences about potential impacts may be made from related species in established markets (e.g. Thaxter et al., 2017). As wind and solar deployment continues to expand globally, there is an increased risk of interactions involving species with no obvious surrogates in more established markets (e.g. fruit bats, hornbills) with unpredictable consequences.

Further unpredictable consequences may be introduced through the development and expansion of emerging technologies, including floating wind and solar (see Table 1). The speed of expansion of both established and emerging technologies, coupled with the potential exposure to new species and ecosystems, increases the probability that reasonably foreseeable developments are overlooked and the consequences of the cumulative impacts associated with these projects underestimated.

11 An ecological threshold is defined by IPBES as the point at which a relatively small change in external conditions causes a rapid change in an ecosystem. When an ecological threshold has been passed, the ecosystem may no longer be able to return to its state by means of its inherent resilience.

Table 1 Challenges for implementing Cumulative Impact Assessment for wind and solar development

CHALLENGES	EXAMPLES
Rapid expansion Wind and solar development is expanding rapidly in parts of the world where there is often limited regulatory capacity, baseline datasets, and resources to support assessment and spatial planning	As of October 2023, at least 140 new industrial-scale onshore wind projects were already in planning across Africa, representing 86 GW of capacity (and a small fraction of around 0.25% of the total technical potential capacity for onshore wind on the continent) (GWEC, 2023).
Data availability The information needed to assess the population-level significance of impacts on individuals (from fatalities or displacement) may be unavailable for many species. Furthermore, little is known about the vulnerability of some species groups in regions where there are, so far, few wind and solar developments and little monitoring of impacts.	Relevant demographic data are extremely limited or non-existent for most potentially impacted species in emerging market countries. Examples of species where little know known include topical and sub-tropical fruit bats (Pteropodidae), and seabirds in taxon groups not typically encountered in northern temperate marine areas (e.g. Phaethontidae, Diomedeidae).
Lack of conservation targets Relevant conservation targets and thresholds may not exist or may be inconsistent across species ranges	Many countries have not yet updated their National Biodiversity Strategies and Action Plans to include explicit targets aligned with the Global Biodiversity Framework
Scale of assessment required Some important types of impacts (e.g. collision risk, underwater noise) may affect species that are wide-ranging and/or migratory, potentially requiring assessment over notably large geographical scales. The relative contribution of cumulative wind and solar energy impacts is difficult to assess in relation to the numerous other threats migratory species face across their ranges.	Including soaring birds in inter-continental flyways, and migratory cetacean species.
Limited knowledge of impacts Little is yet known about the potential impacts of some emerging wind and solar technologies.	Including floating offshore wind and floating solar ('floatovoltaics')

Source: Authors.

Because of these issues, the potential cumulative impacts of wind and solar energy on some species may be of much greater significance than might be anticipated if any one project is considered in isolation, potentially significantly increasing local or global extinction risk. For example, the hoary bat (*Lasiurus cinereus*) is currently assessed as Least Concern on the IUCN Red List of Threatened Species™,[12] meaning it might be overlooked by traditional ESIA approaches. However, it is the species most frequently killed by turbines in North America. Frick et al., (2017) used population projection models to estimate that the hoary bat population could decline by as much as 90% in the next 50 years without targeted mitigation to reduce mortality from turbine collisions.

Background pressures and trends that are not associated with regulated developments can also contribute to cumulative impacts. For example, avian mortality linked to disease or predation at breeding colonies could combine with mortality due to collision with wind turbine blades, and with the loss of coastal breeding habitat due to ports and harbours development. Such combined impacts may take species or ecosystems across ecological thresholds or tipping points[13] (see Section 3.3.3), depending on the type and status of the receptor. For instance, threatened species

12 https://www.iucnredlist.org/species/11345/22120305

13 A tipping point is defined by IPBES as a level of change in system properties beyond which a system reorganises, often abruptly, and does not return to the initial state even if the drivers of the change are abated.

and longer-lived, slower to reproduce species (e.g. migratory soaring birds) may be more likely than others to experience population-level impacts, and to experience them more rapidly, because such traits influence the ability of the population to absorb change and/or recover from perturbations.

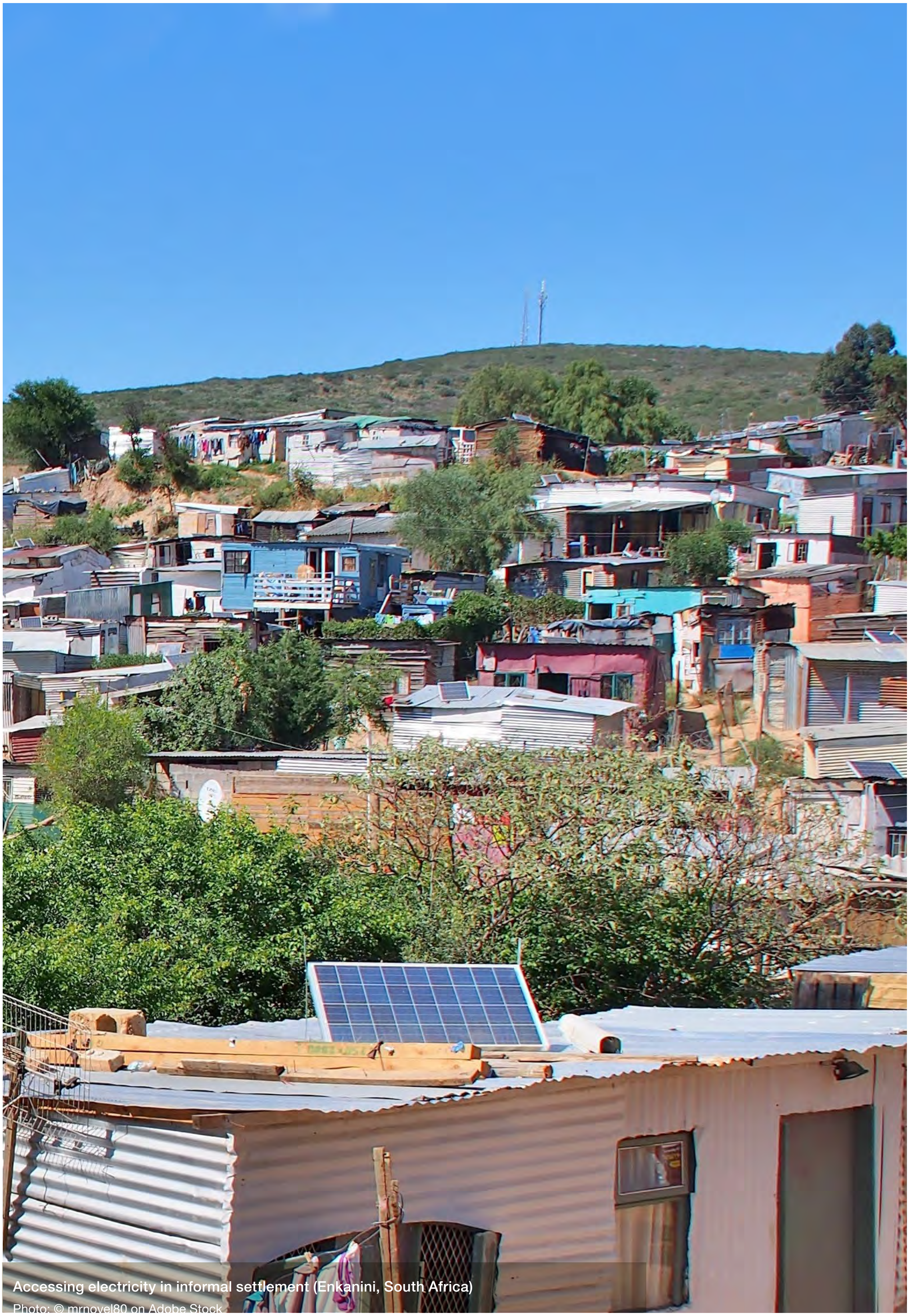
Understanding cumulative impacts is an important part of informing strategic, coherent, and efficient collective approaches to mitigation and ecological compensation including spatial planning. This relates not only to project-level objectives and mitigation efforts, which could be affected by impacts or mitigation actions from other developments (Bennun et al., 2021), but also to achieving global and jurisdictional goals and targets for nature (see Box 1 and Section 3.3.3).

Assessment across sectors, as well as between projects, has the potential to improve the planning and effectiveness of mitigation by highlighting opportunities for coordination and collective action, which may contribute to achieving cross-policy objectives (see Case study 3 and Case study 4). This could include regulatory requirements to ensure effective mitigation for species and ecosystems identified as at-risk through strategic assessments, in line with national or regional biodiversity conservation targets.

For developers, collaborative actions in the same land- or seascape (for example, data sharing, aggregated offsets, or other joint interventions and initiatives)[14] can have the benefit of spreading risks and costs between several developers, as well as reducing overall transaction costs and potentially improving efficiency and effectiveness (Bennun et al., 2021).[15] In the past, the lack of government strategic intervention has contributed to situations whereby individual developers have engaged in a race to submission to avoid their project(s) being the one to tip the balance between CIAs being acceptable and unacceptable (see Case study 2).

14 Such as the UK's Collaborative Offshore Wind Research into the Environment (COWRIE), the Strategic Ornithological Support Services (SOSS), and the Offshore Renewables Joint Industry Programme (ORJIP), which promote collaboration between developers.

15 See also Pizzolla et al. (2024) and the ScotWind leasing round, in which developers responsible for 11 different projects have worked together to deliver a review of potential compensation measures at a regional scale.



Accessing electricity in informal settlement (Enkanini, South Africa)
Photo: © mrnovel80 on Adobe Stock

2 About this guidance

Whereas the ecological and practical benefits of CIA are clear, implementation remains problematic in practice, for both practical and conceptual reasons. In addition to sector-specific challenges (outlined in Section 1.2), challenges for CIA in general include: the frequent absence of government-led strategic planning and assessment (including absence of conservation targets and thresholds for Valued Ecosystem Components, or VECs); poor integration of CIA into project ESIA and approvals processes (in particular being treated as a separate bolt-on process that is carried out too late (e.g. Olagunju & Gunn, 2015), with the effectiveness rarely being assessed); the absence of agreed definitions and a lack of standardised terminology and methods for assessing cumulative impacts (Annex I); handling uncertainty; difficulties defining geographic, temporal, and biodiversity scope; data availability and access to information; achieving effective and inclusive stakeholder engagement; and resourcing constraints (e.g. cost, time, expertise).

Conceptually, a fundamental challenge for CIA is that it is commonly implemented as an element of impact assessment and framed in terms of damage limitation, or defining what constitutes 'acceptable loss' of biodiversity, such as how many of a species, or what extent of an ecosystem. This approach is now misaligned with global biodiversity goals (e.g. KMGBF, see Box 1) and jurisdictional targets, which are increasingly aspirational and framed around recovery and restoration.

These commonly encountered practical and conceptual barriers can prevent or hinder the assessment of cumulative impacts, which are often exacerbated in emerging market contexts where enabling policy and regulations are emerging or yet to be developed. From the perspective of conservation and biodiversity outcomes, these challenges will become even more significant as wind and solar development scales up in countries and regions with emerging regulatory oversight and/or a limited biodiversity data and information base.

Thus, a key aim of this guidance is to **reframe CIA to help support biodiversity conservation and the achievement of global biodiversity goals** (alongside climate and other societal development goals). In addition, this guidance complements the existing literature and guidance on CIA (see Annex IV), and offers an approach to addressing some of the key implementation challenges by:

- **Outlining pragmatic and scalable approaches** to implementation of CIA by government planners responsible for the renewable energy transition, and by wind and solar energy project developers (see Section 3) that:
  - are **aligned with existing good practice** such as the mitigation hierarchy (see Annex II), while recognising that the timeframe to meet global and national climate targets is short;
  - show how the requirement for individual developers to assess multiple other projects or activities can be avoided; and
  - show how CIA can be better integrated into project-level ESIA, and what developers can do when there is not a government-level CIA to draw on.
- **Facilitating an 'entry point' for government-led CIA**, showing how CIA can be approached even in data-poor contexts, where the available biodiversity baseline information remains scarce, especially where regulatory requirements are still emerging, and/or resources and capacity are constrained.
- **Signposting emerging technical methods** showing promise for improving CIA in wind and solar contexts, which governments and project developers may consider trialling or improving further (see Section 3).

- **Summarising the key biodiversity features**, where cumulative impact are likely to have the greatest effect, and thus likely to be a focus of a CIA for wind and solar and transmission infrastructure (see Annex III).

- **Highlighting priority areas that still need improvement**, either through technical development or regional- or sector-scale collaboration (see Section 4).

2.1 Scope

The practical approaches outlined in this guidance focus on assessment of cumulative impacts on biodiversity[16] from wind and solar development carried out by: i) governments at the sector level; and ii) developers at the individual project level (and the relationship between the two) (see Section 2.2). VECs – receptors considered important by governments, project proponents and other stakeholders – should be defined through an evidence-based, consultative, and consensus-based process. As outlined in Section 1.2, this guidance aligns with the predominant definition of 'cumulative impact' used in practice. Although it does not specify which types of impact contribute to cumulative impact or at what spatial scale, the guidance assumes that this determination will be made as part of a proportionate approach to understanding VECs (see Section 3.3.3).

To facilitate CIA focused on conservation needs, while acknowledging that the information base for VECs could be limited, the guidance outlines a category-based approach to establishing the current status and trend of VECs, prior to setting conservation targets and impact thresholds for wind and solar development. In this way, the intention is to capture 'relevant past and present' effects on a VEC (Section 1.2). 'Future actions' (see Section 1.2) are more challenging to define and evaluate meaningfully and inclusively. At the government level, this guidance suggests that an appropriate 'future look' can be achieved, at least for impacts of the renewable energy development through scoping spatial and temporal boundaries of assessment in line with national renewable energy targets (see Section 3.3.1). This then feeds down to the individual project level. Where government-led CIA is not available for projects, the general approach in this guidance is to ensure that the impacts of the individual project are mitigated and remain below established thresholds. More detail is provided in Section 3.3.3.

2.2 Intended users

This guidance is aimed primarily at government planners and project developers. However, since it is designed to help tackle some of the existing challenges of CIA, there is potentially broader applicability.

The guidance distinguishes CIA at two different levels:

- **Government-led CIA**: an approach for government planners responsible for the sustainable roll-out and/or expansion of wind and solar and associated infrastructure,[17] carried out at the appropriate strategic (e.g. national, regional or sectoral) scale.

- **Project-level CIA**: approaches for developers of wind and solar and associated infrastructures to undertake at the individual project level.

These two scales are intrinsically linked. Ideally, the government-led CIA provides the framework within which project-level CIA is implemented. As part of this, government can establish guiding principles and minimum standards for CIA, including requirements for stakeholder engagement, technical methods, and data sharing between projects (Box 4). Project level CIA can then help fill any gaps in government-led CIA, leading to incremental improvements.

16 Ecosystem services impacts and impacts on human well-being and economy are not specifically addressed in this guidance. However, assessing such impacts is a fundamental part of robust strategic and project-level assessments aligned with global goals and targets, and for a just energy transition.

17 Including: photovoltaic (PV) plants, concentrated solar power (CSP) plants, onshore wind farm developments, offshore fixed and floating wind developments, and associated transmission infrastructure. A synthesis of these typical developments is given in Bennun et al. 2021.

Lenders and investors could also benefit from the information and practical approaches described. The approaches are designed to address and work around some of the key conceptual and practical challenges of implementing CIA at the project level, thus they may be a useful complement to the existing standards and guidance of financial institutions (depending on the specific project situation). Development finance institutions (DFIs) also support broader enabling programmes to promote the renewable energy transition, including supporting and advising governments in emerging markets. DFIs and other lenders thus often work collaboratively with governments to implement strategic-level CIA or similar types of assessment at the strategic scale, sometimes also involving developers. This means less resource-intensive approaches to government-led CIA that can be implemented relatively quickly, in the context of the accelerating renewable energy transition, could be particularly beneficial.

3 Practical approaches to cumulative impact assessment

This section outlines practical approaches to CIA for wind and solar development at the government and project levels

3.1 Government-led cumulative impact assessment

Since the need to ensure implementation of good mitigation practice at the individual project level is clear (Bennun et al., 2021; WWF & TBC, 2023), a broader perspective is needed to effectively and efficiently address potential cumulative impacts. To maximise the carbon-saving potential of renewable energy technologies, manage risks, and align with global goals[18] and national targets, wind and solar roll-out and expansion must account for biodiversity at national or regional scales. In the past, lack of government-level strategic intervention has contributed to situations whereby individual developers have engaged in a race to submission to avoid projects tipping cumulative impact thresholds (see Case study 2). Development informed by strategic-level spatial planning is much more likely to avoid significant biodiversity risks, meet national biodiversity goals, and thus make the subsequent permitting process more efficient and more predictable (Bennun et al., 2021; World Bank Group, 2021).

The benefits of CIA at the government level include the ability to take a broad and holistic view and deliver conservation outcomes on a much larger scale than project-by-project assessment (DCCEEW, 2023), by identifying national or regional conservation priorities and defining conservation targets/thresholds at that scale. Project-level CIA can then help fill any gaps in government-led CIA, leading to ongoing and incremental improvements (see Section 3.2). Importantly, for government-led CIA to be effective, a suite of broader enabling actions will often be needed (see Box 4).

The accelerated pace of renewable energy development also brings with it a push for regulators to streamline and speed-up consents and permitting processes so that national renewable energy targets can be met. Barriers to planning and permitting (Annex V) are a key cause of delays for wind and solar projects (Dosanjh et al., 2023; Willsteed et al., 2018b), stretching out project development processes from site selection through to commissioning, and affecting the likelihood of achieving renewable energy and climate targets according to plan.[19]

A government-led strategic approach to CIA can improve project level planning and licensing processes by providing greater certainty about predicted impacts, reducing resultant delays to wind and solar projects (see Case study 2). Government-led CIA supports more efficient and consistent project-level permitting processes by enabling developers to integrate CIA and conservation priorities more easily into the project ESIA process from the beginning. This aids transparency and equitability between projects and could enable coherent data collection to support regional and local assessment and monitoring. Government-led CIA also avoids the requirement for individual developers to assess multiple other projects or activities (i.e. other relevant past, present, and reasonably foreseeable future actions'), which is a common expectation and often beyond the ability of individual developers to achieve meaningfully (e.g. because information is often difficult to access and verify, incomplete, and potentially inconsistent with a developer's own methods and assessment approaches). Additionally, the ability of individual developers to achieve the necessary 'future look'

18 For example, the Kunming-Montreal Global Biodiversity Framework (CBD, 2022) and the '30 x 30' target to ensure and enable that by 2030, at least 30% of the planet (especially areas of particular importance for biodiversity and ecosystem functions and services) is effectively conserved and managed.

19 In terms of the consenting and development process, UK offshore wind can take around 12 years of project development, while onshore wind in Spain can take around 10 years, and utility scale solar in France commonly takes around four years (ETC, 2023).

Box 4

Enabling actions for cumulative impact assessment

Cumulative Impact Assessment (CIA) is a means to an end, in the context of renewables, to enable a nature-safe energy transition (WWF & BCG, 2023). For CIA to be effective, strong links are needed to the wider spheres of planning, policy making, and regulation (Blakley, 2021). Beyond the CIA process itself, a range of enabling actions in line with the GBF mainstreaming target (Target 14; see Box 1) are needed to support effective use of CIA, and thus achieve better societal, environmental, and economic outcomes.

Important enabling actions for government-led CIA could include:

- Establishing an enabling framework for CIA in order to ensure that definitions and standards for baseline and monitoring data collection and analysis are applied consistently across all projects.
- Mandating inclusive spatial planning, including CIA as a key input, for major sectors in advance of anticipated development across relevant jurisdictions.
- Integrating global or policy goals for nature explicitly into CIA targets (see Box 1 and Section 3.3.4)
- Ensuring public and private development sectors (e.g. infrastructure commissioning agencies, extractives, energy, agriculture, lenders), communities, and civil society are represented effectively in government-led CIA to deliver benefits to all stakeholders.
- Supporting national biodiversity research institutions or others to identify, prioritise, and fill data gaps, and compile and manage baseline and monitoring datasets, for relevant biodiversity features.

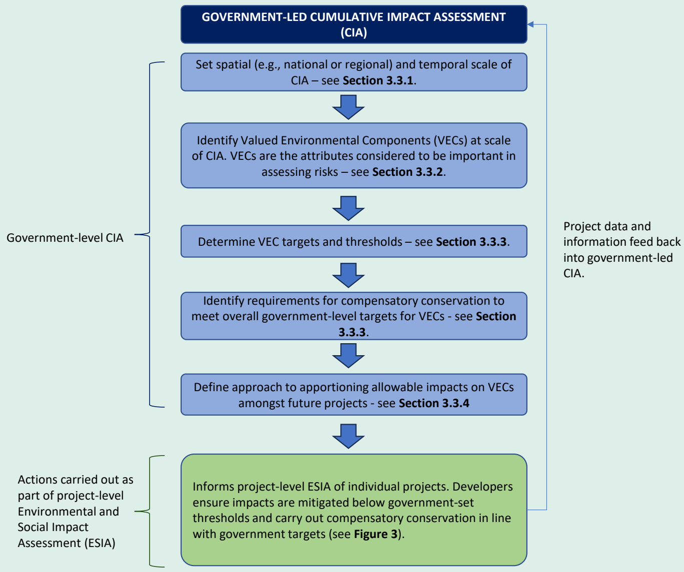


Figure 2 **Practical approach to government-led cumulative impact assessment** *Source: TBC*

- Where appropriate, working with development banks to provide early resources for CIA as an input to inclusive spatial planning to enable scaling up the renewables sector.
- Developing a review process for identifying valued ecosystem components (VECs) (see Section 3.3.2) and limits of acceptable change/project-level thresholds or targets (e.g. in relation to nature-inclusive design).
- Incorporating appropriate and proportionate oversight and controls into the project-level permitting practice (e.g. requirements for monitoring, auditing of sites).
- Requiring robust application of the mitigation hierarchy, mitigation plans to achieve project-level thresholds, and science-based monitoring and adaptive management of project impacts.
- Maintaining a register of project impacts on VECs to facilitate monitoring and checking that project-level impacts and overall limits of acceptable change in VECs will not be exceeded.
- Defining data standards and mandating baseline and monitoring data sharing by project proponents. Incorporate project-level data into open-access regional/national datasets to inform future work.

