THE BIODIVERSITY CONSULTANCY

Mitigating biodiversity impacts associated with solar and wind energy development

Synthesis and key messages

IUCN GLOBAL BUSINESS AND BIODIVERSITY PROGRAMME

BirdLife International — Partnership for nature and people

Fauna & Flora International

The Nature Conservancy

WCS

About IUCN

IUCN is a membership Union uniquely composed of both government and civil society organisations. It provides public, private and non-governmental organisations with the knowledge and tools that enable human progress, economic development and nature conservation to take place together.

Created in 1948, IUCN is now the world's largest and most diverse environmental network, harnessing the knowledge, resources and reach of more than 1,400 Member organisations and some 15,000 experts. It is a leading provider of conservation data, assessments and analysis. Its broad membership enables IUCN to fill the role of incubator and trusted repository of best practices, tools and international standards.

IUCN provides a neutral space in which diverse stakeholders including governments, NGOs, scientists, businesses, local communities, indigenous peoples organisations and others can work together to forge and implement solutions to environmental challenges and achieve sustainable development.

www.iucn.org
twitter.com/IUCN/

About The Biodiversity Consultancy

The Biodiversity Consultancy is a specialist consultancy in biodiversity risk management. We work with sector-leading clients to integrate nature into business decision-making and design practical environmental solutions that deliver nature-positive outcomes. We provide technical and policy expertise to manage biodiversity impacts at a project level and enable purpose-driven companies to create on-the-ground opportunities to regenerate our natural environment.

As strategic advisor to some of the world's largest companies, we lead the development of post-2020 corporate strategies, biodiversity metrics, science-based targets, and sustainable supply chains. Our expertise is applied across the renewable energy sector, including hydropower, solar, wind, and geothermal, where we specialise in the interpretation and application of international finance safeguards.

www.thebiodiversityconsultancy.com/
www.linkedin.com/company/thebiodiversityconsultancy
twitter.com/TBCbiodiversity

Mitigating biodiversity impacts associated with solar and wind energy development

Synthesis and key messages

IUCN is pleased to acknowledge the support of its Framework Partners who provide core funding: Ministry of Foreign Affairs of Denmark; Ministry for Foreign Affairs of Finland; Government of France and the French Development Agency (AFD); the Ministry of Environment, Republic of Korea; 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 by funding from Électricité de France (EDF), Energias de Portugal (EDP) and Shell.

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

Citation: Bennun, L., van Bochove, J., Ng, C., Fletcher, C., Wilson, D., Phair, N., Carbone, G., (2021). *Mitigating biodiversity impacts associated with solar and wind energy development. Synthesis and key messages.* Gland, Switzerland: IUCN and Cambridge, UK: The Biodiversity Consultancy.

The full report *Mitigating biodiversity impacts associated with solar and wind energy development* is available here: https://doi.org/fw2c

ISBN: 978-2-8317-2104-0 (PDF)

DOI: https://doi.org/10.2305/IUCN.CH.2021.06.en

Cover photo: © EDF Renewables (left), © EDF Renewables (middle), © Shell (right)

Design and layout: Imre Sebestyén, jr / Unit Graphics

Available from: IUCN (International Union for Conservation of Nature)
Global Business and Biodiversity Programme
Rue Mauverney 28
1196 Gland
Switzerland
Email: biobiz@iucn.org
www.iucn.org/resources/publications

Table of contents

Foreword

Today our planet faces the interconnected, existential threats of climate change and biodiversity loss. Human activities, especially burning fossil fuels and deforestation, have disrupted the Earth's climate system. Concurrently, biodiversity loss has reached unprecedented rates with three-quarters of land surface now severely altered by human activity and one million species threatened with extinction.

These two crises are deeply interlinked: climate change is a significant driver of biodiversity loss, and the loss of biodiversity exacerbates the climate crisis.

To limit global warming to 1.5°C and avoid the most catastrophic effects of climate change, humanity's carbon dioxide (CO_2) emissions must reach net-zero by 2050. Using renewable energy is one of the most effective and readily available ways of reducing CO_2 missions. A combination of renewable energy, mostly from wind and photovoltaic solar, with more electrification to substitute fossil fuel use could deliver three-quarters of the required energy-related emissions reductions. If poorly managed, however, the expansion of renewable energy may cause additional loss of biodiversity and disruption of the ecosystem services on which we all depend. Solar and wind energy developments, for example, often involve the destruction or fragmentation of wildlife habitat, and the extraction of the raw materials needed for renewable energy technologies carry substantive biodiversity risks.

A transition to renewable energy which both avoids harm and contributes to nature conservation is, therefore, essential, but can only happen with the support of all relevant decision makers at every stage of planning and implementation. Governments need to ensure risks to nature are identified as early as possible and take action to mitigate them, such as protecting undisturbed areas from developments. Financial institutions can attach similar safeguards to loans and investments, and energy companies should avoid, minimise, restore and then offset the remaining impacts on biodiversity throughout the lifecycle of all projects. If we are to achieve net-zero emissions through renewable energy sources we also need new energy technologies, to make energy consumption more efficient, and to integrate circular economic principles.

Furthermore, recognising that energy is a basic human right and integral to alleviating poverty calls for the provision of 'clean' electricity to all people across the world. Any increase in the supply of renewable energy must be matched by investment to guarantee reliable and widespread access to it, and a transition away from fossil fuel production and subsidies.

The picture is complex, and reaching our sustainable energy and biodiversity goals requires action from us all. In these guidelines, we aim to define practical, evidence-based measures to mitigate the impacts on biodiversity associated with solar and wind projects. We hope they will stimulate discussion, and help ensure that both the nature and climate crises are addressed collaboratively. It has become increasingly clear that investment in renewable energy is critical, but to be successful any transition to a net-zero carbon energy model must also protect nature.