Ideally, these enabling actions will mean that CIA can address multiple policy objectives, making it applicable to different institutional users, and supporting alignment across multiple sectors (for example energy generation, nature protection, and fisheries).

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(e.g. in terms of geographic scale and time frame over which to consider future projects, and/or the likely scant and uncertain detail available for those future projects)[20] is virtually impossible – hence, the importance of government-led, receptor-focused CIA (Annex VI).

Figure 2 presents a practical approach to CIA for government planners. Guidance on the steps outlined is given in Section 3.3.

3.2 Project-led cumulative impact assessment

Developers of wind and solar and associated infrastructure typically implement project-level CIA where it is a regulatory requirement. In some cases, projects may conduct CIA due to lender or investor requirements, even if there is not a regulatory framework requiring it.

Ideally, project-level assessment is informed by government-led CIA, and developers can use government-led CIA to inform project design, mitigation, and monitoring. However, in practice, government-led assessments often are not available, meaning project-level CIA is developed in isolation. While this creates challenges (see Section 1.2), project-level CIA can still be an effective part of an overall impact assessment and mitigation process.

The value of CIA for project developers includes:

- Providing confidence that receptors at high-risk of cumulative impacts, and consequently material project impacts, are identified in a timely manner so that project design, mitigation and monitoring actions are effective and efficient, and that the risk of additional mitigation requirements being identified at late stages of project development or even operations is reduced.
- Clearly setting potential project impacts within the context of other pressures on biodiversity (e.g. impacts on migratory species in other portions of their range), allowing clear assessment and communication of project responsibility for potential population-scale impacts.
- Guiding effective collaborations with other project proponents and stakeholder partners (e.g. environmental NGOs, civil society) to implement collective mitigation, compensation and monitoring actions at appropriate spatial scales.

Supporting due diligence, demonstrating alignment with corporate environmental, social and governance (ESG) requirements (for example, CSRD in Europe) (EU, n.d.) and improving investor confidence.

Figure 3 outlines a practical approach to CIA at the project level, for developers drawing on the outcomes of an existing government-led CIA. Figure 4 outlines a fallback approach where a government-led CIA is not available.

Where there is an existing government-led CIA, those outputs are integrated directly into the project ESIA at the scoping stage and inform the subsequent process (e.g. establishing the baseline, informing impact assessment and mitigation requirements). Projects should follow existing good practice for ESIA. It is assumed that existing government assessments are robust, up to date, and have been developed in consultation with appropriate stakeholders and remain representative.[21] It is not expected that individual developers should be required to validate the outcomes of government-led CIA, since the scope of a project-level ESIA baseline is unlikely to capture or represent the spatial scale of government-led CIA.[22] If project ESIA scoping identifies VECs that are not captured in the government-led CIA, the project may need to follow the approach outlined in Figure 3 for determining targets and thresholds for those VECs.

20 Which is at odds with the demand for defensible and factual assessment (Hegmann, 2021).
21 For example, it remains current and not so dated that the findings are no longer applicable.
22 Although developers may, if they wish, be able to verify VEC trajectories at the spatial scale of government-led CIA, using desk-based approaches.

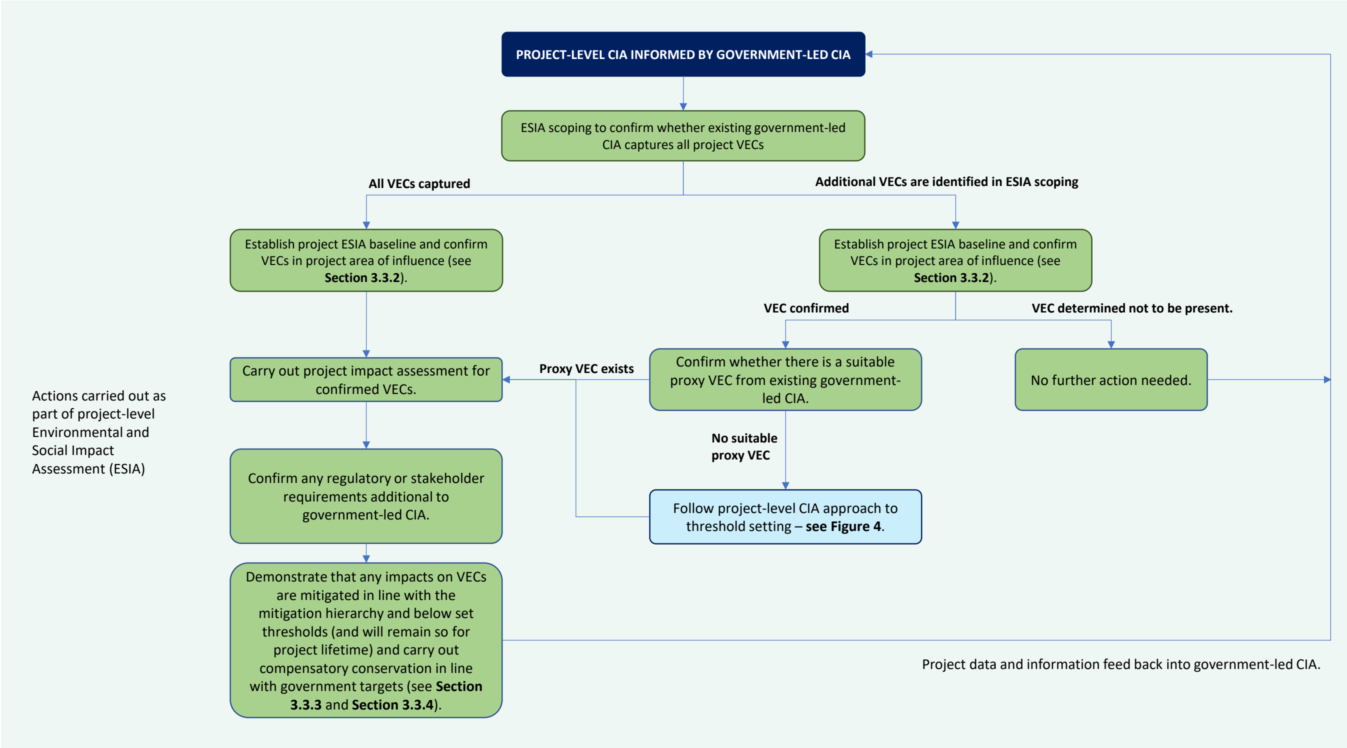

Figure 3 Project approach to Cumulative Impact Assessment where a government-led Cumulative Impact Assessment is available *Source: Authors.*

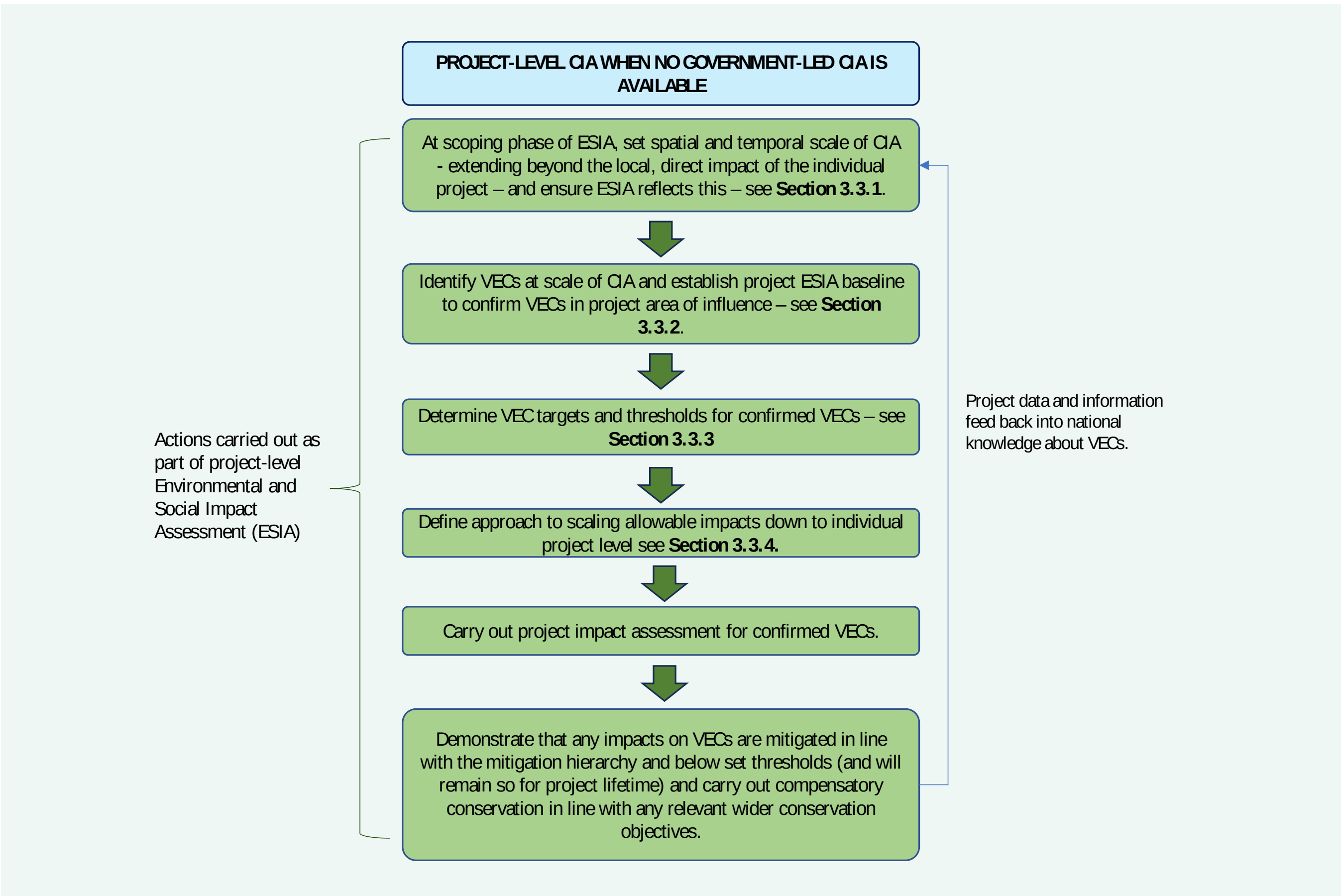

Figure 4 Project approach to cumulative impact assessment where a government-led CIA is *not* available *Source: Authors.*

In both cases, the project approaches are designed to be implemented during the ESIA scoping and baseline stages. They show how establishing the status of biodiversity features and defining thresholds for impact can help work around the challenge of having to evaluate impacts linked to other developments. Since developers working in the same landscape or seascape are likely to have the same (or many of the same) biodiversity priorities, there are opportunities for collaboration to identify relevant features and to set thresholds. An important outcome of project-level CIA and ESIA will be to facilitate data availability to feed into and inform government-level assessments.[23] Further detail on the steps is given in Section 3.3.

3.3 Key steps

The steps outlined in this section apply to both the government-led CIA approach shown in Figure 2, and the project approaches shown in Figures 3 and 4. Prior to these steps, it will be essential as part of the scoping to establish the CIA's objectives, key definitions, and terminology (see Sections 1.2 and 1.3), as well as the underlying principles for the CIA (Judd et al., 2015; Willsteed et al., 2018a; see also Box 4 on enabling actions for CIA).

3.3.1 Set spatial and temporal boundaries for cumulative impact assessment

The spatial scale over which cumulative impacts are considered should be large enough to incorporate the distribution of the resource or system affected (e.g. a flyway or a watershed) (O'Hanlon et al., 2023). There is no predetermined optimum spatial scale for CIA[24] – it should be appropriate for understanding cumulative effects and changes in the relevant biodiversity features such as VECs (see Section 3.3.2). Hence, confirming the appropriate spatial boundary for government-led or project-level CIA will be closely linked to identifying the VECs relevant for the CIA, and may be an iterative process.

Ideally, the spatial scope of a government-led CIA will be as large as is feasible and appropriate, to reduce the requirement for multiple adjacent government-led CIAs and increase consistency. For practicality, assessments often fall within management areas and jurisdictions. Hence, the spatial boundary for government-led CIA will usually align with available biodiversity baseline information, jurisdictional boundaries, and other administrative considerations. It may be set using administrative (e.g. regional, national, sub-national) or ecological boundaries where the default scale is likely to be national. Using administrative boundaries makes it easier to incorporate conclusions into existing legislation, administration structures and to align with national or regional conservation goals or targets.

At the same time, it is also important to consider ecological boundaries (e.g. for catchments, ocean basins, islands, ecoregions or flyways) that are relevant to the VECs being included. Species migration routes and foraging ranges during the breeding season (e.g. as shown in GPS tracking data) might provide useful information to define the spatial boundary (Pollock et al., 2021; Thaxter et al., 2012). For the wind sector and flyways, especially, it is important that CIA at regional, national or sub-national scales is coordinated and considers how impacts may add to those elsewhere on the flyway (Busch & Garthe, 2018).

A balance is needed when setting spatial boundaries to ensure that assessments are ecologically meaningful but not so large-scale that they become unwieldy and unhelpful for decision making. Available budget and resources may be better spent on improving mitigation planning than on scaling up the geographical area of assessment.

Where developers have no government-led CIA to draw on, the appropriate spatial scale for project-level CIA should be determined during initial ESIA scoping and subsequently reflected in the ESIA itself. The appropriate spatial scale must extend beyond the local, direct impact of a single development (IFC, 2013; Noble, 2022), but remain proportionate to the scale of the

23 In addition to the information shared as part of the regulatory permitting process.
24 In some cases, the courts have stepped in to define the spatial scale of assessment (MacDonald, 2000).

project and the likely scale or nature of potential cumulative impacts. The assessment area should be large enough to represent the effects of the project alongside those of other human actions, to the point where the project's contribution is measurably distinct (Hegmann, 2021). IFC (2013) suggests some rules of thumb: i) include the area that will be directly affected by the project; ii) list the important VECs (see Section 3.3.2) within this area; iii) define whether these VECs occupy a wider area beyond the area of direct project influence; and iv) consider the range over which a potential effect could occur, and other impacts the VEC might be exposed to across its range. To account for the different spatial distributions and responses of VECs (which may vary seasonally), smaller assessment areas for particular VECs may be nested within the overall spatial boundaries when appropriate (e.g. for an ecosystem type in a landscape versus soaring birds in a regional flyway).

Establishing the appropriate spatial scale for both government-led and project-level CIAs should involve stakeholder consultation (see Section 3.3.5), and it is likely to be an iterative process. Initial boundaries are often set based on expert judgement, and adjusted or refined as appropriate as information emerges (IFC, 2013). In all cases, the basis for the final spatial boundary delineated should be documented.

With respect to the temporal boundaries for assessment, government-led CIA should be informed by national (or potentially regional) renewable energy targets and goals for developing the sector at a national level, within the spatial boundary for CIA. The temporal scope of assessment should also allow for potential time lags in observed impacts, because these may persist beyond the lifetime of a project. For example, populations of long-lived and slow to breed species, such as vultures, may take many years to recover from an impact, since it can be several years before juvenile individuals enter the breeding population.

In parallel, it is important that government-led CIA establishes a common biodiversity baseline for all the planned development that needs to be considered within the defined spatial and temporal scope. Without a common baseline, it is challenging (or even impossible) to compare between impact assessments carried out for different projects. This is because the magnitude of an impact will be influenced by the starting point for a species population (among other things).

Shifting baseline syndrome is a widely acknowledged issue in ecology (Soga & Gaston, 2018). This means that impacts from historic anthropogenic pressures are likely to have influenced the population(s) concerned, although given the extent of anthropogenic pressures on the environment, it is unlikely possible to set a baseline that truly reflects the natural state of the population. Thus, a common baseline could, for example, be defined following the processes set out in the EU Birds Directive (EU, 2009), whereby a population at the time of designation is defined, and assessments are then made in relation to this population.

3.3.2 Identify valued environmental components

Ideally, conservation targets and management actions would be defined for every species and habitat and/or ecosystem with a government's jurisdiction or a project's sphere of influence. In practice, tracking all biodiversity features is unfeasible. Therefore, it is useful and pragmatic to identify a suite of biodiversity priority features for assessment and conservation actions. Although this could be done in a variety of ways, the concept of VECs (Box 5) has been widely used and is an appropriate framework for prioritising features for cumulative impact assessment.

Selection of VECs precedes assessment of potential impacts (and identification of cause-effect relationships). For government-led CIAs, an initial VEC list is likely to comprise features that national or international processes have already identified as important, such as threatened[25] or legally protected species, ecosystems, or other features, since these designations represent collective societal and scientific agreement on

25 Threatened species are usually considered to be those evaluated as Critically Endangered, Endangered or Vulnerable, and potentially Data Deficient and Near Threatened. This determination may be made at a global (e.g. via the IUCN Red List), national or regional level.

Box 5

Valued environmental components (VECs)

VECs are the receptors considered important by governments, project proponents, the public or other stakeholders, based on cultural values or scientific concerns (Hegmann et al., 1999). They are defined as environmental and social attributes considered to be important in assessing risks (IFC, 2013). This guidance document focuses specifically on biodiversity (species and ecosystem) VECs, but more broadly, VECs may also comprise:

- Physical features (e.g. habitats, landscape features, wildlife populations)
- Ecosystem services (e.g. carbon sequestration, flood mitigation, soil stabilisation)
- Natural processes (e.g. water and nutrient cycles, microclimate)
- Social conditions (e.g. health, economics)
- Cultural aspects (e.g. traditional spiritual ceremonies).

Biodiversity VECs are selected based on their importance to healthy, well-functioning ecosystems, or to society from an economic, aesthetic or values standpoint (IFC, 2013; Olagunju & Gunn, 2015). VECs manifest environmental change, so they are the 'building blocks' of assessments. As CIA is an inherently future-oriented process, the desired future condition of VECs also determines the assessment end points (IFC, 2013).

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conservation priority. However, other features that may be particularly vulnerable to cumulative impacts should also be considered, such as species where population-level effects are most likely, because of their behaviour or demographic characteristics. These may be informed by previous assessments (Furness et al., 2013; Garthe & Hüppop 2004; Kelsey et al., 2018), or analyses of species interactions with infrastructure (e.g. Thaxter et al., 2017). Additional VECs may be identified through consultation with key stakeholders. However, VECs valued by stakeholders may be different from those prioritised based on regulation or conservation status.[26]

Key biodiversity datasets that could be useful in identifying VECs include the IUCN Red List of Threatened Species™ (the 'IUCN Red List') or equivalent national/regional datasets (also used in vulnerability assessments), the IUCN Red List of Ecosystems, or satellite imagery such as Copernicus or Esri Land Cover for habitats. For many potential VECs, there may be limited biodiversity baseline information, especially in offshore areas and emerging market contexts, and the approach to identifying VECs will primarily be consensus-based and driven by expert judgement (see Section 3.3.5).

Where a government-led CIA exists, projects in that area should initially adopt all VECs[27] from that CIA. They should then undertake a VEC verification process using expert judgement and available data to identify whether any VECs can be discounted (e.g. if they are not present at the spatial scale established for project-level CIA) and whether additional VECs should be included (e.g. due to the involvement of different stakeholder groups, or changes in features' conservation status). Developers can then proceed with the standard project ESIA baseline and impact

26 For example, Indigenous peoples and local communities may value biodiversity features for their cultural, spiritual, religious, or socio-economic significance, even if those features are common and/or widespread at the national level.

27 VECs for CIA are synonymous with biodiversity receptors for project-level ESIA.

assessment phases and determine whether predicted project impacts on relevant VECs are below the level of allowable impacts established in a government-led CIA (see Section 3.3.4). Where there is no government-led CIA to draw on, developers should use the project ESIA scoping phase to identify VECs of importance at the spatial scale identified for project-level CIA (see Section 3.3.1), including wide stakeholder engagement.

3.3.3 Determine valued environmental components trends, targets, and thresholds

For CIA to be an effective input to spatial planning, project mitigation, and prioritisation of conservation actions, the desired 'end points' for identified VECs should be informed by biodiversity targets. Targets for specific species and ecosystems may already be set in regional, national or sub-national biodiversity strategies and action plans. More generally, the KMGBF (Box 1), aimed at halting and reversing biodiversity loss by 2030 and restoring nature by 2050, provides a sound basis for target-setting, as summarised in Box 6.