We welcome others to join us on this mission.

Bruno Oberle, Director General,
International Union for
Conservation of Nature (IUCN)

Helen Temple, Chief Executive,
The Biodiversity Consultancy

Patricia Zurita, Chief Executive Officer,
BirdLife International

Mark Rose, Chief Executive Officer,
Fauna & Flora International

Cristián Samper, President and Chief Executive
Officer, Wildlife Conservation Society

Carine de Boissezon, Chief Sustainability Officer,
Électricité de France (EDF)

Miguel Setas, Executive Board Member,
Energias de Portugal (EDP)

Elisabeth Brinton, Executive Vice President,
Renewables & Energy Solutions, Shell

About this document

The Synthesis report provides a high-level overview of the main themes addressed in the Guidelines on *Mitigating biodiversity impacts associated with solar and wind energy development*, published by IUCN and TBC in 2021. The Guidelines aim to provide practical support for solar and wind energy developments to effectively manage risks and improve biodiversity and ecosystem service outcomes. They are industry-focused and can be applied across the whole project development life cycle, from early planning through to decommissioning and repowering, using the mitigation hierarchy as a clear framework for planning and implementation. The guidelines focus on the needs of businesses in the solar and wind energy sectors, including project developers, investors and operators. The information is also relevant to government planners in the energy and power sector, and other government agencies and non-governmental organisations (NGOs) working in nature conservation. The guidelines have been developed through a multi-stakeholder process and are based on an extensive review of the scientific literature, supported by input from industry leaders and specialists.

This Synthesis report does not attempt to summarise the detailed recommendations for solar and wind projects developers on how to implement the Guidelines.

Download *Mitigating biodiversity impacts associated with solar and wind energy development* here https://doi.org/fw2c and watch the video here https://youtu.be/VMlDMBnRigM.

Acknowledgements

Reviewers
Alberto Arroyo Schnell (IUCN European Regional Office), Julia Baker (Bangor University), Violeta Barrios (IUCN Centre for Mediterranean Cooperation), Pedro Beja (CIBIO), Etienne Berille (EDF Renewables), Koen Broker (Shell), Gerard Bos (IUCN Global Business and Biodiversity Programme), Ludmilla Caillat (EDF Renewables), Andrew Carryer (Renewables Grid), Florence Clap (IUCN French Committee), Emerson Clarke (GWEC), Erwin Coolen (The Rich North Sea), Ifereimi Dau (IUCN Oceania Regional Office), Ella Diarra (IUCN Global Business and Biodiversity Programme), Bengt Enge (Klinkby Enge), Thomas Engmose (Klinkby Enge), Melina Gersberg (IUCN French Committee), Sara Goulartt (EDP), Giulia Guidi, Xavier Guillou (European Commission's Directorate-General for Maritime Affairs and Fisheries), Pippa Howard (Fauna & Flora International), Regitze Theill Jensen (Klinkby Enge), Ben Jobson (BirdLife International), Dorien de Jong (Shell), Agathe Jouneau (EDF Renewables), Maxime Kelder (Luminus), Joseph Kiesecker (The Nature Conservancy), Charlotte Laisne (Shell), Adrien Lambrechts (Biotope), Clarisse Leon (IUCN French Committee), Nadine McCormick (IUCN Global Business and Biodiversity Programme), Sonia Mendez (JNCC), Mizuki Murai (IUCN World Heritage Programme), Barbara Nakangu (IUCN Global Programme on Governance and Rights), Eline van Onselen (The Rich North Sea), Jean-Philippe Pagot (EDF Renewables), Christina Pantazi (European Commission's Directorate General Environment), Peter Skjoldager Plantener (Klinkby Enge), Andrew Plumptre (KBA Secretariat), Fabien Quetier (Biotope), Hugo Rainey (Wildlife Conservation Society), Harvey Rich (BirdLife International), Howard Rosenbaum (Wildlife Conservation Society), Raffaele Rossi (Solar Power Europe), Trevor Sandwith (IUCN Global Protected Areas Programme), Marylise Schmid (WindEurope), Peter Shadie (IUCN World Heritage Programme), Hany el Shaer (IUCN Regional Office for West Asia), Noa Steiner (BirdLife International), Pauline Teillac-Deschamps (IUCN Commission on Ecosystem Management), Alexandre Thouzeau (Biotope), Julia Touron (Shell), Anita Tzec (IUCN Global Programme on Governance and Rights), Claire Varret (EDF), Reka Viragos (World Heritage Centre), Olivia White, Laura Williamson (REN21), Piet Wit (IUCN Commission on Ecosystem Management), Stephen Woodley (IUCN World Commission on Protected Areas).

Other contributors
Case study contributors
Leon Bennun (The Biodiversity Consultancy), Etienne Bérille (EDF Renewables), Richard Caldow (SeaMast/Natural England), Erwin Coolen (The Rich North Sea), Sara Goulartt (EDP), W.L. Greene (BHE Renewables), Joseph Kiesecker (The Nature Conservancy), Paul Lochner (CSIR), David Mandaha (CSIR), Mizuki Murai (IUCN World Heritage Programme), Eline van Onselen (The Rich North Sea), Guy Parker (Wychwood Biodiversity Limited), Louis Phipps (Vulture Conservation Foundation), Kate McClellan Press (New York State Energy Research and Development Authority), Fabien Quétier (Biotope), Howard Rosenbaum (Wildlife Conservation Society), Paulette Rush (BHE Renewables), Ed Salter (The Crown Estate), Marylise Schmid (WindEurope), Parikhit Sinha (First Solar), Paul Taylor (Scottish Natural Heritage), Ricardo Tomé (STRIX).