Defining desired 'end points' in turn provides the basis for assessing the cumulative level of impact that VECs can (in theory) support. Determining an acceptable threshold level of impact, beyond which a biodiversity feature may undergo undesirable change, is often a challenging technical problem. There are many reasons why ecological thresholds are difficult to define, determine, and standardise (Johnson & Ray, 2021). For species, this often involves translating impacts on individuals to potential population level changes (see Section 4.4).

Where information and resources allow, methods such as those outlined in Section 4 can be used to assess population or ecosystem level impacts and thresholds for individual VECs. In relatively data-poor situations, a practical way forward is to assign VECs based on overall conservation targets and specific VEC characteristics to a set of general categories of VEC trend and significance or threat status with associated thresholds. This is a means of considering past, present and ongoing impacts and influences on a VEC through trends and/or status at the time of assessment. For ecosystems and species VECs, this approach is summarised in Figures 5 and 6, respectively.

In each case, individual VECs can be placed in four main categories, based on relatively simple information about their status and characteristics. For each category, the need to align with global biodiversity targets determines the overall approach to setting cumulative impact thresholds, and the overall mitigation approach required (see Figures 5 and 6), as follows:

- **Species and ecosystem VECs that are in decline or in the early stages of recovery, below targets, and have unfavourable characteristics[28] effectively have a zero-impact threshold (categories E4 and S4).** This will require strict spatial avoidance of impacts, or in exceptional circumstances stringently implemented minimisation (e.g. through shutdown on demand for wind turbines) to keep impacts at an extremely low level. This may have implications for project viability, highlighting the importance of both government-led strategic conservation planning and spatial planning for wind and solar development.

- **Species and ecosystem VECs that are in decline and below targets, but do not have unfavourable characteristics 26 (categories E3 and S3), require strict mitigation (emphasising avoidance and minimisation) to reduce impacts as far as feasible.** Compensation actions to achieve net gain will also be required to meet targets for such VECs. For species VECs in this category, it is also important to understand the main drivers behind ongoing population declines. Where population declines are driven primarily by loss or degradation of habitat, cumulative impacts from displacement or disturbance need particular attention both in threshold setting and in design of compensation measures. Where population declines are driven primarily by additional mortality (e.g. through hunting, poisoning or

28 **For species**: threatened with extinction and/or demographically vulnerable. **For ecosystems**: threatened with collapse, of high integrity, high biodiversity importance, and/or not feasible to restore.

Box 6

The Kunming-Montreal Global Biodiversity Framework as a basis for valued environmental components target-setting

The GBF sets out a suite of goals and targets for overall biodiversity outcomes by 2030 and 2050 (see Box 1) (CBD, n.d.). The framework aims to put nature on a path to recovery, halting biodiversity loss and reversing it through ecosystem and species restoration. The GBF goals and targets are wide-ranging in scope but have some quantitative elements. They are global, hence must be translated by CBD Parties into national commitments and plans. Typically, this will involve governments updating their existing National Biodiversity Strategies and Action Plans to reflect the revised global framework. National plans should be aligned with global goals but may be more ambitious or less ambitious for specific targets, depending on national context and capacity.

Where updated national targets exist, an appropriate basis exist for setting cumulative impact thresholds for VECs. In other cases, general targets for VECs can be derived by considering their alignment with the GBF's goals and targets. Table 2 shows such examples for species and ecosystems).

Table 2 **Examples of valued environmental components* and targets aligned with the Kunming-Montreal Global Biodiversity Framework.** Such targets may be applied to set cumulative impact thresholds where relevant updated biodiversity targets are not available

EXAMPLES OF VALUED ENVIRONMENTAL COMPONENT(S)*	EXAMPLES OF GBF-ALIGNED TARGETS
Threatened species	Extinction risk reduced
Demographically vulnerable species	Population increased
Other species	Population maintained at viable and functional level
Threatened ecosystems	Risk of ecosystem collapse reduced
High-integrity ecosystem	No loss of ecosystem area or integrity
Key Biodiversity Area	
Difficult-to-restore ecosystem	
Other ecosystems	Overall area covers at least 30% of original extent
	Overall integrity (condition and connectivity) increased
	At least 30% of degraded ecosystem area under restoration

* Also referred to as valued environmental and social component(s)

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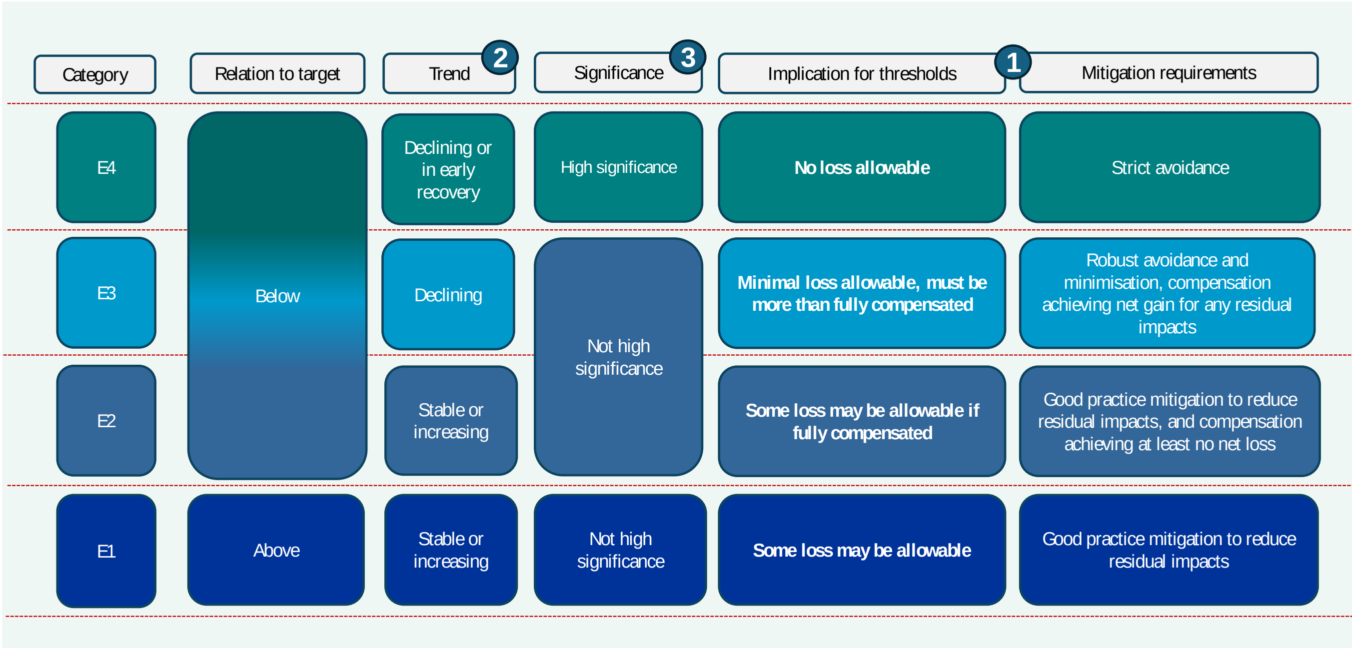

Figure 5 Broad categories of ecosystem valued environmental components *Source: Authors.*

Notes:

1) The implications for cumulative impact thresholds and mitigation requirements indicated for each valued environmental component assume biodiversity targets align with Goal A and Targets 1–3 of the Global Biodiversity Framework.
2) Trend refers to trend in ecosystem area and integrity (condition and connectivity).
3) Significance: High significance ecosystems are threatened, and/or of high integrity, and/or of high biodiversity importance, and/or not feasible to restore.

Area and/or integrity trends and ecosystem significance inform the allowable level of loss for each category. Mitigation requirements are additionally informed by ecosystems' relation to biodiversity targets. Ecosystem integrity has various definitions, but typically is considered to be the degree to which an ecosystem's characteristics reflect its natural range of variation (Carter et al., 2019), (Nicholson et al., 2021). These characteristics include ecosystem condition (with components of composition, structure and function) and connectivity. The Capitals Coalition (2023) has produced a primer for business on measuring ecosystem condition.

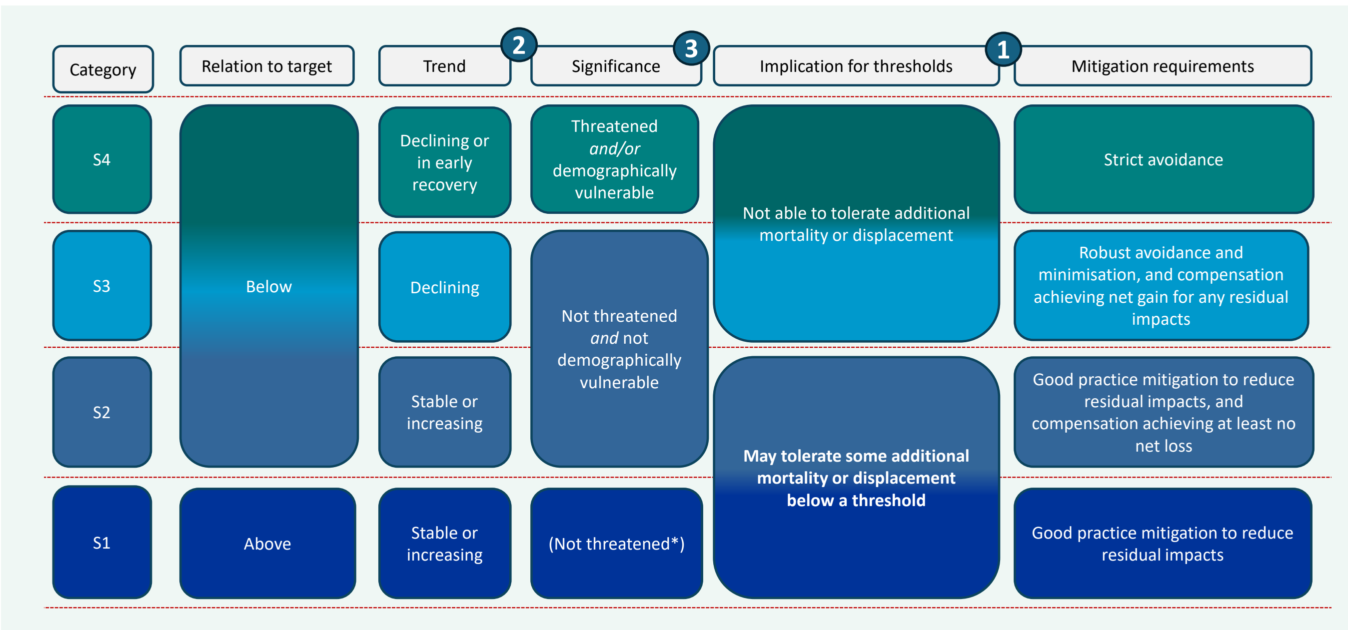

Figure 6 Broad categories of ecosystem valued environmental components *Source: Authors.*

Notes:

1) The The implications for cumulative impact thresholds and mitigation requirements indicated for each valued environmental component assume biodiversity targets align with Goal A and Targets 1–3 of the Global Biodiversity Framework.
2) Species' population trends, extinction threat status and demographic characteristics determine their ability to tolerate additional cumulative mortality, or displacement impacts at population level. Mitigation requirements are additionally informed by species' relation to biodiversity targets.
3) Only species that are not threatened with extinction are expected to be above population targets.

electrocution), particular attention is needed to assess cumulative impacts from collisions or other causes of fatalities, and to compensation measures that reducing additional mortality.

- **Species or ecosystem VECs that are stable or increasing in population or integrity and do not have unfavourable characteristics (ecosystems), or are not threatened with extinction (species, categories E1, E2, S1, and S2), may have some capacity to absorb additional cumulative impacts.** This capacity will depend on a VEC's characteristics and context, for instance, it may be small or zero for species that are demographically vulnerable, or substantially below target population size. Good practice mitigation to reduce residual impacts as low as reasonably possible remains essential, and for VECs that are below target levels compensation for any residual impacts will be needed. For species VECs, the methods outlined in Section 4 can be applied to assess appropriate cumulative impact thresholds.

Information from the IUCN Red List of Threatened Species™ and IUCN Red List of Ecosystems can be used to assess VEC status and characteristics. Regional and national Red Lists may also be useful information sources, and the Red List of Ecosystem criteria can be used to make an initial assessment of threat category where a full assessment has not yet been carried out. For species, potential biological removal (PBR) estimates (see Section 4.3) are helpful in assessing relative demographic vulnerability to cumulative impacts from mortality but should be used with caution in setting quantitative thresholds.

Consultation with stakeholders and experts will generally be essential to achieve consensus on categorisation of VECs and for setting targets and thresholds. This consultation should consider the social and cultural value of the VECs, in addition to the ecological vulnerability, and this should be accounted for when setting targets and thresholds.

Using a categorisation approach helps to identify VECs that will require implementation of additional conservation actions to meet conservation targets. It is helpful for the CIA document to identify the nature and scale of actions needed, as an input to spatial and other conservation planning and as a guide for potential additional conservation actions by project developers. Box 7 outlines some examples of threshold-setting at the government level. In general, threshold setting should include a mechanism for validating modelled and predicted outcomes through empirical data, such as collected through monitoring programmes, and adapting thresholds on that basis. Project-level baseline and monitoring data collection can then also feed back into, and improve, government-led assessment.

In the absence of government-led assessments, it may be difficult for project-level CIA to identify relevant government commitments or national targets to inform threshold setting. However, reference to the KMGBF (with the overall goals of improving ecosystem integrity and species recovery) should allow VECs to be placed into the broad categories outlined in Figures 5 and 6. A particularly important action for projects is to identify VECs that are potentially vulnerable to cumulative impacts but that may not be prioritised for mitigation action in the project ESIA process. Such VECs might be identified using an existing government-led CIA, via the ESIA scoping phase, or later when project-specific impact assessment is underway. A common example may be those species that are demographically vulnerable to cumulative impacts but are not currently assessed as threatened or declining (Furness & Wanless, 2014). Where relevant data for setting impact thresholds are limited or unavailable, it may be necessary to identify VECs in other assessments that can act as a suitable proxy and use an expert process, such as expert elicitation (Kuhnert et al., 2010) (see Section 3.3.5), to adjust thresholds as appropriate.

Box 7

Examples of good practice approaches to strategic threshold setting

The Netherlands: The Government of The Netherlands has taken a national strategic approach to offshore wind development and the assessment of associated impacts, including defining impact thresholds for priority VECs. For bird VECs, targets for an acceptable level of population change were set at either 15% or 30% population decline (depending on the likely level of stakeholder concern and considering the policy perspective). Equivalent threshold values were set using matrix population models (Potiek et al., 2022a). Collision impacts for each species were estimated using collision risk modelling, and habitat loss impacts were converted into impacts on species' life-history parameters. The thresholds and impacts were then compared for future build-out of The Netherlands offshore wind areas to determine whether existing plans would exceed the thresholds (Potiek et al., 2022b; Soudijn et al., 2022).

South Africa: In response to the increasing mortality of bats at wind farms in South Africa, the South Africa Bat Assessment Association (SABAA) established a national approach to setting bat impact thresholds at the project level, with the goal of preventing population-level cumulative impacts. The targets were to maintain at least current bat population levels. Based on known bat life history, SABAA determined that fatalities equivalent to 2% of a bat population would be the threshold beyond which population declines would occur. Using a percentage of the population as the impact threshold rather than an absolute number means that this threshold is area-independent, and therefore equally applicable at both the national and project levels. This 2% threshold was translated into a threshold number of individuals that could be applied to any project site through scaling by the area of the site and the number of bats predicted to be present (based on the assumed density of bats in each ecoregion across South Africa). This approach leads to a threshold based on the total project area, rather than a per MW-based threshold.*

Jhimpir, Pakistan: A CIA was conducted for the wind farms in the Jhimpur region of Pakistan, setting impact thresholds for bird and bat VECs. The thresholds were defined as the maximum number of individuals of a species that could be lost without impacting the viability of that population. Hence, the targets were to maintain at least current bird population levels. For birds, this threshold was set using a PBR-based approach (see Section 4.3). The species' PBR value was reduced by the level of existing impacts on the VEC across the area of interest (based on expert opinion). This was then proportionally scaled to levels considered to be socially acceptable by relevant stakeholders. The process resulted in thresholds of between 0 and 10 for bird VECs across all wind farms in the assessment area.

For bat VECs, thresholds were set using two approaches, which differed from that taken for birds due to the limited knowledge of bats in the region. For all IUCN threatened bat VECs, the threshold was set at zero. For IUCN Least Concern or Data Deficient species, an impact threshold of 2% of the population was set, beyond which impacts could result in adverse impacts on the long-term viability of a bat population. In this case, the targets were to maintain at least current bat population levels. This was adjusted for each VEC to a per MW threshold by multiplying the threshold percentage by the estimated VEC population size in the land area of Pakistan considered suitable for wind development (this varied per species), and dividing by the predicted build-out by 2030. This process resulted in a threshold of nine bats per MW. It should be noted that for both bird and bat VECs, comparison of thresholds with impacts should use the number of estimated fatalities (after appropriate adjustment for bias), and not the number of carcasses detected. * The Pakistan CIA also set impact thresholds for habitats and vegetation, defined as 20% change in extent and condition from the 2022 baseline.

*For a full description of the process and supporting information, see MacEwan et al. (2018).

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3.3.4 Define approach to apportioning allowable impacts on valued environmental components amongst future projects

The thresholds for each VEC established in the previous step apply at the scale of the CIA (see Section 3.3.1). For VECs with a zero-impact threshold, no adjustment is required to translate this to the project-level: all projects within the CIA must also adopt a zero-impact threshold for that VEC. For VECs where some impact is allowed at the scale of the CIA, a transparent and equitable approach is required to apportion that impact across projects, considering the distribution of the VEC and the predicted future wind and solar build-out within the CIA area. Governments will need to do this to allocate allowable impacts between future projects and in the absence of government-led CIA, developers will need a similar approach to understand how much of the overall threshold could be allocated to their project.

For governments, a simple indicative approach could be to apportion the total allowable impact threshold for a VEC between projects within the spatial scope of the government-led CIA based on MW capacity (see Box 7 for examples). Thus, if there is a government target of **x** MW of wind energy in a region and the overall threshold for a VEC is **y**, then the per MW impact is **x/y**. This simple example of an approach assumes that VECs are evenly distributed across the spatial scale of CIA and that predicted impacts are also equally distributed. This also assumes that wind energy expansion will be the key future impact on that VEC in the region; if other impacts are also significant, the total allowable impact for wind energy must be reduced accordingly, as in the Jhimpir, Pakistan example in Box 7. This approach reduces the requirement for regulatory oversight, provided the assumptions are validated and that each project demonstrates that its impacts are below the allocated threshold.

Alternatively, governments could develop a cap and trade system that allows different projects to 'take' different allocations of the allowable impact, with the cap set as the allowable VEC impact at the scale of the CIA. Whilst flexible for developers, such approaches require significant government oversight, regulatory control mechanisms, and a robust understanding of the VEC in question – so it can only be appropriate or feasible in a small number of cases.

Provided the government target or cap is not increased, neither approach ensures the VEC threshold at the scale of the CIA will not be exceeded. In the absence of robust strategic spatial planning to identify development areas of the lowest environmental and social sensitivity (see Box 3), these approaches also optimise project-level implementation of the mitigation hierarchy, as developers are incentivised to seek areas where project impacts are lower (and therefore where the mitigation effort required to meet thresholds is minimised).

Where a government-led CIA has defined an approach for apportioning allowable impacts, projects do not need to attempt to quantify the impacts of any other projects or activities in the region. In the absence of a government-led CIA, developers would need to determine a project-level threshold based on an estimate of the total potential MW capacity for a given renewable energy type within the spatial area of CIA. For example, this could be based on published government targets for wind or solar, if they are available (e.g. a national target of **x** MW of wind energy in a region). Other credible source estimates for the potential capacity of a region might also be appropriate (e.g. from industry bodies).

3.3.5 Stakeholder engagement

Stakeholder engagement is central to CIA, especially when documented biodiversity baseline data are lacking. Consultation with relevant stakeholders should inform each step of the approaches outlined in this guidance – engaging constructively is vital to help identify important VECs, determine the status of VECs, and understand how relevant stakeholders value them. Likewise, it is important to ensure that all the stakeholders identified and engaged have a shared understanding of the CIA approach, and that expectations are clear. A stakeholder mapping process is likely to be valuable for both government-led and the project level CIA, and should be undertaken as early as possible (e.g. at the scoping phase of project ESIA).

There are likely to be many stakeholders in common between government-led and project-level CIA. Stakeholders with an interest in biodiversity are both internal and external to government departments and individual projects. They are likely to include biodiversity experts with both field and analytical expertise, country and local-level specialists, international expertise, and those with demonstrable experience of/connection to the identified VECs. Stakeholders could include representatives from multiple different government agencies/departments and relevant statutory bodies, non-governmental organisations and civil society organisations, academic institutions, individual experts and specialists, local communities and land managers, natural resource planners, groups with special ties to the spatial area for CIA and/or specific VECs, and any other representatives with a legitimate interest in relevant biodiversity features or issues. In cases where the stakeholder group becomes particularly large, which is especially likely for government-led CIA, smaller focus or working groups can be considered (e.g. for specific VEC groups like migratory birds, or marine mammals).