Additional input through workshops
Tony Beck (Shell), Sharon Baruch-Mordo (The Nature Conservancy), Lizzie Crudgington (Bright Green Learning), Leigh Ann Hurt (IUCN Global Business and Biodiversity Programme), Josh Kovacic (Shell), Noelle Kumpel (BirdLife International), Lourdes Lázaro Marín (IUCN Centre for Mediterranean Cooperation), Gillian Martin Mehers (Bright Green Learning), Mireia Peris (BirdLife International), Eugenie Regan (IBAT), Jason Sali (Fauna & Flora International), Lewis Youl (IBAT).

Technical reviewers
Guy Parker (Wychwood Biodiversity Limited)
Martin Perrow (ECON Ecological Consultancy)

Peer reviewers
Tilman Jaeger
Vanessa Tedeschi

1. Renewable energy and biodiversity

Achieving a low-GHG emissions, climate-resilient future, in accordance with the Paris Agreement and the Sustainable Development Goals (SDGs), necessitates rapid, sustained and far-reaching transformations in energy, land-use, urban infrastructure and industrial systems.[1] A crucial component of these transformations is the rapid scaling up of renewable energy generation. However, these technologies themselves pose potential risks to biodiversity and ecosystem services. Expansion must be carefully planned and managed so that environmental benefits are maximised, and damage to nature is minimised.

Land or sea occupancy is one of the most visible impacts for any energy development. For renewables, the land or sea area required per unit energy varies according to conditions and technology, but is typically greater than for natural gas, coal or nuclear energy.[2] Estimates for the USA show broadly comparable land takes for wind, hydropower and solar PV (with wind the highest on average), all also broadly comparable to oil extraction.[3] Geothermal and Concentrated Solar Power require smaller land takes per unit energy, broadly on a par with natural gas and coal, while biofuels require far more (around an order of magnitude greater) than other renewables.[4]

Solar and wind developments can also pose risks to biodiversity. An assessment by Rehbein et al.[5] found that ~17.4% of large-scale (>10 MW) renewable energy facilities comprised of wind, solar (PV) and hydropower globally operate within the boundaries of important conservation areas, including Key Biodiversity Areas (KBAs). Of the total projects, 559 wind power developments and 201 solar (PV) developments, or respectively 9% and 7% of all projects, currently operate within KBAs. Another 162 wind and 152 solar projects are currently under development within KBAs. Research by Kiesecker et al.[6] estimated that over 3.1 million ha of KBAs and ranges of 1,574 threatened and endanger species could be impacted. The expansion of renewable energy into new regions, such as Southeast Asia, is of particular concern, given its global biodiversity significance.

Solar and wind developments, therefore, need to consider not only potential impacts to biodiversity but also associated risks to the continued delivery of ecosystem services, i.e. the benefits and values that people obtain from natural resources. If not carefully managed, such developments can change the supply of, or limit access to, ecosystem services, including provisioning services, such as food and water as well as recreational, cultural (including a sense of place and belonging) and other non-material benefits. In turn, this can impact the livelihoods and well-being of local people, particularly those who heavily depend on such services for their daily sustenance, health, security and jobs. Developments should also not undermine the rights of indigenous peoples and marginalised and disadvantaged groups such as women and youth.

Where these goods and services are compromised, it can generate conflict. A common source of public opposition to wind developments is the visual impact they can have to the landscape and people. For example, permission to develop a wind farm near a World Heritage Site in South Africa, which was recently overturned, would not only have impacted

1 Díaz et al. (2019).
2 McDonald et al. (2009).
3 Ibid.
4 Ibid.
5 Rehbein et al. (2020).
6 Kiesecker et al. (2019).

birds, but also the peoples' view and "sense of place".[7] Such impacts to scenic landscapes can be perceived as highly negative, and are difficult to mitigate. Where significant potential impacts to ecosystem services exist, accounting for and addressing these is essential to the long-term success of renewable energy development.

Furthermore, the increase in renewable energy development will also see an increased demand for the materials that make these technologies possible. These include materials needed for the construction and storage of wind and solar technologies, such as neodymium for permanent magnets in wind turbines, silver for solar cells and cobalt and lithium for storage batteries. The vast majority of materials used in the manufacture of wind and solar facilities are comprised of substances, which can be recycled during site decommissioning and repowering. For example, wind turbines have a recyclability rate of ~90% if all materials are recovered, although turbine blades still pose a challenge in terms of recyclability due to their complexity.[8,9] Note, however, that certain materials, such as copper, lithium, silver and rare earth metals needed to manufacture magnets (such as dysprosium and neodymium), present practical and technological challenges for recycling. Procurement of these materials should ensure they are sustainably sourced.[10] Mining of materials needed for renewable energy development can themselves have significant biodiversity impacts where they are mined in sensitive areas. Without strategic planning, these new threats to biodiversity risk surpassing those averted by climate change mitigation.[11] Typical impacts include direct habitat loss and degradation from the mining footprint and associated infrastructure and indirect impacts associated with induced in-migration into previously inaccessible areas[12]

7 Yeld (2019).
8 European Technology and Innovation Platform on Wind Energy; Sánchez et al. (2014).
9 Welstead et al. (2013).
10 Dominish et al. (2019).
11 Sonter et al. (2020).
12 Ibid.

2. Main considerations for project developers

The relatively large land take for wind and solar highlights the importance of good mitigation practice to help facilitate the transition into renewable energy. Fortunately, the abundance of solar and wind energy means that, unlike other energy sources, there is often flexibility in project siting, allowing the use of already converted or disturbed land or offshore locations away from areas of high sensitivity, including, for example closed landfill sites.[13] Careful siting and planning of wind and solar projects can thus help to avoid many significant impacts and provide broad support for their development. By contrast, large-scale hydropower – while also a low-carbon energy source with comparable land take – is often highly constrained by location, with pervasive impacts upstream and downstream that are difficult to mitigate.