For obtaining expert input on specific CIA elements (e.g. for target and threshold-setting), a structured expert elicitation process is recommended (Burgman, 201; Kuhnert et al., 2010). Such approaches have been used successfully in, for example, assessing the impacts of underwater noise on marine mammals (Donovan et al., 2016) or of wildfires on Australian fauna (Legge et al., 2022). To support the expert elicitation process, the IDEAcology interface[29] is available, based on the IDEA (investigate, discuss, estimate and aggregate) protocol (Courtney Jones et al., 2023) that builds on the well-established Delphi technique (Hsu & Sandford, 2007).

3.3.6 Data sharing and dissemination

One of the key challenges of CIA is biodiversity data availability, both in terms of the existence of baseline data, evidence of cause-effect relationships and associated impacts, and with respect to data held/owned by different parties (see Section 3.3.6). This challenge is exacerbated by the fact that where data are available, they are often of insufficient quality to provide useful information (Wilding et al., 2017), either because they have been collected as part of surveys with inappropriate design or lack the statistical power to draw robust conclusions (Methratta, 2020; Vanermen et al., 2015). To avoid these issues, a minimum set of standards for data collection should be set by governments,[30] with the resultant data hosted in a common repository accessible to all projects of relevance to assessments.

The impacts of particular pressures on species VECs are frequently reported at the individual level, for example as collision fatalities at wind farms, or displacement from foraging areas. As discussed in Section 3.3.3, for more meaningful input to CIA, these impacts need to be assessed in relation to thresholds set at the population level. A range of approaches, with varying degrees of complexity and data requirements, exist for CIA and can be used for defining impact thresholds (Willsteed et al., 2023). The appropriateness of these approaches will be linked to both the status of VEC concerned (see Section 3.3.2) and the baseline knowledge and data available to inform any assessment.

29 Please see: www.ideacology.com
30 Examples include the Regional Wildlife Science Collaborative for Offshore Wind, available here: https://rwsc.org/science-plan/

4 Technical methods supporting threshold setting

This section outlines potential approaches to threshold setting, in order of increasing complexity (summarised in Table 3). In general, more complex methodologies may be viewed as being more ecologically realistic, and hence more desirable. However, assumptions underpinning models can strongly influence conclusions about the resilience and viability of any population (Miller et al., 2019). Consequently, it is important to ensure that where these more complex approaches are used, they are underpinned by robust evidence and that assumptions are clearly stated.

The availability of data to inform approaches to threshold setting varies between regions and jurisdictions (Proença et al., 2017; Bernard et al., 2021). It is important to acknowledge the uncertainty that this will introduce into any assessment, and not proceed with a methodology that cannot be supported by the available data (Milner-Gulland & Shea, 2017). In such circumstances, it would be more appropriate to use simpler approaches but ensure that any limitations and assumptions underpinning the resulting thresholds are clearly communicated.

4.1 Expert knowledge

Since the types of data available to feed into assessments may vary between jurisdictions, it is important to acknowledge that it is rather rare to start from a position of no understanding or knowledge of the VEC concerned. In addition to any pre-existing scientific knowledge, there is often a substantial understanding of the VEC concerned amongst Indigenous peoples and local communities (Hill et al., 2020), which can provide evidence about the status and vulnerabilities of any VEC used to inform threshold setting. This can be accessed either informally or, ideally, through formal structured elicitation processes (Kuhnert et al., 2010; Stern & Humphries, 2022).

Elicitation has been widely used in situations, such as conservation management, which are often characterised by an urgent need to make decisions, and a lack of data on which to base those decisions (Kuhnert et al., 2010). In the absence of empirical data, the information derived has the potential to improve decisions, an approach which has been applied to assessing the impacts of pile-driving for offshore wind farms on marine mammals (King et al., 2015). In the absence of data needed for more complex approaches to threshold setting, a carefully designed elicitation process could be used to determine a level of impact that a VEC is believed to be able to sustain. Involving Indigenous peoples and local communities in the process would have the added advantage of ensuring that the social and cultural value of the VEC is considered.

In situations where data are limited, this approach would be suitable for any VEC in categories E1-E4 or S1-S4 (Figures 5 & 6). It is likely to be particularly useful for groups, such as Bucerotiformes (hornbills and hoopoes) and Pteropodidae (fruit bats), which are believed to be vulnerable to wind farms, but for which limited population and demographic data are available.

4.2 Species distribution modelling and assessment of connectivity

Data on species distributions may be available from sources such as historic surveys (e.g. Waggitt et al., 2020) or GPS tracking studies (e.g. Wakefield et al., 2017). At a basic level, these data can be used to assess potential connectivity and the degree that organisms or natural processes can move unimpeded across habitats, in relation to wind and solar projects. Assessing connectivity is especially relevant in fragmented landscapes (or where development projects will contribute to fragment the landscape), or in linear habitats, such as rivers (Wiens et al., 1993). In the marine

Table 3 Summary of technical approaches to threshold setting

APPROACH	SUITABLE VEC* CATEGORIES**	DATA REQUIREMENTS	STRENGTHS	CONSIDERATIONS
Expert knowledge	E1-E4 or S1-S4 (any VEC)	Specialist knowledge on VEC status, vulnerabilities and ecology.	Likely to be particularly useful for species with limited population and demographic data	◆ Suitable for situations where data are not available, and it is not likely to be feasible to collect the necessary data within the constraints of the project ◆ Should not be seen as an alternative to data collection where this can feasibly be achieved
Species distribution modelling and assessment of connectivity	E1-E3 and S1-S4 (VECs that do not have an effective zero-threshold for impact)	Known occurrence location and data on environmental covariates.	◆ Can be used to predict VEC distribution and identify especially important areas ◆ Likely to be particularly appropriate for marine species where data on historic distribution are available	There can be considerable uncertainty surrounding modelled estimates of species distributions. The extent of this uncertainty varies depending on the modelling approaches used and the level of risk that decision makers are willing to tolerate.
Potential biological removal	S1 or S2: only VECs with stable or increasing population trends:	Adult survival, age at first breeding and population size	Simple metric, can be estimated using only a few parameters	Relies on several assumptions, which may reduce reliability in many situations
Population viability analysis (PVA) – matrix models	S1-S4 – species VECs	Basic: demographic rates (e.g. breeding success). More complex: can incorporate density dependence and immigration/ emigration.	Suitable where robust demographic data are available	Use of density dependence in modelling requires robust evidence
PVA – integrated habitat and population models		Demographic rates	Suitable for species with robust data on demographic parameters related to habitat	Data and analytical requirements demanding
PVA – agent based models		Movement data (e.g. GPS tracking), data on energetics and demography	Predictions made at the level of individuals, meaning it is possible to better account for variation between individuals when estimating cumulative impacts	◆ Data-intensive – only suitable for species with high data availability. ◆ Specialist technical skills are required for modelling

* Valued environmental components
** See Figures 5 and 6

Source: Authors.

environment, tools such as published estimates of seabird foraging ranges are widely used to assess connectivity with offshore wind farms (Thaxter et al., 2012).

Building on assessments of connectivity, approaches such as species distribution modelling (SDM) could be used to assess the magnitude of any interactions with wind and solar infrastructure. SDM is a quantitative modelling approach that relates known locations of species occurrences to environmental covariates (e.g. altitude, temperature, precipitation, land cover) that may influence or define habitat potential. These models predict the distribution of a species using environmental data and allow the estimation of species' ecological requirements. SDM can be used to understand how environmental conditions or changes in these conditions can influence the occurrence or abundance of a species, so they are frequently used in land-use planning (Brotons et al., 2004; Roscioni et al., 2013) and conservation (Guisan et al., 2013).

In the context of CIA, SDM can be used to predict a VEC's distribution, where this is not known, and to identify areas that are especially important. This will allow the development of sensitivity maps, as the distribution of ecosystem components can be mapped, taking into account the approximate sensitivity to human pressure of each component (Andersen et al., 2020; Goodale & Milman, 2019 & 2020). From this, a cumulative exposure (CE) score can be estimated (e.g. Goodale et al., 2019), reflecting the proportion of the population potentially exposed to wind and solar infrastructure. The CE score could be used as the basis for setting thresholds for VECs with a view to minimising potential exposure.

Where distributional data are available, this approach is likely to be suitable for VECs in categories E1-E3 or S1-S4 (Figures 5 and 6) (i.e. those VECs that do not have an effective zero-threshold for impact). The approach is likely to be particularly appropriate for marine species (e.g. seabirds, marine mammals, turtles) for which data on historic distributions are available.

4.3 Potential biological removal

Potential biological removal (PBR) is a measure of the number of individuals that can be removed from a population annually by human-induced mortality whilst retaining a viable population (Wade, 1998). Therefore, it can be used to predict if impacts are significant at a population level and to set an acceptable level of impact for species that are not currently suffering population declines. Where species have populations that are already declining there is no capacity to incorporate additional mortality.

PBR has significant practical advantages, as it is a simple metric that can be estimated using a small number of parameters, even when detailed demographic information is unavailable (Dillingham & Fletcher, 2011; IFC, 2017; Wade, 1998). This makes it attractive for use in CIA in less well-studied parts of the world. However, it should also be noted that PBR relies on several assumptions, particularly relating to density dependence and population trajectory, which may reduce its reliability in many situations. Crucially, when used to set thresholds, it also requires that all sources of anthropogenic mortality are captured and not just those associated with a single pressure (O'Brien et al., 2017; Žydelis et al., 2009).

O'Brien et al., (2017) compared PBR to outputs from demographic matrix models for seabirds, showing that levels of mortality allowable from PBR estimates result in some level of population decline in most situations. PBR estimates should therefore be used with caution for setting impact thresholds but may offer a useful summary of demographic characteristics. Compared across species, PBR estimates give an indication of relative recovery potential and thus are potential inputs to risk-based approaches (see Section 4.5). Similarly, PBR estimates can be used as scale factors to assess the relative significance of cumulative individual impacts, and to identify priority species of concern at project level. PBR can also be applied to demonstrate where an impact is not sustainable. However, as the metric is based on a species' maximum theoretical growth rate, it does not necessarily follow that an impact below this value is sustainable (Niel & Lebreton, 2005). Consequently, although estimates of PBR may offer a useful index of a species demographic vulnerability, it should not be used as a threshold for additional mortality.

Logically, where populations are already declining, they cannot sustain additional mortality. Consequently, PBR should only be applied in relation to species with stable, or increasing population trends, such as those in categories S1 or S2 (see Figure 6).

4.4 Population viability analysis and PVA-based metrics

An alternative, metric-based approach to threshold setting is to use the outputs from demographic models (Cook & Robinson, 2017; Katzner et al., 2022). Using a "matched runs" approach, pairs of models can be run whereby the only difference is the presence or absence of an anthropogenic impact on the population. The outputs from these models can then be used to estimate the counterfactual or impacted and unimpacted (CIU) populations. As a ratio of estimates from models which are identical, save for the impact of an anthropogenic stressor, CIU is relatively insensitive to misspecification of model input parameters (Cook & Robinson 2017; Green et al., 2016), making it a valuable approach in data-limited situations. Estimates of CIU could be used to set thresholds for allowable impact based on expert knowledge and the conservation, social, and cultural value of a VEC. This approach is likely to be appropriate for VECs in categories S1-S4 (Figure 6).

Technically, the most demanding step is to build appropriate population models, of which three potential approaches are described in the next sections.

4.4.1 Matrix models

Matrix models provide a flexible, unifying statistical framework for linking impact to demography and abundance (Croll et al., 2022). At a most basic level, input data are needed on demographic rates, including breeding success and stage-specific survival (e.g. juvenile, immature and adult), though more complex models can be built incorporating processes such as density dependence and immigration/emigration. Ideally these parametres should be derived on a colony or regional basis, as there can be spatial regional variation in demographic parameters (Frederiksen et al., 2005). However, the relative insensitivity of metrics like CIU to parameter misspecification mean that even where parameters are inferred from other populations, the models can still provide useful outputs. Where possible (e.g. where historical trends in abundance are available), models should be calibrated to ensure that modelled population trends match observed population trends.

This approach is likely to be suitable for species like black-legged kittiwake for which robust data on demographic parameters are available. Processes, such as density dependence, should not be incorporated into modelling frameworks unless underpinned by robust evidence in relation to both magnitude and direction (Horswill et al., 2017; Miller et al., 2019).

4.4.2 Integrated habitat and population models

Integrated habitat and population models address population dynamics in response to changing landscapes and land use. Models can incorporate variation in demographic rates in relation habitat and/or in response to interspecific interactions in multi-species systems (Bastos et al., 2015; Rempel et al., 2021). These models can be used to assess community shifts or population level changes between a pre-impact baseline and post-impact landscapes (Mahon et al., 2019; Mahon & Pelech, 2021).

Data and analytical requirements for such models are relatively demanding. For their model of the cumulative effects of wind farm development on skylark in Portugal, Bastos et al., (2015) modelled local population dynamics according to habitat favourability within 1 km2 cells across northern Portugal. They then estimated current wind farm related mortality and projected this forward based on predicted habitat changes and wind farm expansion. This approach is likely to be suitable for species for which robust data are available in relation to variation in demographic parameters in relation to habitat such as the golden plover

4.4.3 Agent-based model

In contrast to the above approaches which focus on the population level, agent-based models (ABMs) focus on the individual level. This approach has been adopted in order to assess the impacts of offshore wind farms on seabird populations (Searle, 2018; van Bemmelen et al., 2021). The approach typically combines movement data, such as those collected using GPS tracking, with data on the energetics and demography of the species concerned. Hence, it is a considerably data-hungry methodology and only likely to be suitable for species with a high level of data availability, for example lesser black-backed gulls, for which extensive GPS datasets and detailed information on demography, diet, and habitat preferences are available.

4.5 Emerging approaches supporting cumulative impact assessment

4.5.1 Risk-based approaches

Recent CIA frameworks use risk-based approaches to improve consistency, simplify complexity, treat uncertainty more transparently, improve uptake of scientific outcomes into policy, and allow iteration to make use of improved evidence (Stelzenmüller et al., 2018; Willsteed et al., 2023).

Environmental risk assessment as a process involves identifying hazards, assessing exposure, assessing effects and characterising risks (Judd et al., 2015; Piet et al., 2021a). CIA frameworks combine environmental risk assessment with a linkage framework that identifies activities, pressures, and ecosystem components (equivalent to VECs) and specifies how these are connected through impact pathways (also called impact chains or cause-effect pathways; see Section 4.5.2). One type of activity, such as offshore wind farm construction, can cause several different pressures, each of which may then impact one or more ecosystem components (Knights et al., 2013).

Stelzenmüller et al., (2018) outline a general risk-based approach to CIA, intended for marine management but also relevant to other contexts. They align their framework with the ISO 73 standard on risk management.[31] Using ISO 73 terminology, the CIA process involves three main steps: risk identification, risk analysis and risk evaluation, embedded in a broader process of risk management, monitoring, and communication:

- **Risk identification** involves identification of relevant VECs, activities, pressures, impact pathways and risk criteria, and assembling relevant datasets.
- **Risk analysis** involves determining risk levels using the available data and information on the implementation and effectiveness of control measures.
- Finally, **risk evaluation** reviews the significance and implications of the risks identified, for example in relation to biodiversity goals and gaps in information or management.

Assessing risks

The level of risk for one or more VECs depends on the degree of **exposure** to a pressure, the **effect** that exposure produces, and the potential for **recovery** (De Lange et al., 2010; Stelzenmüller et al., 2020) (see Table 4 for examples).

Piet et al. (2021a) outline a systematic risk assessment approach that could be applied widely in other CIAs (see Case study 5).[32] They assessed cumulative impacts of wind farms on the North Sea ecosystem, using a semi-quantitative scoring framework for criteria relating to VEC exposure to pressures, and the effect of pressures on VEC status. Combining scores for exposure and effect gives a measure of potential impact.

31 For further information, please se: https://www.iso.org/standard/44651.htm (Note: this standard is now withdrawn.)

32 Case study 5 is an example of the driver-activity-pressure-state-impact-response, or DAPSIR, framework, an established approach for assessing the ecosystem consequences of anthropogenic activity and environmental management (Patrício et al., 2016). It is increasingly being applied to questions relating to cumulative impacts (Bryhn et al., 2020). The strength of DAPSIR approaches is showing the relationship between activities and receptors, how cumulative effects are occurring, and the relative contribution of activities to pressures on receptors, permitting assessment of the implications of those effects on society and the environment.

Table 4 Metrics and relevant assessment variables for the components of environmental risk (exposure, effect and recovery), for two examples of VEC-pressure combinations

COMBINATION 1	VALUED ENVIRONMENTAL COMPONENT* – MIGRATORY RAPTOR SPECIES/PRESSURE – FATALITIES FROM WIND TURBINES	
	Metric	**Relevant variables for assessment**
Exposure	Proportion of population exposed to collision risk	Number and routes of migrating birds; flight height; location, density and height of wind turbines; implementation and effectiveness of mitigation measures
Effect	Proportion of at-risk individuals killed	Species-specific avoidance rates
Recovery	Population-level effect of fatalities	Age at first reproduction; reproduction rate; survival rates of different age classes
COMBINATION 2	**BENTHIC MARINE ECOSYSTEMS/PRESSURE – SMOTHERING FROM SEDIMENT DURING OFFSHORE WIND FARM CONSTRUCTION**	
	Metric	**Relevant variables for assessment**
Exposure	Proportion of ecosystem at risk from smothering	Spatial overlap of ecosystem and wind farms, turbine size and density, construction methods, implementation and effectiveness of mitigation measures
Effect	Loss of ecosystem condition caused by smothering	Sensitivity of benthic organisms to smothering
Recovery	Long-term ecosystem condition	Ecosystem recovery potential

* Also known as valued environmental and social components

Source: Authors.

Building on this study, Piet et al. (2021b) illustrate a stepwise quantitative approach for risk assessment in the same ecosystem for two sectors (fisheries and offshore wind farms) and three groups of VECs (seabirds, seabed habitats, and marine mammals). This approach can also be generalised. However, in practice it probably can only be applied in well-studied ecosystems, since it has relatively demanding data requirements.

4.5.2 Network analysis

Network analysis provides a formalised way to identify and characterise impact pathways (see Case study 5) and their interactions. It is a modelling technique based on the concept that there are links and interaction pathways between individual components of the environment, and when one component is affected, this will affect other components that interact with it. Network analysis identifies the pathway of impacts or interaction through a series of chains (network) or webs (systems diagrams) between the project and the receptor (Cooper, 2004; 2010). By mapping cause and effect relationships among different projects or stressors and environmental components, possible cumulative effects can be identified.

Recently, Bayesian approaches have been used for deriving explicit and complex cause and effect relationships using probabilistic relationships (Downs & Piégay, 2019).

5 Case studies

Case study 1 EU Habitats Directive and in-combination assessment

In the European Union, plans and projects must comply with the Birds Directive (Directive 79/409/EEC) and the Habitats Directive (Directive 92/43/EEC, 1992),[33] which provide the legislative framework for the protection of the most valuable and threatened biodiversity in the EU. These two directives have created the Natura 2000 network, the largest coordinated network of protected areas in the world. The Habitats Directive conveys a requirement for proposed plans and projects to assess whether they are likely to have significant effects on Natura 2000 sites, either **alone, or in combination with other plans or projects.**[34] This includes sites in other Member States. The Habitats Directive is transposed into national law of Member States separately via the regulatory process of the relevant country. The competent national authorities must ensure that the assessment of significant effects arising from plans or projects has been properly carried out and includes the three main stages: i) screening; ii) appropriate assessment; and iii) derogation under certain conditions.

Screening is a relatively quick step to determine whether the plan or project is likely to have a significant effect on Natura 2000 site(s) (alone or in combination with other projects/plans), in view of the site's conservation objectives. If the screening concludes that significant effects on the site are likely or possible, an appropriate assessment must be carried out. If it cannot be excluded that a plan or project could have a significant effect on Natura 2000 site(s) (alone or in combination with other projects/plans), the plan or project must undergo an appropriate assessment. The screening is typically based on existing data, available knowledge and experience, and expert opinion.

Appropriate assessment is intended to determine whether the plan or project (alone or in combination with other plans/projects), will affect the integrity of the Natura 2000 site, considering possible mitigation measures. It can be coordinated with or integrated into the environmental impact assessment (EIA) for projects and the SEA for plans and programmes. However, the conclusions of the appropriate assessment must be presented clearly and separately from those of the EIA or SEA. An appropriate assessment involves the following steps:

- Gathering information on the project and on the Natura 2000 sites concerned.
- Assessing the implications of the plan or project in view of the site's conservation objective, assessing all designating features (species, habitat types) significantly present on the site. Significance of impacts must be assessed and quantified for each habitat/species using appropriate indicators, e.g. area of habitat loss/deterioration (ha and % of total area); changes in a species' demographic parameters (e.g. breeding success). Cumulative impacts with other plans/projects must also be considered.

33 In addition to separate regulations for Environmental Impact Assessment such as the EU EIA Directive 2014/52/EU (amends Directive 2011-92/EU).

34 Any plan or project likely to affect a Natura 2000 site should be assessed. What constitutes the 'other plans/projects' to consider in combination is not defined.

Case study 1 (continued)

- Determining whether the plan or project can have adverse effects on the integrity of the site. 'Integrity' relates to the site's conservation objectives, key natural features, ecological structure and function. It also includes the main ecological processes and factors that sustain the long-term presence of species and habitats in a site. A checklist is available to assess the effects on integrity of a site:

- Does the plan/project have the potential to:
  - hamper or cause delays in progress towards achieving the site's conservation objectives?
  - reduce the area, or quality, of protected habitat types or habitats of protected species present on the site?
  - reduce the population of the protected species significantly present on the site?
  - result in disturbance that could affect the population size or density or the balance between species?
  - cause the displacement of protected species significantly present on the site and thus reduce the distribution area of those species in the site?
  - result in a fragmentation of Annex I habitats or habitats of species (EU, 2009)?
  - result in a loss or reduction of key features, natural processes or resources that are essential for the maintenance or restoration of relevant habitats and species in the site (e. g. tree cover, tidal exposure, annual flooding, prey, food resources)?
  - disrupt the factors that help maintain the favourable conditions of the site or that are needed to restore these to a favourable condition within the site?
  - interfere with the balance, distribution, and density of species that are the indicators of the favourable conditions of the site?

- Considering mitigation measures to remove, pre-empt or reduce impacts identified in the appropriate assessment to a level where they will no longer affect the site. This may include: explaining how each measure will avoid/reduce adverse effects on site integrity; providing evidence of how they will be implemented and by whom, along with a timescale; providing evidence of their effectiveness; and explaining the proposed monitoring scheme.

- Conclusions of the appropriate assessment. Conclusions on the effects of a plan/project on the site must be complete, precise, and definitive. Where the appropriate assessment cannot exclude adverse effects on integrity of the site after applying mitigation measures, it should identify residual adverse effects.

Derogation: Plans/projects that have been ascertained to adversely affect the integrity of a Natura 2000 site may still be permitted, following three sequential legal tests: i) there must be no feasible alternative solutions that would be less damaging, or avoid damage to the site; ii) the proposal needs to be carried out for reasons of imperative reasons of overriding public interest (IROPI, under Article 6(4) of the Habitats Directive); and iii) the necessary compensatory measures are secured.

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Case study 2 Greater Wash wind farms (United Kingdom)

As part of the The Crown Estate's Round 2 of UK Offshore Wind Licensing, planning consent was sought for three wind farms within the Greater Wash area – Docking Shoal, Dudgeon, and Race Bank (Broadbent & Nixon, 2019). Due to several planned and existing projects within the region, the Round 2 Strategic Environmental Assessment highlighted a concern in relation to the potential impact on the local sandwich tern breeding population, a designated feature of the nearby North Norfolk Coast Special Protection Area.

Initially, the relevant authority, the Department for Energy and Climate Change (DECC), indicated that they would take a 'building block' approach to assessments whereby projects would be considered in the order they were submitted until a tipping point was reached and the projected cumulative impacts were deemed to be unacceptable (Broadbent & Nixon, 2019). This triggered a race to submission as developers sought to ensure that their project did not constitute the tipping point. Applications were submitted for Docking Shoal in December 2008, Race Bank in January 2009, and Dudgeon in April 2009. As the three projects were under consideration concurrently and following advice from Statutory Nature Conservation Bodies (SNCBs), DECC altered their approach to apply a more strategic, cumulative approach to consenting.

The North Norfolk Coast sandwich tern population has been well studied over a period of more than 30 years. Consequently, a PVA was commissioned with a view to identifying a maximum level of mortality that could be sustained by the population, while ensuring there was a reasonable chance of retaining population and site integrity. The outputs from this model suggested that a mortality threshold of 94 birds per year would reduce the population by 5 to 10% over the 25-year lifetime of the projects and that this may be deemed acceptable (Broadbent & Nixon, 2019).

Outputs from collision risk modelling suggested that the threshold of 94 birds per year was likely to be exceeded if all three projects were consented. Two potential options were identified in order to limit the annual mortality of Sandwich terns to 94 birds:

1. refuse consent for Docking Shoal and grant consent for Race Bank and Dudgeon.
2. restrict the capacity of all three projects.

Given that Docking Shoal was projected to kill a greater number of birds than either of the other projects, and the combined capacity of Race Bank and Dudgeon was greater than the potential capacity should all three projects be restricted, the decision made was to refuse consent for Docking Shoal and grant consent for the other projects.

The planning process for the Greater Wash wind farms faced substantial criticism (Broadbent & Nixon, 2019). Many stakeholders felt that the initial building block approach to CIA resulted in a race to submission, compromising the quality of evidence presented in assessments. Consequently, there was a lack of agreement between stakeholders during the assessment process, contributing to a three and a half-year period between submission of the applications and the final consenting decision (Broadbent & Nixon, 2019). Subsequently, planning consent has been granted for extensions to two of the Greater Wash wind farms (Sheringham Shoal and Dudgeon), with substantial compensatory measures agreed as a result of the projected cumulative impacts within the region.[35]

Contributed by: The Biodiversity Consultancy

35 Including the restoration of nesting habitat for affected species, the creation of new nesting habitat, and predator control (DESNZ, 2024).

Case study 3 The landscape scale vulture conservation – The strategic environmental assessment for wind energy and biodiversity in Kenya

An SEA for wind power and biodiversity in Kenya was developed in 2019 by The Biodiversity Consultancy, in partnership with BirdLife International, Nature Kenya, and The Peregrine Fund, supported by USAID through its Power Africa programme implemented by Tetra Tech. The Kenya Ministry of Energy was a proponent.

Whilst it was difficult for the SEA to identify cumulative impacts at the national scale due to the data available and timeframes for the assessment, a PBR analysis determined which species had smaller PBR values and consequently were at higher risk of higher population-level effects from wind farm mortality.

The PBR found that vultures were among the most sensitive receptor species. Through a spatial analysis, a band of areas that were identified as ‘Very High’ or ‘Outstanding’ sensitivity could be seen to be correlated with the presence of vulture colonies and tracking data – representing sites that would have highly elevated risk for wind farm development. Lower risk areas for development were identified across counties in northern and eastern Kenya.

The Environmental Management and Monitoring Plan (EMMP) of the SEA outlined actions needed to reduce, manage, and monitor adverse biodiversity impacts in the wind energy sector, as identified in the sensitivity analysis of the SEA. One of the recommendations was for aggregated offsets, that meet the compensation needs of two or more wind power projects. Aggregated offset interventions should be performed at landscape scale to benefit species of conservation concern that might be threatened by multiple wind farms in Kenya such as vultures. One suggestion was an integrated anti-poisoning programme for vultures to tackle one of the major causes of existing population declines in vulture species in Africa. An aggregated approach could deliver greater outcomes for wind power developers and vultures overall compared to smaller unconnected offsets. Collaboration in the design of a scaled-up approach would also improve efficiency and reduce the time and cost of design, set-up and monitoring. Other offset options considered included the support for conservation conservancies focused on managing declines of raptors, retrofitting high risk powerlines to mitigate electrocution and collision, rehabilitation and subsequent release of injured birds outside project areas, and captive breeding and release of priority species.

Anti-poisoning measures are already being implemented at Kipeto Wind Farm in Kenya, an operational project near nesting colonies of two Critically Endangered vulture species: Rüppell’s vulture (*Gyps rueppelli*) and white-backed vulture (*G. africanus*). Offset measures, in addition to mitigation, including shutdown on demand (SDOD), and carcass removal on site, involve a suite of interventions in the wider landscape to reduce human-wildlife conflict and thus retaliatory poisoning of predators. Offset activities are overseen by a multi-stakeholder Biodiversity Committee and implemented by a partnership of four conservation NGOs and the Kenya Wildlife Service.

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Case study 4 Black harrier, population viability analysis, and implications for wind farm management in South Africa

The black harrier (*Circus maurus*) is an endangered raptor restricted to southern Africa with a core range in the Western Cape. The species has started to face additional threats from wind energy development in the region, which has been identified as a Renewable Energy Development Zone (REDZ). PVA, considering life history information and annual reporting rates for the species, have determined that, based on an overall population of 1,300 birds declining at 2.3% per year, the population could collapse if as few as 3–5 birds are killed per year cumulatively between all wind farms (Cervantes et al., 2022). The increased rate of decline would lead to a 61% chance of extinction within 100 years. In the context of wind farm development, this elevated risk of extinction highlights the need for collective action and landscape scale strategies.

Proposed opportunities for collective action include increasing the habitat attractiveness outside of wind development areas, re-orienting foraging harriers away from areas of elevated risks. This could involve supplementary or diversionary feeding or reducing habitat attractiveness on wind farm sites. However, the main threat to harriers has been habitat loss following the transformation of Fynbos and Renosterveld habitats and, consequently, the most effective landscape scale collective action is to restore these habitats to ensure safe breeding and foraging grounds for the species (Simmons et al., 2020). The Excelsior wind farm, completed at the end of 2020 in the Overberg, has implemented an extensive monitoring and SDOD programme for the lifespan of the project, as well as contributing towards the Overberg Renosterveld Conservation Trust's (ORCT) easement programme, offering additional incentives to landowners in the form of assisting with key management interventions when undertaking negotiations for new easements, which would provide much needed habitat for the black harrier.

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Case study 5 Semi-quantitative risk assessment for cumulative impact assessment

Context

A study by Piet et al. (2021a) is an example application of the DAPSIR framework, drawing from an extensive evidence base to assess cumulative impacts of wind farms on the North Sea ecosystem. Several knowledge gaps were identified in this evidence base in relation to quantitative data (e.g. spatial distributions) and ecological relationships (e.g. the effects of pressures on particular VECs). These were filled using a formalised methodology based on expert judgement that can be iterated and improved over time. Expected developments of wind energy and other human activities in the North Sea were mapped out to 2030 and 2050. The spatial distribution of habitat and species VECs, and expected wind energy and other human activities out to 2030 and 2050, were mapped. Direct effects from human pressures were considered, but not indirect effects such as food-web shifts.

Main methodological steps

Mapping: A key step in the study was to compile a North Sea spatial data inventory, for a prioritised selection of human activities (current and future wind farms, oil and gas, cables, fisheries, aquaculture, sand extraction, shipping, and nature protection) and ecosystem components. For the prioritised suite of human activities, future scenarios were developed using national data and projections, with construction, operation, and decommission phases considered separately, where relevant.

Other mapping included:
- current and anticipated Natura 2000 areas ;
- distribution of ecosystem components (potential VECs, though that terminology was not used in the study), such as seabed habitats, water column habitats, plankton, benthic invertebrates, fish, birds, marine mammals, and bats; and
- an existing Wind turbine Sensitivity Index (WSI) map for birds (Leopold et al., 2014).

Identification of pressures and causal impact chains: Pressures are 'the mechanism through which an activity has an effect on any ecosystem component'. A human activity may be the source of multiple pressures and any single pressure may be caused by more than one activity (Knights et al., 2013). The study was able to draw on previous international research covering the North Sea (Borgwardt et al., 2019) that established typologies of human activities, associated pressures (including 18 relevant to offshore wind farms), and potential VECs impacted by those pressures. This earlier study also compiled casual impact chains linking activities, pressures and VECs.

Scoring framework: The study adapted a semi-quantitative scoring framework already developed by Borgwardt et al. (2019). For a set of criteria, as outlined below, the framework assigns a numerical score based on qualitative or quantitative categories. Scoring is carried out for each activity/pressure and VEC combination.

For example, for the 'spatial extent' criterion, on a scale of 0 to 1:
- An activity overlapping with up to 5% of the area occupied by a VEC would score 0.03.
- An activity overlapping with 50–100% of the area occupied by a VEC, but with a patchy distribution within that area, would score 0.67.

Risk assessment: The approach separates risk into **exposure** (how far a VEC is exposed to a pressure) and **effect** (the degree to which that exposure affects the VEC, sometimes called 'sensitivity'). In the study by Piet et al. (2021a), recovery potential was included within effect. Scores were assigned using the semi-quantitative scoring framework for seven criteria:

For assessing **exposure** (proportion of VEC potentially perturbed by a pressure):
1) Extent: proportion of spatial overlap of VEC with activity
2) Dispersion: potential of pressure to spread beyond initial overlap
3) Pressure load: proportional activity-specific contribution to the intensity of a particular pressure (adding to 1 over all activities for each pressure).

For assessing **potential effect** (proportion of VEC actually disturbed to a defined significance level, where its contribution to ecosystem integrity and functioning is compromised):

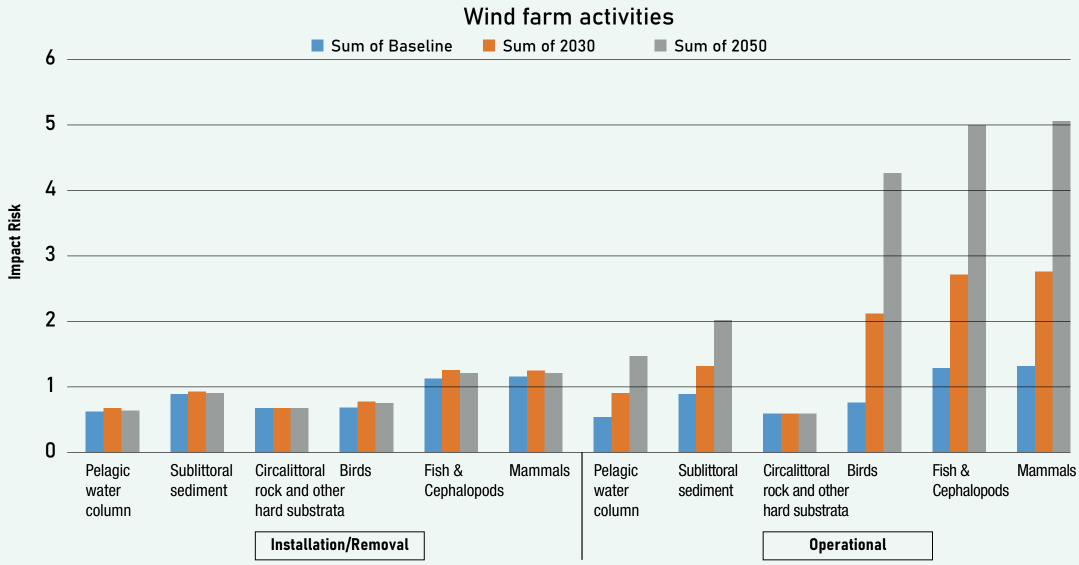

Figure 7 Cumulative (additive) impact from installation and operational wind farm activities on ecosystem components of the North Sea *Source: Reproduced from Piet et al. (2021a, p. 28)*

4) Severity: degree of response of VEC to the pressure
5) Frequency: rate of interaction between activity and VEC
6) Persistence: how long it takes for pressure to disappear after activity ceases
7) Resilience: recovery time for the VEC after pressure ceases.

For each impact chain, **impact risk was calculated as the product of exposure and the potential effect.** Impact risk can be aggregated across impact chains to show the overall likelihood of impacts on each VEC, or the relative contribution to impacts of each activity/pressure.

Effects of wind farms

The risk analysis enabled assessment of the additive cumulative impact on particular VECs from installation and operation of wind farms (Figure 7). An impact risk of zero means the ecosystem component is undisturbed, while a value of 100 or more implies (local) extinction.

Operational impacts for birds, fish, and marine mammals showed substantial increases with anticipated future developments, the wind farm impacts remained a relatively small share (around 5–10%) of the overall cumulative impacts of all activities.

Interpretation

The study's authors note that the CIA:

- does not address indirect effects, e.g. via food web relations or ecological cascade;
- is mainly useful for showing the relative importance of activities and pressures across VECs, and relative intensity of future trends, and for ranking rather than absolute differences;
- can be aggregated and disaggregated at different scales, across different ecosystem components or for the ecosystem as a whole;
- although based on spatial mapping, currently has only limited value in providing spatially explicit guidance;

Case study 5 (continued)

- the semi-quantitative scoring framework can be applied where data are limited, which is practically useful and an approach that may be useful for many CIAs. However, as the categories and scores are relatively coarse, there is substantial uncertainty in the calculated impacts; and
- uncertainty is particularly high (because of limited empirical data) in cases where the extent of an activity is small, but dispersion of pressures is thought to be high, e.g. for aquaculture.

A fully quantitative assessment (as outlined in Piet et al., 2021b) would substantially reduce uncertainties but requires a lot of quantitative information that is unlikely to be available for most CIAs.

Conclusions

Outcomes were interpreted in relation to EU's biodiversity targets, the concept of carrying capacity, and application to marine spatial planning. The study stresses the importance of CIA as a key tool for marine spatial planning, taking a 'top down' approach to ecological carrying capacity, where VEC abundance is determined by the cumulative impact of human activities. In this context, carrying capacity was defined as the maximum cumulative pressure that can be supported without significant deterioration of ecological processes and features. While there is not yet any scientific basis to define 'significant', CIA outcomes provide strategic guidance that can focus further work on mitigating the most important pressures. In this context, CIA shows the need for actions (some already planned), such as the designation of Marine Protected Areas, to reduce pressures overall and meet defined biodiversity goals. It further highlights that while the local effects of offshore wind can be significant, particularly for marine mammals and fish, these are often additive in relation to other ongoing pressures. Of these, bottom trawl fisheries have the greatest impacts on the ecosystem, far exceeding those predicted in relation to offshore wind development.

Quantitative extension

Piet et al. (2021b) build on the semi-quantitative CIA for the North Sea to illustrate a stepwise quantitative approach, for certain sectors and ecological components where there is sufficient information (Figure 8).

The conceptual approach is similar: identifying impact chains (activity – pressure – impact on VEC) and risk assessment (identifying exposure and effect, and characterising risk).

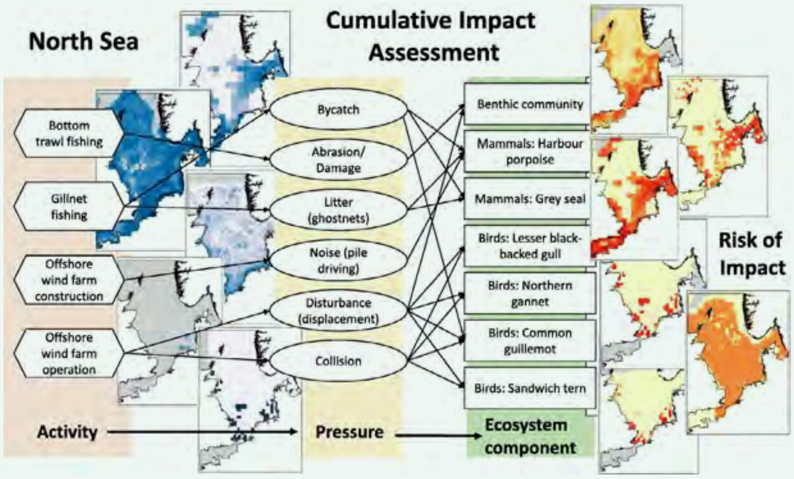

Figure 8 Graphical abstract for the cumultaive impact assessment quantitative approach *Source: Reproduced from Piet et al. (2021b, p. 1)*

Exposure: This is based on spatio-temporal maps of VEC abundance and pressure intensity. Combining these allows quantification of overall exposure, a combination of the spatio-temporal distribution of pressure magnitude and VEC abundance.

Effect: This requires specification of a pressure-state relationship, for example how the VEC responds to pressure of a particular magnitude. The response reflects either growth or depletion, at the level of an organism, population, or community/ecosystem. Both the form of the relationship (e.g. linear, exponential) and its parameters may vary considerably, and need to be specified based on ecological theory and (so far as possible) empirical data.

Impact: Impact reflects the change in state of a VEC, or a group of VECs. A common metric is needed to allow aggregation across impact chains for the CIA. For species or groups of species, Piet et al. (2021b) propose to use the difference between carrying capacity and the equilibrium abundance associated with a particular depletion rate. Relevant parametres can be estimated using the species-specific survival rates of different life history stages and formulae for these are provided.

Contributed by: The Biodiversity Consultancy

Case study 6 Shaping a greener tomorrow – Cumulative impact assessment guidance for wind and solar developments in the Northern Cape, South Africa

Relevant aspects of CIA: baseline assessments, identification of development scenarios, impact analysis, CIA, mitigation strategies, monitoring and reporting.

Renewable energy sources, particularly wind and solar developments, have become pivotal components of sustainable energy transitions worldwide. To effectively harness their potential, the planning, implementation, and management of these projects require thorough assessments of their cumulative impacts on the environment. The Northern Cape Province boasts numerous resources and wide-open spaces suitable for the construction of renewable energy developments (Figure 9). As a result, the province has been targeted for the development of

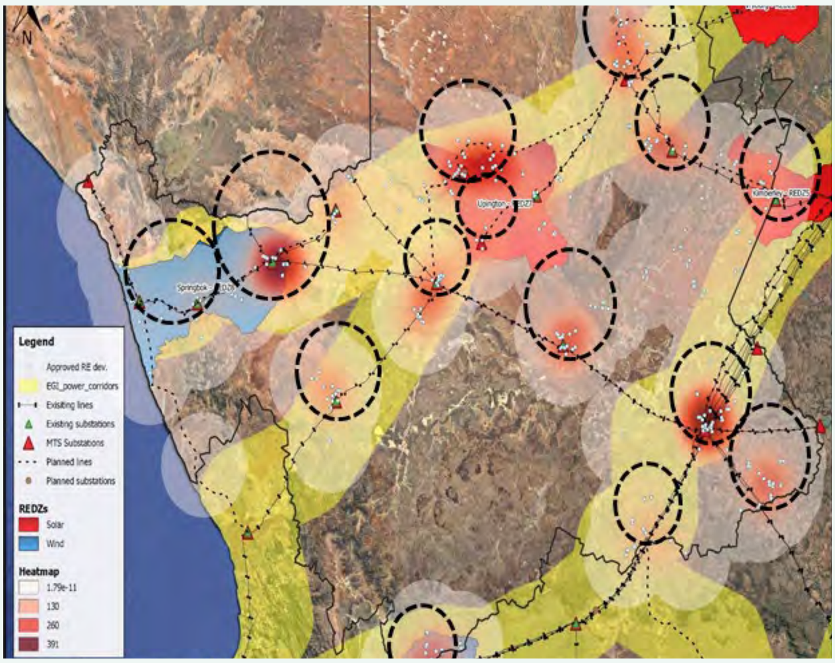

Figure 9 The renewable energy development concentrations (black dashed circles) are more likely to be associated with electricity infrastructure as opposed to the Renewable Energy Development Zones
Source: Piet et al. (2021b, see graphical abstract)

renewable energy facilities to meet the country's energy demands and international climate change commitments. It is, nevertheless, important to note that these developments, regardless of their green energy status, could have significant impacts on ecosystems within this open arid landscape. However, there is a lack of clear guidance and standards for conducting cumulative impact assessments for wind and solar developments in South Africa. A comprehensive framework for conducting cumulative impact assessments for wind and solar developments, including associated transmission infrastructure, is imperative to strengthen the EIA process.