For wind and solar projects, there is often also a potential to maintain or restore biodiversity within the infrastructure matrix. In some cases, this can generate positive biodiversity impacts. For example, solar farms placed in modified habitat can provide biodiversity enhancement opportunities when well designed and managed,[14] while offshore wind farms can create refuges for benthic habitats, fish and marine mammals.[15]

Early planning and site selection

Selecting a site with low biodiversity sensitivity for wind or solar developments, such as on land that is already converted for agricultural or other use, reduces potential impacts and the need for mitigation measures. When the development has no significant residual impacts, positive biodiversity outcomes can be achieved through enhancement of biodiversity on site. Developments on sites with higher biodiversity sensitivity are likely to have more demanding and expensive mitigation requirements. To achieve net gain goals, they may require offsets, which frequently pose practical and reputational challenges.

Early planning informs **avoidance through site selection**, which is the most effective mitigation measure available to renewable energy developers. At this early stage, it is feasible to make changes to infrastructure siting and operational planning, with the greatest potential for reducing project risks and requirements for further mitigation. A key strategy to reduce project risks focuses on avoiding siting solar or wind projects in areas of high biodiversity, including protected areas and conserved areas, World Heritage Sites or other areas of high biodiversity significance, such as Key Biodiversity Areas. In addition, projects need to consider potential impacts to ecosystem services and the diverse societal rights, and only proceed after free prior and informed consent (FPIC) of the affected communities.

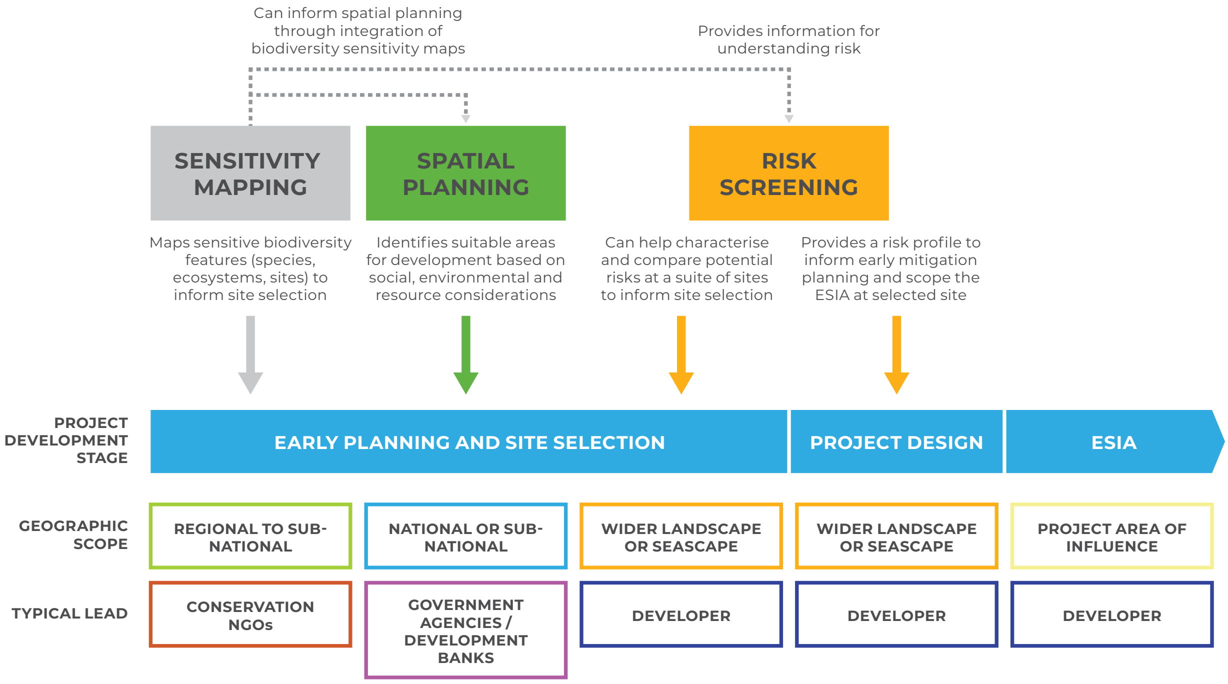
Ideally, effective avoidance through site selection will be informed by existing spatial plans developed before permitting starts. These are usually developed by government agencies, sometimes working with development banks, including through Strategic Environmental Assessments that identify suitable areas for development with biodiversity as

13 Szabó et al. (2017).
14 Montag et al. (2016).
15 Coates et al. (2014); Hammar et al. (2015); Krone et al. (2013); Lindeboom et al. (2011).

a consideration. Given the potentially large energy contribution and space requirements of renewable technologies, such a proactive strategic spatial assessment is important to avoid undermining biodiversity conservation goals.

In the absence of specific guidance from policy makers, biodiversity **sensitivity maps** can help identify sites to avoid. Further **risk screening** can then be undertaken to support site characterisation and help assess biodiversity sensitivities for one or more potential project sites (Figure 1).

Fig. 1 Spatial planning, sensitivity mapping and risk screening in the early planning process



Note: Outputs from sensitivity mapping and spatial planning help developers identify suitable areas for development as part of early planning and site selection. Spatial planning may be informed by, or a component of, Strategic Environmental Assessment (see section 3.2). Early risk screening then provides an effective tool to compare potential sites. Risk screening is also useful as part of project design, to help identify early mitigation options at the selected site and scope the ESIA to focus on key risks.

Renewable energy development within protected areas

Renewable energy developments that are incompatible with the objectives or the conservation outcomes of a protected or conserved area (for example, as they cause environmental and/or social damage) should be avoided, unless these can be mitigated to the point of not having any residual impacts. This includes developments that are located outside of a protected area, the impacts of which may reach the conservation values within that area, for example, where development of a wind farm could impact a threatened population of raptors residing in the protected area.