The study focuses on guiding cumulative impact assessments within the context of renewable energy projects in the Northern Cape and discusses the unique considerations associated with wind and solar developments. Examples from wind and solar developments within the Northern Cape will be presented, showcasing diverse cumulative impacts on biodiversity. These examples can promote successful strategies, lessons learned, and effective mitigation practices. Guidance on cumulative impacts assessments for wind and solar developments and associated transmission infrastructure serves as valuable resources for policy makers, developers' environmental consultants, and local communities involved in wind and solar energy projects to make informed decisions that ensure the sustainable growth of renewable energy while minimising negative and irreversible impacts on biodiversity.

Contributed by: Peter Cloete, Northern Cape Department Agriculture, Environmental Affairs, Rural Development and Land Reform, South Africa

Case study 7 Cumulative effects assessment of Tafila Region wind power projects

Overview

The Tafila Region Wind Power Projects Cumulative Effects Assessment was commissioned by the IFC (2017) to help promote more sustainable wind energy investments in Jordan. This was the first CEA of its kind in the Eastern Europe, Middle East, and North Africa regions. Jordanian EIA Regulation (No. 37, 2005) did not require CEA to be conducted at the time of the assessment. However, new legislation opening up the Jordanian market for private sector investments for renewable energy, as well as the geographical context of the region within the Rift Valley/Red Sea flyway and adjacent to Dana Biosphere Reserve/Important Bird and Biodiversity Area (IBA), made this an appropriate scenario for a CEA.

The project represented a collaborative approach between five wind farm developers who agreed to share and pool pre-construction environmental survey data. The study area of the Tafila Region Wind Power Projects CEA included the Dana Biosphere Reserve, the surrounding IBA, five wind power projects (WPPs), and a 2-km buffer area around each WPP (Figure 10).

The objective of the CEA was to identify potential cumulative effects on biodiversity and propose mitigation, monitoring, and other management measures to address the highest risks to VECs.

The CEA process took place between January 2015 and March 2016 in three phases:

1) Phase 1 – an initial scoping to review existing data, engage with stakeholders, define spatial and temporal scale and select initial VECs;

Case study 7 (continued)

2) Phase 2 – supplementary data collection and capacity building; and
3) Phase 3 – six-step CEA framework development and assessment.

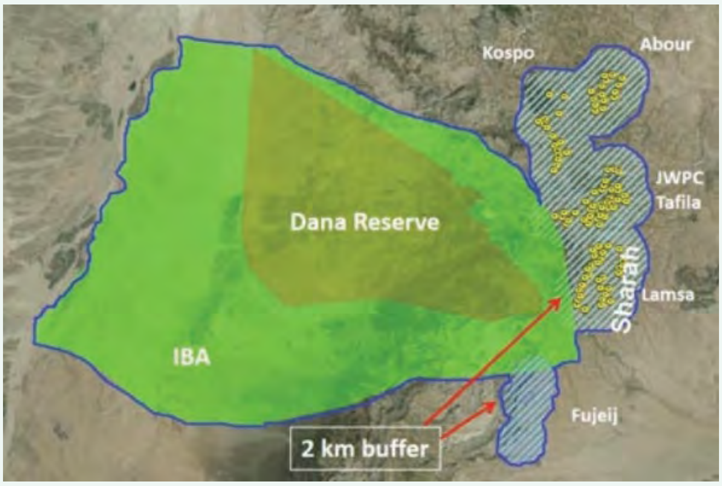

Figure 10 Tafila Region Wind Power Projects CEA study area
Source: IFC (2017, p. 4)

Priority VECs and threshold-setting

Birds. For avian VECs, an initial list of 171 avian populations identified as being potentially at risk was filtered down to 13 priority bird VECs. For each priority bird, fatality thresholds were identified, representing the 'limits of acceptable change', which, if exceeded, would reduce the viability and sustainability of the population and trigger adaptive management measures. The process of setting thresholds comprised two main parts:

1. Determination of the number of WPPs that would allow long-term viability of the population. A zero-fatality threshold target was applied to species with a minimum population size of ≤20. For larger populations, a potential biological removal (PBR) analysis was used to determine the annual number of fatalities that could be sustained without compromising long-term viability. The annual fatality estimate was combined with annual fatalities from primary external stressors (e.g. illegal killing, power-line electrocution, taking of live birds). Where these combined losses exceeded the PBR level, a zero-fatality threshold was applied. Where the PBR level was not exceeded, a population viability analysis (PVA) was conducted to aid determination of an appropriate annual fatality threshold target, with the help of an Expert Review Panel.

2. The iterative adaptive management process triggered if thresholds are exceeded. This process should: i) review reasons why the threshold was exceeded; ii) review the effectiveness of existing mitigation and whether revisions are required; iii) define a revised threshold target if needed; and iv) define actions to be taken if this new threshold is exceeded.

The Tafila CEA includes a decision tree for threshold setting for priority bird VECs. The assessment concluded that any cumulative effect was considered unacceptable for all priority bird VECs and consequently, all WPPs committed to a zero-fatality target for these species through mitigation measures. An 'extreme events threshold target' was also recommended to minimise the (very low) risk of multiple-fatality events to five additional non-priority migratory soaring bird (MSB) populations that may migrate in large flocks in the vicinity of the WPPs.

For bat species, two priority VECs were identified. Fatality threshold targets were not determined for priority bat VECs due to a lack of information on the regional size and status of these populations.

Four habitat types and four other species were identified as potentially being at risk within the study area. Limited data on habitats and other species precluded setting threshold targets for impacts. However, mitigation and management measures were proposed.

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Annex I Definitions from literature

Table 5 captures some existing definitions for cumulative impacts and related or similar terms from the literature, standards, regulations, and policy. There are various degrees of overlap between these definitions, adding complexity to the challenge of implementing CIA (as discussed in Section 1.2). Hence, it will be important to establish at all levels of CIA which definitions are being applied.

Table 5 Summary of existing definitions from literature, standards, regulations, and policies

DEFINITION	DATE	SOURCE	LINK
Cumulative effects			
Those that result from additive impacts caused by other past, present or reasonably foreseeable actions together with the plan, programme or project itself and synergistic effects (in combination), which arise from the reaction between impacts of a development plan, programme or project on different aspects of the environment	2015	British Standards Institution (BSI)	https://knowledge.bsigroup.com/products/environmental-impact-assessment-for-offshore-renewable-energy-projects-guide/standard
A change in the environment that results from the combined impacts of multiple human activities and natural processes that accumulate over time and space.	2014	Canadian Council of Ministers of the Environment	https://osdp-psdo.canada.ca/en/learn-about
Cumulative effects are defined as changes to the environment, health, social and economic conditions as a result of the project's residual environmental, health, social and economic effects combined with the existence of other past, present and reasonably foreseeable physical activities, as well as within activities of the project itself	2019	Canadian Impact Assessment Act	https://www.canada.ca/en/impact-assessment-agency/services/policy-guidance/practitioners-guide-impact-assessment-act.html
Where the intensity of development remains low, the impacts can be assimilated by the environment over time, and cumulative effects do not become a significant issue. However, when development reaches a high level of intensity, impacts cannot be assimilated rapidly enough by the environment to prevent an incremental build-up of these impacts over time. Changes over time and space accumulate and compound so that in aggregate the effect exceeds the simple sum of previous changes. This temporal and spatial accumulation gradually alters the structure and functioning of environmental systems, and subsequently affects human activities	1994	Eccles et al.	https://www.dffe.gov.za/sites/default/files/docs/series7_cumulative_effects_assessment.pdf

continued→

Table 5 (continued)

DEFINITION	DATE	SOURCE	LINK
Effects that result from incremental changes caused by two or more past, present and/or reasonably foreseeable actions. These can be economic, social or environmental in nature. Cumulative effects could arise from single or multiple responses (environmental, economic or social) to single or multiple pressures from single or multiple activities. The term "cumulative" is extended to include the term "in combination" effects as used in some legislation.	2022	Welsh National Marine Plan	https://www.gov.wales/sites/default/files/publications/2019-11/welsh-national-marine-plan-document_0.pdf
Cumulative effects result from a combination of two or more individual effects on a receptor. Such effects can occur as a result of plans, programmes, projects and other actions (this guidance uses the term 'actions' to describe all of these) in the past, present and the reasonably foreseeable future. They can result from impacts that may be individually insignificant, but collectively significant.	2020	Environmental Protection Agency (EPA), Ireland	https://www.epa.ie/publications/monitoring--assessment/assessment/strategic-environmental-assessment/EPA-Good-Practice-Guidelines-SEA.pdf
Cumulative effects, which are 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 such other actions	2020	US Code of Federal Regulations	https://www.govinfo.gov/app/details/CFR-2020-title40-vol37/CFR-2020-title40-vol37-sec1508-7
Cumulative effects assessment and management			
CEA has been modified to include an 'M' (CEAM) to also address the increasingly recognised need for management and mitigation of cumulative effects.	2010	Canter & Ross	https://doi.org/10.3152/146155110X12838715793200
Impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project	1999	European Commission	https://wayback.archive-it.org/12090/20151221014945/http://ec.europa.eu/environment/archives/eia/eia-studies-and-reports/pdf/guidel.pdf
The impacts (positive or negative, direct and indirect, long-term and short-term) arising from a range of activities throughout an area or region, where each individual effect may not be significant if taken in isolation... Cumulative impacts include a time dimension, since they should calculate the impact on environmental resources resulting from changes brought about by past, present and reasonably foreseeable future actions.	1999	European Commission	https://www.eea.europa.eu/help/glossary/eea-glossary/cumulative-impacts
Cumulative impacts can be defined as the additional changes caused by a proposed development in conjunction with other similar developments or as the combined effect of a set of developments, taken together. In practice the terms 'effects' and 'impacts' are used interchangeably	2012	Scottish Natural Heritage	https://tethys.pnnl.gov/sites/default/files/publications/SNH-2012-CumulativeOnshoreWind.pdf

continued→

Table 5 (continued)

DEFINITION	DATE	SOURCE	LINK
Cumulative impacts versus cumulative effects			
An impact can include more environmental changes than an effect. They define an effect as a direct and observable change in the current circumstance, whereas an impact represents the longer-term consequences that flow from that change. Impacts are much wider and more nebulous, and oftentimes they are much more difficult to discern	2016	Gillingham et al.	https://www.worldscientific.com/doi/epdf/10.1142/S1464333218500084
Cumulative Impact Assessment and Management is the process through which the potential environmental and social risks and impacts of a proposed project are analysed, in a context that incorporates, over time, potential aggregated impacts of other human activities (projects), natural factors or external social or environmental stressors, carried out in the past, present, and with a reasonable probability of being carried out in the future; in order to propose measures to avoid, reduce, restore or mitigate said impacts and incremental risks	2023	IDB Invest	https://www.idbinvest.org/en/publications/practical-guide-cumulative-impact-assessment-and-management-latin-america-and
CIA is the process of (a) analyzing the potential impacts and risks of proposed developments in the context of the potential effects of other human activities and natural environmental and social external drivers on the chosen VECs over time, and (b) proposing concrete measures to avoid, reduce, or mitigate such cumulative impacts and risk to the extent possible	2013	IFC	https://www.ifc.org/wps/wcm/connect/58fb524c-3f82-462b-918f-0ca1af135334/IFC_GoodPracticeHandbook_CumulativeImpactAssessment.pdf?MOD=AJPERES&CVID=kbnYgI5
Cumulative effects assessment			
Cumulative effects assessment is a systematic procedure for identifying and evaluating the significance of effects from multiple activities. The analysis of the causes, pathways and consequences of these impacts is an essential part of the process	2004	Imperial College London	https://www.researchgate.net/publication/370067502_Guidelines_for_Cumulative_Effects_Assessment_in_SEA_of_Plans
Cumulative effects assessment (CEA) is an integrated analytical approach that considers the stressors' (factors affecting the system) connectivity in generating effects.	2017	Afroze et al.	https://www.sciencedirect.com/science/article/pii/S2352146517307974
Cumulative effects assessment is defined as a systematic procedure for identifying and evaluating the significance of effects from multiple human activities. It can also provide an estimate of the overall expected impact to inform management decisions.	2017	OSPAR	https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/chapter-6-ecosystem-assessment-outlook-developing-approach-cumul/
Cumulative effects assessment is defined as a systematic procedure for identifying and evaluating the significance of effects from multiple sources/activities and for providing an estimate on the overall expected impact to inform management measures. The analysis of the causes (source of pressures and effects), pathways and consequences of these effects on receptors is an essential and integral part of the process.	2015	Judd et al.	http://cmscoms.com/wp-content/uploads/2015/09/Principles-for-cumulative-effects-assessment-2015-54-254-262.pdf

Annex II Mitigating biodiversity impacts associated with solar and wind energy development

IUCN has produced industry-focused guidelines to support wind and solar energy developments to manage risks and improve outcomes related to biodiversity and ecosystem services (Bennun et al., 2021). The mitigation hierarchy provides developers with an effective framework to address risks through the sequential and iterative application of four actions: avoid, minimise, restore, and (if necessary) offset (Figure 11).

Effective application of the mitigation hierarchy focuses on early avoidance and minimisation through project planning and design, including identification of site alternatives, design modifications, and continual evaluation and improvement. Project repowering also provides opportunities to address unforeseen impacts and implement new and effective mitigation measures.

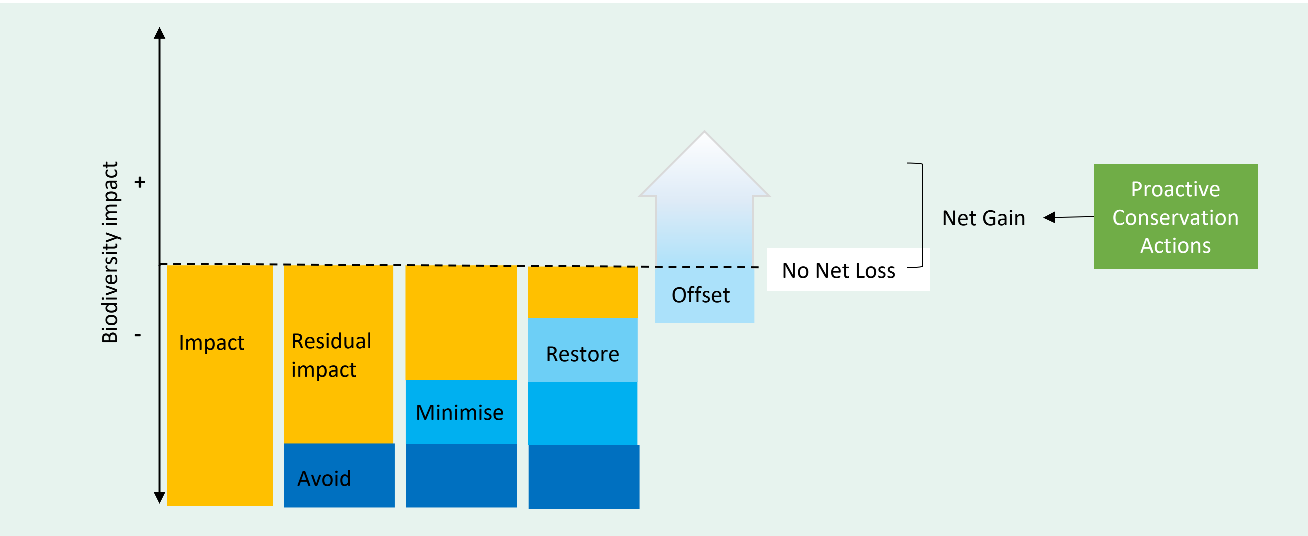

Figure 11 **The mitigation hierarchy** *Source: TBC*

Avoidance measures that are effective during project design include burying power lines or routing them to avoid sensitive areas such as wetlands or bird migration corridors. Infrastructure micro-siting options include adapting the configuration of turbines to reduce risk of collision and barriers to species movement. Marking transmission lines with bird diverters is now standard good practice and has been shown to significantly reduce the numbers of collisions. Risk of bird electrocution can be almost eliminated through construction of safe distribution lines that include insulation and spacing of conductors. Such measures are often straightforward and cost-effective to integrate into design.

New mitigation approaches and technologies offer opportunities to minimise risks while operating wind and solar projects. These include procedures to shut down specific turbines based on real-time observations of bird activity in the area using either field observers, image-based detection and/or radar technology. Measures to reduce collisions by making turbine blades more visible to birds are showing promising results but require further field testing. For bats, stopping turbine blades from operating during low wind speeds provides a proven strategy to reduce collision risk at a minimal cost to energy generation. Acoustic deterrents may also be effective for some species.

Careful siting through early project planning combined with on-site mitigation can often eliminate the need for biodiversity offsets. However, offsets may be required where projects have unanticipated impacts, or predicted impacts that cannot be fully addressed. Offsets for wind and solar developments can bring particular challenges, including accurately predicting residual impacts, particularly in data-poor areas where the technologies may be new. For migratory birds, the most effective interventions may be at breeding or wintering grounds that are far from the project site, making it challenging to secure offsets and gain support from local project stakeholders.

Where significant residual impacts are unavoidable, offsets should be planned and implemented based on best practice principles to ensure that they achieve demonstrable gains, do not negatively affect people, and ideally contribute towards wider national or regional conservation goals. One way for developers to address cumulative impacts to similar biodiversity is to channel resources into a single, aggregated offset. Aggregated offsets have the benefit of increasing the likelihood of success whilst spreading risks and costs across several developers.

Beyond actions that aim to deliver measurable no net loss or net gain targets, there is often potential for proactive conservation actions to contribute to local conservation efforts and help deliver positive outcomes for people and nature. Onshore wind and solar farms offer opportunities to restore and enhance habitats in previously degraded areas, while artificial reefs protecting the foundations of offshore turbines can enhance biodiversity and fish stocks.

For more information and to download the guidelines, see: https://doi.org/10.2305/IUCN.CH.2021.04.en

Annex III Key biodiversity features and potential cumulative impacts to consider for wind and solar development

Where conditions are favourable for wind and solar resources, multiple developments can be concentrated in the same locality. These projects will have individual impacts on the habitats and species occurring at that locality. While the impacts of individual projects are likely to accumulate on the same suite of habitats and species, the population-level effects of these cumulative impacts will vary between habitats or species. The features where the effects are of greatest concern (either due to the potential change in population status or because features are of high stakeholder concerns) should be the focus of any CIA.

The biodiversity features where cumulative impacts are likely to have the greatest effect, and more likely to be a focus of a CIA for wind and solar and transmission infrastructure, are summarised in Figure 12.[36] A high-level overview of typical types of solar plant (photovoltaic, or PV, and concentrated solar power, or CSP), onshore wind, and offshore wind (fixed and floating) developments can be found in *Mitigating biodiversity impacts associated with solar and wind energy development – guidelines for project developers* (with a summary of the potential project-level biodiversity impacts and mitigation measures linked to each development type).

36 Although it is important to be aware that all types of impact have the potential to contribute to cumulative impacts to some degree.