The use of biodiversity offsets to address residual impacts within protected areas is considered incompatible with the area's management objectives. For the Outstanding Universal Value, which is recognised in World Heritage Sites, there is by definition no opportunity to offset such impacts.

Most industrial scale activities are therefore incompatible in protected areas, as the likelihood of their impacts on the objectives of the protected area would be very high. However, small- and micro-scale developments may be acceptable under certain conditions, for example in instances where solar power systems are needed to meet the energy needs of the protected area, such as powering electric fencing, visitor centres or parking (thus also preventing the need for larger scale energy infrastructure).

Therefore, the approach should be commensurate with the following scale of activities and associated biodiversity risks:

- Large-scale, industrial renewable developments likely to have impacts that cannot be fully mitigated: such development should in all circumstances considered a 'no go'.
- Intermediate, non-industrial scale: developments, serving local needs: assess on a case-by-case basis through rigorous ESIA, and early and comprehensive consideration of site alternatives. Approvals would be subject to clear demonstration of effective mitigation to reduce any impacts to non-significant levels, and a comprehensive monitoring and evaluation plan.
- Small and micro-scale sites, serving local needs: assess on a case-by-case basis.

For World Heritage sites, given their globally significant value, only small to micro-scale could be considered compatible, subject to a case-by-case assessment.

In all cases, developers must work closely with national, local and other relevant authorities to assess the legality and feasibility of operating within or close to a protected area or a conserved area.

Working with stakeholders

Constructive engagement with stakeholders, especially the diverse rights holders, is vital for helping to identify and effectively manage biodiversity risks. Having a structured approach to stakeholder engagement is considered good environmental practice by various governance standards including the IFC Performance Standards, the OECD Guideline for Multinational Enterprises and the UN Global Compact. Stakeholder involvement should guide a developer in identifying risks and confirm the feasibility of mitigation measures, as well as prove the opportunity to raise any concerns.

Stakeholder engagement is rarely a straightforward or simple process. It requires a degree of up-front effort and helps lay the foundation for constructive relationships and for creating shared values. Where adequately integrated into early project planning, it can save significant time and resources later on with issues, such as permitting delays, protests, complaints and lawsuits.[16]

A first step is to identify the appropriate level and type of engagement with stakeholders through a mapping exercise. This should take place as part of early planning, and inform the development of a stakeholder engagement plan. A wide variety of potential stakeholders may be of importance, depending on the nature of the company or project. Biodiversity-relevant stakeholders typically include the following: national government, intergovernmental agencies and organisations; national and international environmental NGOs; biodiversity specialists; local communities, including the diverse rights holders, indigenous peoples and natural resource users; financial institutions; and universities or research institutions, including IUCN Specialist Groups.

After stakeholder identification, communication and effective engagement with the identified stakeholders follows and continues throughout the project lifecycle. Early disclosure and regular reporting help majority stakeholders understand the project risks, impacts and opportunities, to jointly produce appropriate solutions. To maintain a constructive relationship, it is important for stakeholder engagement to move beyond mere process and actively engage in shaping the development, implementation and stewardship of the natural resources as well as their participation in the decision-making process. Those views may be diverse, so project

16 Pollard & Bennun (2016).

responses may often need to be carefully considered and explained. Establishment of grievance mechanisms may be set up to provide stakeholders with the opportunity to raise concerns which were considered to not have been adequately dealt with through the consultation process.

Effective stakeholder engagement requires commitment of capacity and resources from the project, as well as a willingness to listen, learn and adapt. It can provide multiple opportunities, which can potentially mitigate impacts and manage risks to the company. Developing transparent and constructive relationships with stakeholders can help:

- Identify priority biodiversity features and ecosystem services for consideration during early screening, impact assessment and mitigation planning;
- Understand the status of important biodiversity features, including their value to local stakeholders (as part of baseline studies);
- Enhance transparency and improve reputation, and thus the social license to operate;
- Identify appropriate actions to mitigate impacts on biodiversity including conservation goals (e.g. through systematic conservation planning); and
- Build partnerships for implementation of mitigation actions, including offsets.

Working with Indigenous Peoples

Indigenous peoples and local communities hold and manage a significant part of the Earth's most biodiverse regions and play a vital role in conserving lands, seas and resources. They cultivate an intrinsic and holistic relationship with their natural environments, and have developed and often maintain local and indigenous knowledge systems and management practices that contribute to biodiversity conservation and sustainable use of natural resources.

Developers should consult and cooperate in good faith with indigenous peoples to obtain their Free Prior Informed Consent (FPIC) on any project affecting their lands, territories and resources that are used by these rights holders.

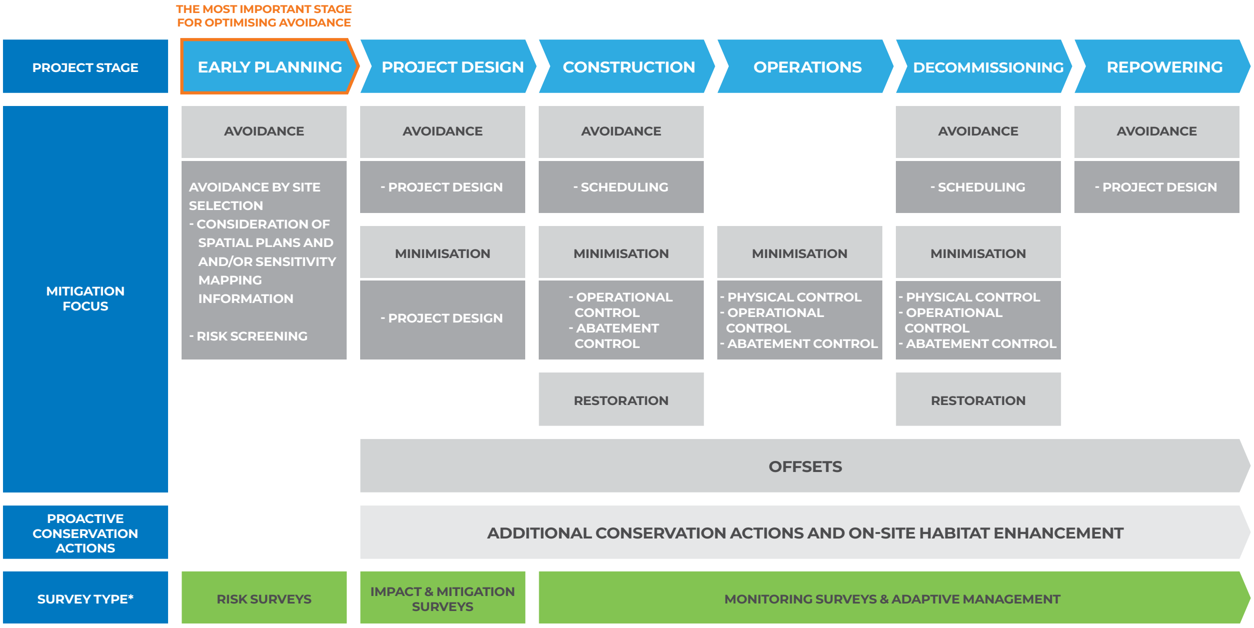
Developers, in conjunction with indigenous peoples, will need to work with the affected communities to identify and secure their: i) sacred or cultural heritage sites and values; and ii) rights to access, use, benefit from natural resources for the guarantee of their subsistence of present and future livelihoods within the project's area of influence. Appropriate actions should be undertaken to avoid or remedy impacts, as well as guarantee the protection of rights of access to such sites or values. Where indigenous peoples' sacred or cultural heritage sites and values may be impacted, developers will need to seek FPIC from indigenous peoples.

In support of the rights of indigenous peoples, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) is the most comprehensive international instrument on the rights of indigenous peoples. It establishes a universal framework of minimum standards for the survival, dignity and well-being of indigenous peoples of the world and elaborates on existing human rights standards and fundamental freedoms as they apply to the specific situation of indigenous peoples. UNDRIP also calls for the right of free, prior and informed consent.

The mitigation hierarchy

The mitigation hierarchy provides developers with a logical framework to address the negative impacts of development on biodiversity and ecosystem services. It is applicable to projects in any sector,

Fig.2 Applying the mitigation hierarchy across the project development cycle, including mitigation components relevant at each stage



* The type of surveys needed to assess and monitor biodiversity risk, impacts and mitigation.

including renewable energy, and is based on the sequential and iterative application of four actions:[17] avoid, minimise, restore and offset (Figure 2). The mitigation hierarchy should be applied to direct, indirect and cumulative impacts.

Implementing the mitigation hierarchy[18] is an iterative process – not a linear one – that involves feedback and adaptive management. Avoidance and minimisation measures prevent or reduce impacts, while restoration and offset measures remediate impacts that have already happened. Preventive actions are preferable from an economic, social and ecological perspective for lenders, regulators and other stakeholders. Compared to avoidance and minimisation, restoration and offset measures tend to have less certainty of success and come at a higher cost to the developer.

Application of the mitigation hierarchy in full implies an overall target, or goal, for the biodiversity and ecosystem services outcomes associated with a project, such as No Net Loss (NNL) or Net Gain. To be able to assess against such outcomes, the mitigation hierarchy steps will need to provide a measurable reduction to the overall project impact.

The mitigation hierarchy is comprised of a sequence of four steps:

- **Avoidance** is the first and most important step of the mitigation hierarchy. It is based on measures taken to anticipate and prevent the creation of impacts. For avoidance to be effective, biodiversity risks need to be identified early in the project planning stages, or opportunities will be missed. Effective avoidance can occur through site selection (to ensure projects are not located in areas of high risk, project design (to locate infrastructure and select designs that avoid impacts) and scheduling (to ensure the timing of project activities is favourable for biodiversity).
- **Minimisation** refers to measures taken to reduce the duration, intensity and/or extent of impacts that cannot be completely avoided, as far as is practically feasible. Potential minimisation measures can be identified during early

17 Cross Sector Biodiversity Initiative (CSBI) (2013); The Biodiversity Consultancy (TBC) (2015). These Guidelines follow CSBI's definition of mitigation hierarchy. To note, there are alternative approaches to implementing the mitigation hierarchy to achieve the same result, such as that detailed in May (2017), which advocates a five-step approach tied to the decision gates for wind farm development: 1) avoid when planning, 2) minimise while designing, 3) reduce at construction, 4) compensate during operation, and 5) restore as part of decommissioning.

18 CSBI (2013).

planning, and when developing design alternatives to be considered. Measures to minimise impacts can be applied throughout the project cycle, from design through construction, operations and closure, decommissioning and repowering.

Minimisation and avoidance are closely related, although minimisation does not provide the same level of mitigation certainty that avoidance does. Whether an action can be considered as avoidance or minimisation is a matter of circumstances and scale. For example, relocating a planned wind farm to completely avoid an important migratory corridor for birds could be considered avoidance through site selection. Shutting down turbines during periods of high bird activity to reduce the number of bird collisions with turbine blades would be considered minimisation.