Annex III-A Key potential cumulative impacts on biodiversity from wind, solar, and transmission infrastructure

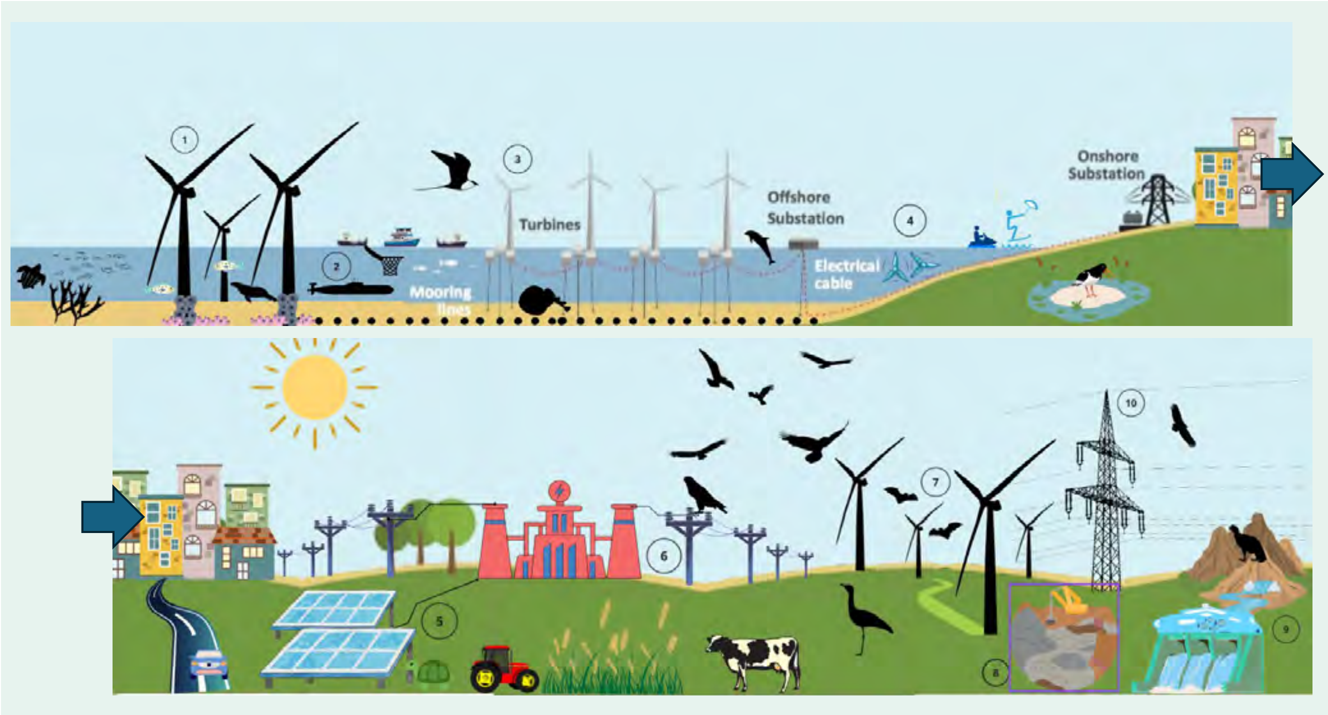

Figure 12 Key potential cumulative impacts on biodiversity from wind and solar and transmission infrastructure *Source: TBC*

Key
1) Fixed offshore wind farms can have cumulative and even ecosystem-level impacts to the composition of the seabed, marine species assemblages, nutrient flows and ocean circulation.
2) In addition to other marine activities like fishing, sports, and military activity, wind energy can add additional construction noise and disturbance to marine ecosystems.
3) Collision and displacement of seabirds is a major impact of increasing offshore wind energy, with floating wind farms now expanding to areas that were previously technically unfeasible.
4) Subsea cables from offshore wind will have a terrestrial impact and combine with other forms of nearshore energy like tidal power.
5) Solar power has a cumulative impact on land use, in addition to other requirements like agriculture, protected areas, real estate and transport infrastructure.
6) Associated renewable energy infrastructure expands the number of distribution and transmission lines needed, incurring greater electrocution risks, especially across vulnerable and migratory species' ranges.
7) Onshore wind energy infrastructure incurs greater collision risks, especially across vulnerable and migratory species' ranges.
8) Expansion of renewable energy has an implication for mining with increased demand for rare earth minerals and metals.
9) Other forms of renewable energy like hydropower will have an impact on freshwater environments and can add cumulative impacts to the water requirements of solar energy for cleaning and cooling panels.
10) Associated renewable energy infrastructure expands the number of distribution and transmission lines needed, incurring greater electrocution risks, especially across vulnerable and migratory species' ranges.

Annex III-B Solar

In general, the habitats and features for which cumulative impacts of solar development are likely to have the greatest effect (and so should be a focus for any CIA), are expected to result from siting/location issues (see Annex 3.5 for impacts related to associated infrastructure). Biodiversity, where cumulative impacts are likely to have the greatest effect, includes:[37]

- **High biodiversity value landscapes**: Utility-scale solar projects can individually and cumulatively cover large areas,[38] with impacts including habitat loss, fragmentation and degradation, and barrier effects. There is multiple potential biodiversity receptors associated with high biodiversity value landscapes, including protected areas, Key Biodiversity Areas, and areas of particular importance to threatened or declining species and ecosystems, restricted range[39] species, and habitat specialists (see third point);
- **Arid ecosystems**: These are often most suited for solar projects in terms of solar capture. PV systems are the most appropriate technology for water-limited regions, as they use less water than CSP (Bukhary et al., 2018; Macknick et al., 2012). Water abstraction could impact arid area wetlands, along with aquatic or groundwater-dependent biodiversity and important ecosystem services (e.g. via habitat loss, degradation, and fragmentation); and
- **Restricted-range species/habitat specialists**: These species, which either have small overall ranges, or are specialised to a particular habitat or topographic feature, may experience the greatest effect from cumulative impacts because multiple solar developments have the potential to cover a large portion of the species' range (Lovich & Ennen, 2011).

37 While birds can potentially be impacted by habitat loss and fragmentation due to solar plants, and may be at risk of collision with project infrastructure (including transmission lines and, to a lesser extent, PV panels), evidence suggests that impacts on birds are not a key risk for solar developments (Harrison et al. 2016; Kosciuch et al., 2021).

38 For examples, see Parker et al. (2018) and Kiesecker et al. (2020)

39 'Restricted range' refers to species with a limited extent of occurrence. IFC Guidance Note 6 (IFC, 2012b) defines what can be considered restricted range for different species groups (terrestrial vertebrates and plants, marine systems, and coastal, riverine and other aquatic species).

Annex III-C Onshore wind

For onshore wind developments, cumulative impacts are most likely to arise from collision risk and displacement, and habitat loss/fragmentation (see Annex III-E for impacts related to associated infrastructure). Biodiversity for which cumulative impacts are likely to result in the strongest negative population-level effects include:

- **Raptors and other large soaring birds** rely on updrafts for long distance flights, have low manoeuvrability, and potentially have a restricted forward field of view (e.g. Portugal & Murn, 2012). These species are most at risk from collision with turbines and as they typically have long generation times and relatively small populations, cumulative impacts have a potentially greater effect (AWWI, 2021);
- **Migratory soaring birds**, especially those where any part of their migratory route is constrained by topographic features (e.g. places where there are bottlenecks due to species optimising use of orographic or thermal uplift, or minimising long water crossings), may experience high levels of mortality because a larger proportion of the population could encounter multiple wind

farms (Cabrera-Cruz et al., 2020; Thaxter et al., 2017[40]), in addition to risks from other human activities;

- **Some bat groups**: migratory tree-roosting species and open-air foraging species are known to be at highest risk of collision with onshore wind turbines because of several factors, including (but not limited to) their foraging height, fast flight speed, commuting flight behaviour across open landscapes, and exploration or attraction with wind turbines (Aronson, 2022; AWWI, 2021; Guest et al., 2022; MacEwan et al., 2020; Thaxter et al., 2017);[41]

- **Restricted-range species, habitat specialists**: Those species, which either have small overall ranges, or are specialised to a particular habitat or topographic feature, may experience the greatest effect from cumulative impacts because multiple onshore wind developments have the potential to cover a large portion of the species' range; and

- **Natural habitats and other high biodiversity value areas**: as for solar developments, utility scale wind power projects can individually and cumulatively cover large areas, causing potentially significant habitat loss, degradation and fragmentation, and barrier effects. Key receptors include protected areas, KBAs, or areas of particular importance to threatened or declining species and ecosystems.

40 The finding was not statistically significant.

41 In contrast, little is known about the risk to fruit and nectar feeding bats (plant-visiting bats) because most studies to date have been in the northern temperate zone, where there are few plant-visiting bat species, and because they have a wide range of characteristics different to insectivorous bats (but see: Cabrera-Cruz et al., 2020; Aronson, 2022).

Annex III-D Offshore wind

For offshore wind developments, cumulative impacts are most likely to arise from collision risk and displacement, underwater noise, and vessel strike (see Annex III-E for impacts related to associated infrastructure). Biodiversity, for which cumulative impacts are likely to result in the strongest negative population-level effect, include:[42]

- **Seabirds**, including species totally reliant on marine waters (e.g. auks, petrels, gannets) **and others foraging in the marine environment at specific times** (e.g. seaducks, divers, skuas, some gulls, and terns). These species are at risk of collision and displacement effects and where offshore wind developments cover an increasing percentage of their range; the cumulative impact could have a large population-level effect. Collision (Skov et al. 2018) and avoidance (Heinänen et al., 2020; Johnston et al., 2021; Peschko et al., 2021, 2024) have been shown for a range of species in the northern hemisphere and are likely to also be experienced for a range of additional species as projects expand globally (e.g. shearwaters, albatrosses, petrels; Reid et al., 2023);

- **Migratory landbirds, shorebirds, and waterfowl.** Many landbirds, shorebirds, and waterfowl make migratory flights across the open sea and may be exposed to offshore wind farms during their migrations. While there is limited information on the behaviour of most species when encountering wind farms during migration, what little is available suggests avoidance of moving wind turbines by both shorebirds and waterfowl (Hüppop et al., 2019; Plonczkier & Simms, 2012) which may create

42 Impacts on bats are increasingly a concern for offshore wind developments. While bats are known to occur regularly in the marine environment and collision fatalities are likely (Bach et al. 2017; Solick & Newman 2021), numbers are low relative to onshore environments (e.g. due to the lack of roosts), suggesting that any cumulative impacts are unlikely to be significant.

strong displacement effects at a cumulative level;

- **Wide-ranging marine mammals.** Many marine mammals are known to be impacted from exposure to underwater noise such as from offshore wind construction activity, (e.g. see Nehls et al., 2019) and also vulnerable to collision with vessels[43] and may therefore be displaced from, or avoid, important areas of habitat due to the presence of wind farms. For wide-ranging marine mammals who are exposed to the cumulative impacts from multiple wind farms, the effects of such displacement may be large at the population level. The complexity of understanding the magnitude of any effect is compounded by the spectrum of potential development scenarios, for example from concurrent to sequential construction, the variety of foundation installation techniques that might be used, and the seasonality of marine fauna movements and behaviour (Bennun et al., 2021); and

- **Natural habitats and other high biodiversity value areas.** Offshore wind farm developments can individually and cumulatively cover large areas, traversing the marine, coastal/intertidal, and terrestrial environments, causing potentially significant habitat loss, degradation, and fragmentation. Key receptors include sensitive natural habitats like corals, mangroves, and seagrasses, protected areas, KBAs, or areas of particular importance to threatened or declining species and ecosystems.

43 Such as endangered North Atlantic right whales at heightened risk of vessel strikes because they spend a lot of time at or close to the water surface. Vessel speeds are restricted in seasonal management areas along the United States east coast at certain times of year to reduce this risk (NOAA Fisheries, 2024).

Annex III-E Associated infrastructure

Wind, both onshore and offshore, and solar developments can have a variety of associated infrastructure, which may also represent significant risk to biodiversity, and it is important that this risk is considered as an integral part of any project.

Overhead transmission and distribution lines are required to connect all project types with the energy grid: for onshore projects, these connect directly to the project substation, while for offshore projects, these connect with a substation at the subsea cable landfall site. All transmission lines present potentially significant risks to bird species and at the cumulative level, these impacts may have large population-level effects. The energy transition will require extensive construction of new transmission and distribution lines,[44] potentially involving habitat clearance of variable widths along the powerline corridor. The scale of the collision impact associated with powerlines is potentially much larger than that associated with wind farms.[45]

Collision and electrocution kill hundreds of thousands to millions of birds every year (Bernardino et al., 2018; Erickson et al., 2005), with the potential for population-level impacts (Bernardino et al., 2018; Burnside et al., 2015; López-López et al., 2011; Travers 2023), including contributing to imminent species extinction risk (Uddin et al., 2021). Species with high wing loading are at higher risk of collision with transmission lines because of their lower manoeuvrability (e.g. bustards, cranes, pelicans, storks, geese, swans, eagles, and vultures) (Janss, 2000). Raptors and other large perching birds, along with fruit bats, are at greatest risk of electrocution at distribution line poles due to their large wingspan, which

44 IEA (2022b) analysis shows that if government targets are achieved on time and in full (the 'Announced Pledges Scenario'), 14 million km of distribution lines and 1.8 million km of transmission lines could be added to the global network by 2030.

45 For example, a comparative study of total bird mortality from anthropogenic causes in the United States estimated that 13.7% (130 million birds) of the annual predicted avian mortality was due to power lines, compared to <0.01% (28,500 birds) from wind turbines (Erickson et al., 2005)

means they can inadvertently create a short circuit (e.g. Martín Martín et al., 2022; Shaw et al., 2018; Tella et al., 2020).

Land clearance for access roads, temporary construction areas, and permanent on-site facilities can also impact biodiversity, both directly through destruction of natural habitats and species mortality, or indirectly by induced access for humans to otherwise inaccessible areas.
In the United States, temporary loss has been estimated at 2.8 ha for a 2.5 MW turbine in forest (Voigt, 2023) and at 0.7±0.6 ha per MW for generic temporary impacts and ~0.2 ha per MW for permanent infrastructure (Denholm et al., 2009).46

Offshore, the cabling for floating wind farm moorings and that connecting turbines with the substation and between the substation and landfall can pose biodiversity risks if not well sited, as it can result in habitat loss or disturbance during burial, primary, and secondary entanglement, as well as disrupt species behaviours through the emitted electromagnetic fields (Tricas & Gill 2011; Hutchison et al., 2018; Maxwell et al., 2022).

46 These values might be out of date as turbine site has increased significantly since this report

Annex IV Existing guidance and approaches for cumulative impact assessment

The requirement for CIA is included in legislation and regulatory frameworks worldwide (Foley et al., 2017; Thérivel & Ross 2007; Willsteed et al., 2018b), although progress, implementation, and practical outcomes vary.[47] It is integrated into regulations applying at the strategic level (e.g. via the European SEA Directive[48]), and regulations for project-level ESIA processes (Olagunju et al., 2021; Roudgarmi, 2018) (e.g. via the European EIA Directive or the Canadian Impact Assessment Act). CIA is also a key component of the standards by which leading international financial institutions evaluate investments, including the World Bank Environmental and Social Framework (World Bank, 2016).

A range of regulatory approaches to and frameworks for CIA exist, as well as an array of guidance (often principles or process based) and a wealth of literature reviewing and exploring the topic of CIA. The existing guidance on CIA, primarily project-level, includes resources commissioned by government agencies linked to their regulatory requirements, prepared by financial institutions (e.g. Box 8), or prepared by industry bodies, NGOs, and practitioners. There are extensive resources in the wider literature that are not explored in further detail herein, including 'how to' documents (including Canter & Ross, 2010; Hegmann et al., 1999; Noble, 2022), critiques (e.g. Cooper & Canter, 1997; Duinker et al., 2013; Jones, 2016) and poor practice reviews summarised in (Burris & Canter 1997; Jones, 2016; Olagunju & Gunn, 2015), general and comparative reviews of practice (e.g. Foley et al., 2017; Halpern & Fujita, 2013; Hodgson et al., 2019), and proposed new approaches (e.g. Lonsdale et al., 2020; Masden et al., 2010; Piet et al., 2021a; Stelzenmüller et al., 2018).

However, as is the case with terminology, there is no single agreed approach to, or methodology for, CIA (either at the government or the project level). Overall, it is generally agreed that (government-led) CIA should be integrated into a rigorous SESA (for example EPA, 2020) or (project-level) ESIA (e.g. Blakley & Franks, 2021), rather than being thought of as a separate process at either level. Although there are some common conceptual elements, what constitutes good practice for CIA is variable (Hegmann, 2021), and practice is not consistent (Foley et al., 2017).[49] There is an agreement that CIA is still not well understood conceptually, and there remains a need for practical guidance for practitioners of CIA (Blakley & Russell, 2022; Foley et al., 2017; Jones, 2016). This exacerbates consenting delays (Willsteed et al., 2018b). Even in developed countries (e.g. UK and Australia), practice efficiency, political leadership, and explicit guidance are still fundamental issues to be addressed (Olagunju et al., 2021).[50]

Amongst the broader guidance on SESA, resources specifically supporting government-led CIA (as a component of SESA) are limited, but there are examples that illustrate a process for integrating government-led CIA into SESA and decision making, identifying links between the processes and specific tasks for government-led CIA (EPA, 2020; Thérivel, 2005).[51] Many general or project-level guidance documents are also intended to be applicable to, or recognise the importance of, wider government-led strategic planning processes as a precursor to project-level impact assessments, at

47 See discussion in Olagunju et al. (2021), for example.

48 European Directives are made applicable in each Member State through Member State law.

49 Foley et al. (2017) compared CIA carried out under United States, Canada, Australia, and New Zealand environmental laws, finding that a broad and varied definition of impact was used, leading to differences in how baseline, scale, and significance were determined.

50 According to Stelzenmüller et al. (2018, p. 1133), based on a range of sources therein, "although a unified and broadly applicable CEA methodology is most probably not feasible, the improvement of guidelines and best practices to facilitate CEA applications are urgently needed".

51 The latter includes a checklist for assessing cumulative effects in SEA.

Box 8

IFC Good Practice Handbook – Rapid cumulative impact assessment approach

The IFC has developed a Good Practice Handbook for Cumulative Impact Assessment and Management – Guidance for the Private Sector in Emerging Markets (IFC, 2007), which emphasises that good practice for CIA requires projects to assess their potential contribution to cumulative impacts as part of the environmental and social impact assessment (ESIA) process. The IFC recognise the importance of CIA in the context of IFC Performance Standard 1, Assessment and Management of Environmental and Social Risks and Impacts (IFC, 2012), in particular, the ability for CIA to act as a risk management framework for climate change, water availability, decline of species biodiversity, degradation of ecosystem services, and modification of socio-economic and population dynamics, among other systemic risk factors.

The handbook notes that where a government-led CIA exists, or where there are clear requirements resulting from regional, sectoral, or strategic planning efforts, projects simply need to comply with the overarching requirements of the existing CIA (as completed by government). It acknowledges the usefulness of government-led enabling frameworks for CIA, including: i) creating transparent mechanisms for disclosing available information on proposed developments; ii) establishing regional thresholds for VEC condition; iii) making available information on current states and trends in VEC condition; iv) providing information on the impacts of existing developments; and v) developing a framework for regional cumulative impact mitigation and monitoring.

Where government-led work does not exist, the handbook proposes a preliminary approach to rapid cumulative impact assessment (RCIA), a simplified CIA – there is no fundamental conceptual difference between the two processes. RCIA may evolve into CIA. The handbook notes that while there may be occasions when it is appropriate for a project developer to lead the CIA process, the resulting impact management recommendations may ultimately only be effective if the government is involved. The six iterative steps of the RCIA are summarised as follows (see Figure 7):

- Steps 1 and 2: Scope VECs, spatial and temporal boundaries, other activities, and environmental drivers.
- Step 3: Establish information on the baseline status of VECs.
- Step 4: Assess cumulative impacts on VECs.
- Step 5: Assess significance of predicted cumulative impacts on VECs.
- Step 6: Design and implement mitigation measures to manage the development's contribution to the cumulative impacts and risks.

continued→

Box 8 (continued)

RCIAs are expected to result in one of three scenarios described in more depth in the IFC Handbook. In summary, RCIA could determine: i) significant risk of cumulative impacts with significant opportunity to leverage strategic approaches to managing cumulative impacts; ii) significant risk of cumulative impacts with limited leverage of other developers, governments, or stakeholders to mitigate cumulative impacts; or iii) limited or no contribution to cumulative impacts. The handbook stresses the need to clearly record key decisions with supporting evidence to capture the fundamental reasoning behind each one. For example, being able to demonstrate why the temporal boundary used for the assessment was chosen, as well as all the different developments and external stressors included in the analysis.

The handbook emphasises the importance of clarifying roles and responsibilities in implementing CIA, and of stakeholder engagement and continual consultation with affected communities, developers, government, and other stakeholders throughout the decision-making process. The advice on stakeholder engagement draws from IFC's Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets (IFC, 2007).

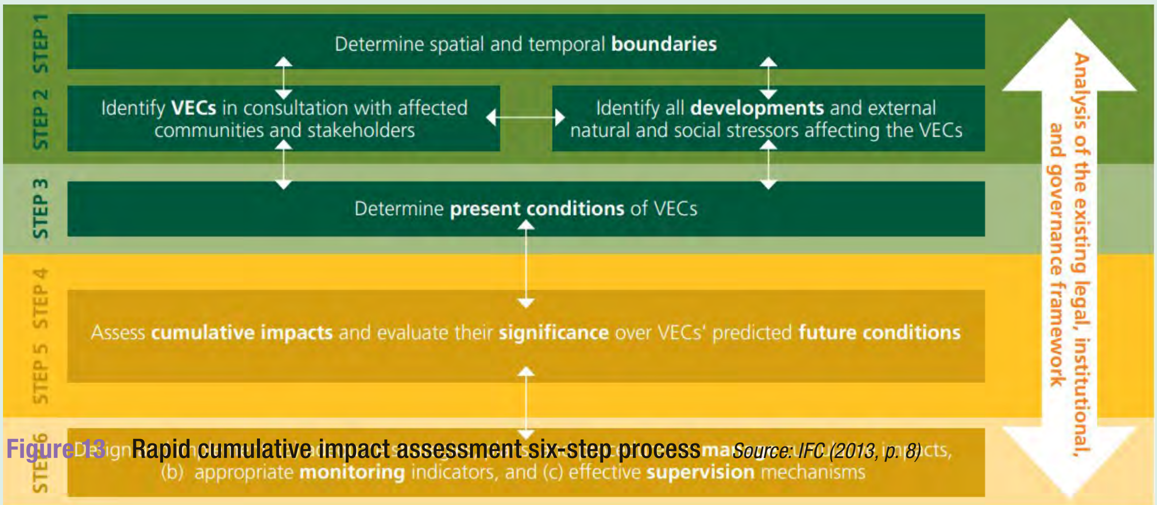

Figure 13 Rapid cumulative impact assessment six-step process *Source: IFC (2013, p. 8)*

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an early enough point at which decisions can be made on most suitable locations for development and on appropriate thresholds of acceptable ecological change (IFC, 2013; RenewableUK, 2013; Roudgarmi, 2018; SNH, 2012).