- **Restoration:** There are many terms linked to restoration, including rehabilitation, reclamation and remediation. In the context of the mitigation hierarchy, restoration refers to measures that aim to repair specific biodiversity features or ecosystem services damaged by project impacts that could not be completely avoided or minimised. This differs from general rehabilitation, which may not set out to restore the original biodiversity or the biodiversity components on which ecosystem services depend. As a mitigation hierarchy step, restoration is also distinct from interventions to offset project impacts by restoring biodiversity elsewhere (see next bullet). Restoration is typically undertaken either during construction (to address impacts from temporary facilities such as laydown areas or roads), or towards the end of a project as part of decommissioning and/or repowering.
- **Offsets** are measures taken to compensate for significant adverse residual impacts that cannot be avoided, minimised or restored. Offsets should only be considered as a last resort to address residual impacts on biodiversity, and only after all avoidance, minimisation and restoration options have been exhausted. Offsets aim to achieve a measurable conservation outcome for the biodiversity features they target.[19]
Offsets involve positive conservation interventions to generate biodiversity gains either through **avoided loss** (addressing threats to prevent predicted biodiversity loss) or **restoration** (for example, improving the quality of degraded habitat). Government regulators and lenders increasingly require biodiversity offsets to address residual impacts and achieve no net loss or net gain outcomes.[20] A growing number of businesses are also adopting voluntary biodiversity commitments that also aim to achieve no net loss or net gain outcomes.[21]

  Offsets can be complex and expensive to implement. Fortunately, wind and solar projects can usually avoid the need for offsets through careful siting and effective minimisation measures that reduce residual impacts to negligible levels. However, if necessary, offsets should produce measurable gains for the biodiversity features they target.

Other conservation actions that can be undertaken independently of, and over and above the mitigation hierarchy steps, to enhance and restore biodiversity are termed Proactive Conservation Actions (PCA).

Biodiversity offsets often involve working with people who live in and around the offset area, and who depend on or value ecosystem services from the landscape. Well-planned offsets can enhance delivery of ecosystem services to local people while delivering biodiversity objectives. However, poorly-planned offsets may restrict resource access or negatively impact delivery of ecosystem services.[22] In turn, this can affect the well-being of vulnerable people and lead to conflict. When planning a biodiversity offset, it is important to take into consideration the Rights-based Approaches to conservation (RBA), which focus on the integration of rights, norms, standards, and principles into policy, planning, implementation, and outcomes assessment to help ensure that conservation practice respect

19 IUCN WCC (2016).
20 GIBOP (2020).
21 de Silva et al. (2019); Rainey et al. (2014).
22 Bidaud et al. (2018).

rights in all cases, and supports their further realisation where possible.[23]

Renewable energy projects have the opportunity to **enhance** the condition of habitat and associated biodiversity, and deliver positive biodiversity outcomes within the project area, particularly when developed on previously degraded areas such as agricultural land. In the UK, for example solar projects on agricultural or other brownfield sites have been found to enhance the diversity of birds, plants and invertebrates.[24] Well-managed sites can also act as a refuge for some species from the surrounding homogenous agricultural landscape.

Offshore wind farm developments can play a role in enhancing seabed habitat and restoring previously degraded ecosystems. For example, in the North Sea, offshore wind farms have been designed to provide artificial reef habitat and support restoration of flat oyster beds.[25]

On-site habitat enhancement can also provide benefits to the project itself through nature-based solutions to technical issues. For example, revegetation with naturally occurring species within solar developments can enhance biodiversity as well as control dust, thereby reducing the need to use water to clean solar panels,[26] while the creation of reef substrate on offshore wind farm foundations can enhance biodiversity whilst reducing the negative effects of scouring.[27]

23 Campese et al. (2009).

24 Montag et al. (2016). Other key references: BSG Ecology (2014); Beatty et al. (2017); Harrison et al. (2016); Hernandez et al. (2014); Jenkins et al. (2015); Visser et al. (2019).

25 Kamermans et al. (2018); Vrooman et al. (2018).

26 Beatty et al. (2017); Macknick et al. (2013).

27 Lengkeek et al. (2017); Wilson & Elliott (2009).

3. Overarching principles for good practice mitigation

Experience in mitigating biodiversity impacts across a variety of sectors suggests a number of overarching principles for good practice mitigation that apply equally to renewable (Table 1). Following these principles can facilitate renewable energy expansion, while ensuring that biodiversity and ecosystem service risks are identified, accounted for, and effectively managed.

Table 1 Overarching principles for good practice mitigation

Overarching principles	Specific aspects
1. Consider biodiversity and landscape-scale risks at the earliest stage of project planning	• Strategic-level planning exercises at national or regional scale that identify suitable sites for wind and solar energy development in areas of low biodiversity sensitivity are invaluable in de-risking development. Where strategic assessments do not yet exist, it may be beneficial for developers to encourage the production of such assessments, facilitate them with the relevant and appropriate stakeholders, or undertake their own assessment to inform project siting. • Early identification of risks to biodiversity, through screening as part of project planning, is critical to avoiding significant impacts. In areas of low biodiversity sensitivity, mitigation is likely to be relatively straightforward and inexpensive. By contrast, in areas of high biodiversity sensitivity, mitigation options may be limited, costly, unpredictable and, in some cases, unattainable. • Early risk screening should identify important biodiversity features and potential project impacts at suitably large, ecologically-coherent scales, and should consider seasonality. All elements of project infrastructure and impact types (direct, indirect, cumulative) should also be considered.
2. Apply the mitigation hierarchy rigorously	• The mitigation hierarchy is a central element of good practice for managing and mitigating impacts on biodiversity and ecosystem services. It prioritises prevention over remediation through rigorous application of the mitigation hierarchy to avoid and minimise to the fullest extent feasible. Applying the mitigation hierarchy is an iterative process – it may often be necessary to revisit the steps more than once, for example reviewing project design to ensure that residual impacts are driven down to as low a level as possible. Offsets should only be considered as a last resort to address residual impacts, and only after all avoidance, minimisation and restoration options have been exhausted. • Wind and solar energy developments often provide opportunities to go beyond traditional mitigation practice and create further/additional biodiversity benefits, for example through on-site habitat enhancement. Such proactive conservation actions (PCAs) can help amplify the positive environmental impacts of renewable energy and build stakeholder support for scaling up these technologies.