Guidance aimed at project-level implementation tends to address CIA as a key component of ESIA and offer more general recommendations (i.e. not specific to CIA itself) designed for developers, impact assessment practitioners and/or decision-makers in multiple sectors and industries.[52] Examples of guidance designed specifically to address CIA issues linked to renewable energy or transmission infrastructure are emerging (some examples are summarised in Box 9), and resources are expected to continue to develop (e.g. as the pace of development increases and barriers to permitting are addressed; see Annex V).

52 Most of the literature from the period 2008–2018 reviewed by Blakley & Russell (2022) are applied to or centred on multiple development sectors.

Box 9

Examples of guidance for project-level Cumulative Impact Assessment for renewable energy development

Note on recommendations for scoping the assessment of cumulative offshore wind impacts (GT ECUME, 2021)

The French Government Working Group on the Cumulative Effects of Marine Renewable Energy Projects, or GT ECUME (Groupe de travail sur les effets cumulés des projets d'énergies marines renouvelables) has developed a method for framing an assessment of cumulative impacts, consisting of determining the activities, pressures, and receptors to be studied as a priority. The recommendations build on experience of offshore wind energy in Normandy, north-western France (illustrated using offshore wind farms off Fécamp and Courseulles-sur-mer as examples) and are designed to apply to future expansion across the English Channel and other coastlines.

The document aims to: i) improve the understanding of cumulative impacts of offshore wind projects for government and developers; ii) identify the missing scientific knowledge needed to carry out this analysis and propose an operational method to fill the identified gaps; iii) improve consideration of other pressures beyond offshore wind energy; and iv) secure administrative authorisations for offshore wind projects with regard to France's commitments to the preservation of marine ecosystems. The overall intention is to guide sectoral expansion in the region by recommending certain operational steps and providing concrete examples of application. Key recommendations from the working group include:

- The need to for recognised scientific expertise, in both the marine environment and the wider ecosystem.
- Impact assessments must first include a comparative assessment of at least two potential alternative development scenarios.
- To address uncertainties through modelling the cumulative impacts on key indicator species and ecosystems.
- The importance of defining and implementing a method of prioritising the combinations of pressures and receptors, accounting for the relative sensitivities of the species and those for which knowledge is lacking and requires more research.
- Monitoring in collaboration with the scientific community, throughout operational life to reduce the uncertainty of CIA, and to update the requirements for avoidance, reduction, and compensation of impacts.

In 2022, GT ECUME published A risk-based method to prioritise cumulative impact assessment on marine biodiversity and research policy for offshore wind farms in France (Brignon et al., 2022). The prioritisation of pressures and receptors is based on a combination of risk-based expert judgement and consensus building, and a scoring system, which enables scientific complexity and uncertainties to be more easily managed. The scoring system is based on the ecological importance of receptors, the degree of knowledge on the effect of a pressure on a receptor and the sensitivity of each receptor to pressures.

continued→

Box 9 (continued)

Scottish Natural Heritage Assessing the Cumulative Impact of Onshore Wind Energy Developments (SNH, 2012)

This Scottish Natural Heritage (SNH, now NatureScot) guidance seeks to identify methodologies which can be used to assess cumulative landscape and visual impacts, and cumulative impacts on birds. It is aimed at public bodies, developers, and consultants involved in onshore wind energy development. The guidance is set in the context of the Scottish Natural Heritage Position Statement on renewable energy and the natural heritage. It provides useful flowcharts outlining the process of CIA for landscapes and visual impacts and birds. For landscapes, both static and sequential cumulative visual impact assessment is recommended. For birds, the guidance recommends that the process should include assessment of the significance of effects (e.g. using population viability analyses, or PVA) to determine overall impact on either designated /classified sites or species/habitat features at a biogeographical scale. However, the guidance also recognises that is not possible to provide generic advice on the significance of cumulative effects, which need to be assessed on a case-by-case basis.

Scottish Natural Heritage Assessment methodology for determining cumulative impacts of wave and tidal marine renewable energy devices on marine birds (SNH, 2010)

SNH commissioned research on cumulative impact assessment for birds in relation to wave and tidal devices to provide guidance on project-level CIA in Scottish Territorial Waters, and to outline possible approaches to the assessment process. The guidance makes 10 main recommendations:

1) Establish the proposed spatial scale to be used through consultation (e.g. regional sea).

2) List all marine/coastal bird species at that spatial scale.

3) List special protection areas (SPAs), marine SPAs and sites of special scientific interest (SSSIs) (with a coastal component), as well as other designated sites that support important numbers of seabirds within the project's zone of influence, as established under Step 1.

4) Obtain data on foraging ranges for species identified in Step 2, apply these as buffer zones around the relevant designated sites identified under Step 3.

5) Based on Step 4, confirm whether the default spatial scale (e.g. regional sea) is still relevant, or should be extended in case of migratory / passage species or species with large foraging ranges.

6) Obtain information on all other relevant development projects within the established spatial scale.

7) Reduce species list to those species where there is a development area within their maximum foraging range.

8) Identify the number of other projects (development areas) within the maximum and median foraging range of each species.

9) Estimate the sensitivity of species using a sensitivity index incorporating indicators of demographic sensitivity, such as adult survival rate or conservation status, as well as indicators of vulnerability to devices (e.g. dive depth, prey preferences).

10) Assess significance based on established guidelines (e.g. CIEEM EIA guidance, 2018).

continued→

Box 9 (continued)

Renewable UK Cumulative Impact Assessment Guidelines – Guiding Principles for Cumulative Impacts Assessment in Offshore Wind Farms (2013)

RenewableUK is the UK trade association for wind, wave, and tidal power industries in the United Kingdom. These CIA guidelines are aimed at planning and offshore industry professionals with an interest in the application of project-level CIAs in the context of the offshore wind farm consenting process in Europe, as well as environmental and public stakeholders interested in regulation and guidance in this sector. The guidelines aim to ensure all stakeholders have the same expectations of the CIA process, reduce uncertainty over the CIA process, and promote streamlining of the consenting process.

The document considers several practical solutions to overcome the challenges of CIA, presented as Guiding Principles (with guidance on implementation) summarised as follows:

General principles: 1) CIA is a project-level assessment; 2) Developers, regulators, and stakeholders will collaborate on the CIA, and 3) Clear and transparent requirements for CIA are to be provided by regulators and their advisors;

Scoping principles: 4) CIAs will include early iterative and proportionate scoping, 5) Boundaries for spatial and temporal interactions for CIA work should be set in consultation with regulators, advisers, and other key stakeholders in line with the best available data, 6) Developers will utilise a realistic project design envelope, 7) Developers will consider projects, plans and activities that have sufficient information available to undertake assessment;

Data principles: 8) The sharing and common analysis of compatible data will enhance the CIA process;

Assessment principles: 9) CIAs should be proportionate to the environmental risk of the projects and focused on key impacts and sensitive receptors, 10) Uncertainty should be addressed and where practicable quantified; and

Mitigation and monitoring principles: 11) Mitigation and monitoring plans should be informed by the results of the CIA.

BirdLife Cape Vulture and Wind Farms Guidelines for impact assessment, monitoring and mitigation (BirdLife, 2018)

BirdLife South Africa have compiled guidelines for impact assessment, monitoring, and mitigation, specifically in the context of the risk of impacts from renewable energy projects and associated infrastructure on Cape Vultures in South Africa. Cape vultures occur regularly in at least three renewable energy development zones, areas where the large-scale development of wind energy will be promoted in South Africa. The guidelines cover site screening, impact assessment and mitigation in general (including a decision tree outlining the recommended approach) and discuss the importance assessing the potential for cumulative negative impacts on Cape vultures. The guidance recommends considering the number (and where possible, impacts) of operational and potential wind farms within a radius of at least 100 km of the proposed wind farm, including the results of pre-construction and operational phase monitoring (where available). It is recommended that a buffer of approximately 50 km around all colonies and regular or seasonal/occasional roosts should be considered as high to very high sensitivity. These guidelines expand on Best-practice guidelines for assessing and monitoring the impact of wind-energy facilities on birds in southern Africa (2015) and are intended to be read in conjunction.

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Scoping
Establish spatial and temporal scope of assessment in consultation with key stakeholders - based on receptors rather than the pressures and proportionate to the potential cumulative impacts of the project with other existing and planned projects and activities.

Identification of key receptors
Refine understanding of key social, species and ecosystem receptors and their baseline condition with a quantification of uncertainty.

Determination of thresholds
Set thresholds for acceptable limits of change to receptors.

Analysis
Analyse potential impacts in relation to acceptable thresholds considering key cause and effect mechanisms. Conduct risk assessment based on the sensitivity and exposure of key receptors.

Mitigation and monitoring
Actively monitor, review and adapt mitigation and management measures based on evidence of effectiveness. Document and justify actions taken and communicate to stakeholders.

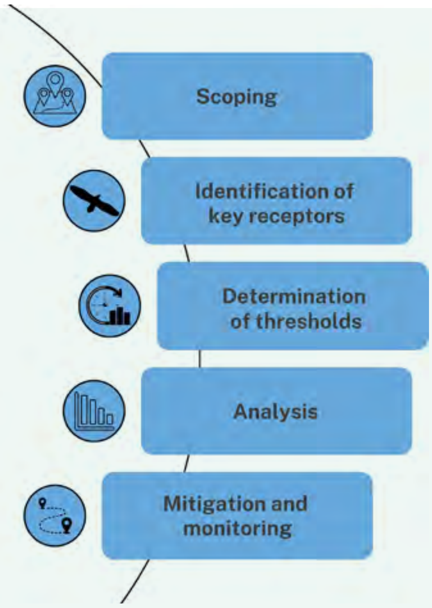

Figure 14 General approach to cumulative impact assessment *Source: The Biodiversity Consultancy*

Figure 14 illustrates a generic approach to CIA (for both government-led and project-level CIA). Project-level CIA differs from government-led CIA primarily because it is designed to provide sufficient information for regulatory decision-making for the specific project (Hegmann, 2021). CIA requires a scoping phase to establish the spatial and temporal contexts for assessment, which is related to the likely receptors for CIA – often termed valued environmental components, or VECs (see Box 5). Information or data gathering is focused on the VECs to inform understanding of the status of the VEC, identifying change over time and longer-term trends, and undertaking impact assessment. This also requires input from multiple different stakeholders. Depending on impacts and the status of VECs, it is then necessary to identify mitigation and management measures[53] and compensatory conservation measures.

In general, while broader SESA approaches and project-level ESIA both focus on the effects of a given action, CIA focuses on the receiving environment (EPA, 2020; Thérivel, 2005; Thérivel & Ross, 2007)[54] relative to a reference condition or to specific targets or objectives. This means CIA is commonly receptor-centred, rather than project-centred, tending to focus on the receptors of impact as opposed to the actions giving rise to the impact(s). This makes it easier to incorporate disparate impact pathways into the assessment. Receptor-centred approaches thus concentrate on: i) understanding the condition of receptors; and ii) identifying thresholds for acceptable impacts on, or limits of acceptable change for, receptors. They also generally incorporate and advocate for stakeholder engagement to varying extents.

53 For examples, see: European Communission (1999); Canter & Ross (2010); Noble & Blakley (2012); IFC (2013); National Infrastructure Planning (2019); DPIE (2022); Impact Assessment Agency of Canada (2023).

54 Emphasis and practical implementation vary.

Annex V Opportunities for streamlining renewable energy planning and permitting

Barriers to planning and permitting can be categorised as regulatory, administrative, related to societal support, and – as an external constraining factor – network availability, leading to stretched out development timelines (ETC, 2023).

Opportunities for accelerating planning and permitting processes include (ETC, 2023):

- Solutions to regulatory barriers, such as fostering strategic vision, identifying dedicated lands, reducing regulatory complexity, and enhancing flexibility of permits.
- Solutions to administrative barriers, including alignment between authorities controlling permitting, digitalising the permitting process, and creating digital spatial mapping tools to aid deployment planning.
- Increasing societal support, for example by engaging where there is public resistance to deployment of new infrastructure, challenging perceptions that developers are not taking adequate action to protect biodiversity or not conducting adequate stakeholder engagement and managing environmental and socio-economic impacts for local communities.

Grid connection and network availability can also be significant challenges. Regulatory review could also support not only deploying new grids but also improving the use of assets (IEA, 2023b).

For offshore wind in particular, consents and permitting can be a complex and sometimes disjointed process (Caine, 2020). It is common for national marine and terrestrial regulatory planning, assessment, and consenting systems to be handled separately (i.e. for project components across the offshore, intertidal/coastal, and terrestrial realms). Even after consent, delays in project financing can occur if regulatory requirements are not aligned with lender environmental and social safeguards.[55] This can be particularly challenging in relation to groups, such as seabirds, which move over significant distances over the course of their annual cycles, and are often only tied to specific locations for the duration of their relatively short breeding seasons (O'Hanlon et al., 2023). This means individuals from a single breeding population may be exposed to the cumulative impacts of projects in multiple jurisdictions. In such situations, it could be appropriate to protect the species in relation to their breeding locations, which may be beyond the jurisdiction of the country in which any development is planned. In these cases, international co-operation and shared approaches to managing this risk is required (Köppel et al., 2019).

Increasing coordination during planning and permitting is critical to ensuring the necessary speed and scale of the energy transition can be achieved. However, there is a risk that faster permitting processes could lead to unsustainable development that does not achieve the necessary balance between environmental and energy targets. Solutions that have been suggested include legally designating priority development status to renewable energy projects, except where there is clear evidence of major adverse effects on the environment and society that cannot be mitigated or managed – maintaining a high priority for biodiversity effects, designating specific renewable energy zones, creating better environmental mapping tools, and reducing the time taken in permitting stages (ETC, 2023).

The EU, for example, is implementing a flagship technical support project to address such issues and accelerate permitting for renewable energy, as part of support for structural reforms to aid the

55 An increasing number of financial institutions are aligning with leading practice international lender standards, including 138 financial institutions in 38 countries that have to date adopted the Equator Principles, which are based on IFC Performance Standards.

green transition in Member States.[56] Some key objectives of the technical support are to establish clearer, faster, and more transparent processes for permitting renewable energy projects, and to support national, regional, and local authorities in improving processes to identify areas suitable for renewable energy deployment and in translating national goals into local plans and projects.[57]62 In the United Kingdom, the government is proposing to speed up the consenting process for offshore wind development through compensating impacts on protected areas at a strategic level across multiple projects (DBEIS, 2023). While it will still be necessary for projects to mitigate the specific impacts of each development, compensation delivered at the strategic level could be more effective and deliver greater ecological benefit.

56 For further information, please see: https://reform-support.ec.europa.eu/accelerating-permitting-renewable-energy_en#objectives
57 In Europe, the REPowerEU Plan has also been initiated in response to the disruption in energy supplies due to Russia's military aggression against Ukraine, A key aim of RePowerEU is to invest in renewables and speed up the transition by implementing new legislation for faster renewables roll out, among other measures.

Annex VI Practical challenges for implementing cumulative impact assessment

Table 6 summarises some of the practical challenges associated with implementing CIA.

Table 6 Summary of some practical challenges associated with Cumulative Impact Assessment

CHALLENGE	OUTLINE
Uncertainty	CIAs inevitably involve uncertainty, which can originate from inadequate knowledge, challenges in predicting ecological responses, natural variability, measurement error or changing plans and policies (Stelzenmüller et al., 2018). There is a need for CIAs to explicitly consider and assess uncertainty and – where it is non-trivial and could constrain effective decision-making (Milner-Gulland & Shea, 2017) – to reduce it, if possible (Searle et al., 2023). The proliferation of different approaches, terminologies, and technical methods in CIA can be confusing, contributing linguistic uncertainty to what is already a complex subject (Masden et al., 2015). Consequently, recent reviews of CIA approaches have stressed the importance of standardised frameworks and best practices, as well as identifying promising technical developments (Willsteed et al., 2023). Emerging approaches to handling uncertainty (Willsteed et al., 2023) include: ◆ Evidence-based review methods and combining multiple lines of evidence (Diefenderfer et al., 2016). An intuitive practical approach to combining evidence assesses the strength of support for each piece of evidence along with source reliability, information reliability and relevance (Christie et al., 2023). Although not designed specifically for CIA, this method is likely to prove useful. ◆ Accounting explicitly for expert uncertainty, by asking for best-case, most-likely and worst-case scores, and combining these for each uncertainty scenario (Jones et al., 2018). ◆ Use of risk-based approaches (Stelzenmüller et al., 2018) (see Section 4.5).
Defining spatial scale	VECs may be subject to multiple, dispersed drivers of change (O'Hanlon et al., 2023). Consequently, CIAs need to be carried out over a broad spatial scale to be a useful strategic tool (Willsteed et al., 2023). As the number of anthropogenic stressors to which a VEC may be exposed increases, the likelihood of overlapping effects increases because there is less space available for the effects to disperse (Willsteed et al., 2017). Therefore, there is a need to ensure that CIA is carried out at a scale relevant to the VECs concerned.
Defining temporal scale	The temporal scale is often left undefined in CIA reflecting challenges in the definition of appropriate temporal scales and a risk that not all impacts are properly considered. While many CIAs use the duration of the project as a temporal scale, more precautionary approaches use the 'reasonably foreseeable future' as a temporal scale, which is difficult to define and standardise across assessments (Hague et al., 2022). Additional challenges arise from lack of data related to the natural state of populations of VECs and shifting baseline syndrome, which may obscure cumulative impacts of wind and solar development on top of historical unrecorded or unrecognised declines (Masden et al., 2010). Masden et al. (2010) suggest that to be able to compare across CIAs and avoid shifting baseline syndrome, strategic decisions should be made at the policy level about the value of species, appropriate baseline levels, and acceptable target population sizes.

continued→

Table 6 (continued)

CHALLENGE	OUTLINE
Data availability and access to information	For developers, a common expectation is that cumulative impacts should be assessed for the project in question, plus ‘other relevant past, present, and reasonably foreseeable future actions’. This is generally challenging and unfeasible for developers needing to evaluate a potentially large array of other projects/activities. In practice, there is usually a big difference between what other projects and activities ‘should’ be considered in CIA for a project, and those for which information is available and accessible for developers,[58] especially with respect to future actions. Where information is available from other projects/activities, it is often incomplete, difficult to verify, and potentially inconsistent with a developer’s own methods and assessment approaches. This weakens the overall premise and leads to variable levels of consideration for an essentially arbitrary list of other past, present, and future actions. Additionally, the ability of individual developers to achieve the necessary ‘future look’ (e.g. in terms of geographic scale and timeframe over which to consider future projects, and/or considering the likely scant and uncertain detail available for those future projects) is a significant challenge – hence the importance of government-led strategic assessment that takes a receptor-centred approach to considering the different cumulative development scenarios, and defines project-specific impact thresholds that account for these. Availability of baseline biodiversity information is also a potential issue affecting the identification of appropriate VECs (see Box 5) and subsequent impact assessment, at both government and project levels and especially in offshore areas and in emerging market contexts. The availability of evidence of cause-effect relationships and resulting impacts is often limited, including an understanding of the relationships between impacts (additive, synergistic, antagonistic, etc.). Hence, the importance of consultative and consensus-based approaches such as defined herein (see Section 3.3.5).
Integrating CIA into project-level ESIA	Section 3 outlines an approach for projects to integrate CIA into ESIA both when there is a government-led CIA available to draw on, and when there is not. It is essential that CIA is integrated at the earliest opportunity in scoping the ESIA, in terms of adopting VECs from government-led CIA, or project identification of VECs. Thresholds defined for individual VECs will represent upper limits of allowable impact, both when defined by governments and allocated to individual projects, and when defined by projects themselves. To date, project-level consideration of cumulative impacts often focuses on a single impact on a single parameter, for example the impact of additional mortality associated with collision risk (Busch & Garthe, 2018). However, an individual VEC may be subject to multiple interacting impacts from an individual project, and from renewable energy projects more widely. Properly quantifying cumulative impacts requires each of these to be accounted for. These impacts may be additive (equal to the sum of their parts), antagonistic (less than the sum of their parts) or synergistic (greater than the sum of their parts) (Masden et al., 2010), but it is often unclear which will be the case in any situation. As an example, there are two potential pathways in which the impact of habitat change may influence collision risk in response to the presence of an offshore wind farm. A reduction in birds may occur due to displacement or habitat loss, resulting in a reduction in collision risk (antagonistic). Conversely, the artificial reef effect may attract birds due to an increased prey density, resulting in an increased collision risk (synergistic). CIA should consider all impacts on VECs, ideally accounting for how they may interact with one another.

58 The UK National Infrastructure Planning’s Advice Note Seventeen on cumulative effects assessment for nationally significant infrastructure projects acknowledges this issue through a tiered system based on the level of certainty and detail linked to the other projects and activities a developer should consider in CIA. This improves transparency, but has no meaningful implications for the outcome of CIA.

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