3. Recognise peoples' rights and needs in planning biodiversity mitigation	• Environmental and social issues need to be considered together, as indigenous peoples and local communities may derive many benefits from their environment. A project's approach to biodiversity mitigation (and especially biodiversity offsets) needs to ensure that the livelihoods and well-being of indigenous peoples and local communities are not negatively impacted. In addition, all development should aim and ensure projects result in just outcomes, where those with the least prospects are not marginalised. Not doing so may undermine a project's social goals and the effectiveness of conservation interventions, which rarely succeed without the support and positive engagement of local communities. • Financial institutions will be sensitive to renewable energy projects where there is potential for adverse impacts on local communities, and where indigenous people also have heighted reputational risk. In some cases, projects may need to provide alternative livelihood opportunities or compensation.
4. Carry out the right surveys to understand risks	• Field surveys are needed to validate desk-based findings and identify any additional risks, even in areas identified as lower-sensitivity. Risks may appear lower as a result of data deficiency; therefore, it is important to understand the quality and reliability of the data supporting the assessment. As biodiversity (and associated social) risk increases, so does the level of certainty required for assessment and monitoring. • For projects planning to operate in highly sensitivity areas, comprehensive surveys will be needed to assess both biodiversity and social risk (including feasibility of offsets), plan mitigation and monitor the effectiveness of mitigation measures. • Scoping of field surveys needs to consider the appropriate geographic and temporal scales for priority biodiversity features and types of impacts, including direct, indirect and cumulative. Open and transparent communication and sharing of monitoring results not only help developers comply with regulations – it is also increasingly recognised as good practice that can help generate credibility and support for their project with stakeholders and help contribute to wider conservation efforts.

4. Setting appropriate biodiversity goals

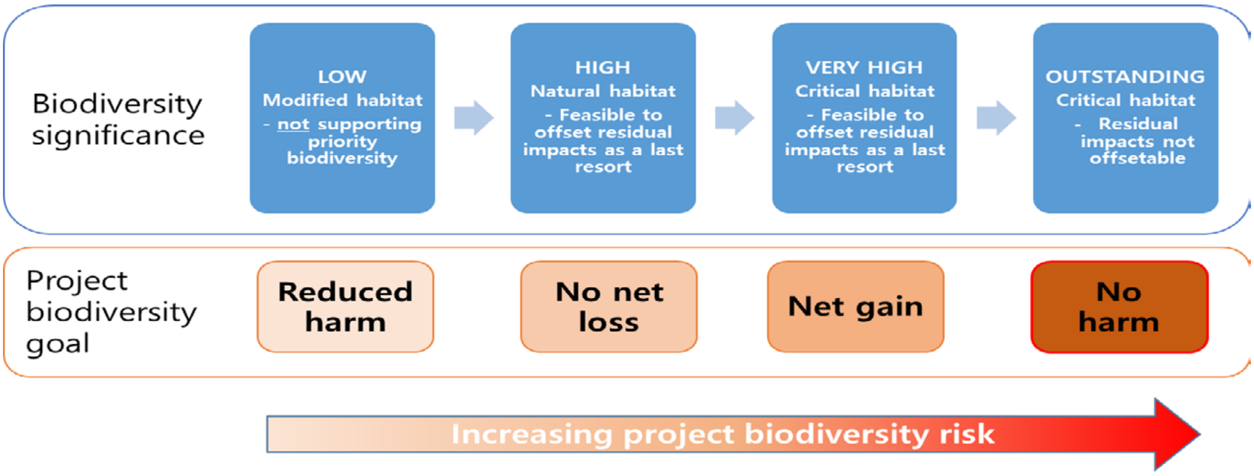
Full application of the mitigation hierarchy implies a measurable goal of at least 'no net loss', but preferably a 'net gain' of targeted biodiversity features[28]:

- 'No net loss' is defined as the point at which project-related impacts are balanced by mitigation hierarchy measures, so that no losses remain.
- 'Net gain' is defined as the point at which project-related impacts are outweighed by measures taken according to the mitigation hierarchy, resulting in a net gain of the relevant biodiversity features. This is also referred to as Net Positive Impact.

The biodiversity goal for a project can be defined based on the biodiversity significance of the area within which it intends to operate (Figure 3). Otherwise the overall goal may depend on the requirements and views of regulators, financers and stakeholders. For example, the goal of 'do no harm' is also used in some frameworks such as in the EU Taxonomy for sustainable financing. Goals may also depend on the biodiversity significance of the area. IFC's Performance Standard 6, a widely applied standard, requires a no net loss to Natural Habitat[29] and a net gain for projects operating in Critical Habitat.[30] In some cases, regulators may set sectoral requirements for impact compensation so that projects contribute to achieving national conservation targets.

Measuring and tracking progress towards biodiversity and ecosystem service goals requires a framework and process for accounting for the losses and gains at each stage of the mitigation hierarchy. Where residual impacts remain, offsets will be required to meet goals.

Fig. 3 Example of how an appropriate biodiversity goal for a project can be defined based on the biodiversity significance of the area within which it intends to operate



Note: This is a schematic example; the appropriate goal will be project specific, and depend on the requirements and views of regulators, financers and stakeholders

28 Biodiversity features can include both species and ecosystems, and are often referred to as 'priority biodiversity features'.

29 IFC (2012) defines Natural Habitats as areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition.

30 In IFC's Performance Standard 6 (2012), features of high biodiversity value (as determined through an assessment of species, ecosystems and ecological processes against a series of quantitative and qualitative criteria) are termed 'Critical Habitat'. Internationally recognised and legally protected areas may also qualify as Critical Habitat. The term 'critical habitat' is also used (and defined differently) in the U.S. Endangered Species Act.

5. Summary of project-specific impacts and mitigation approaches

Impacts

Poorly sited projects, together with associated infrastructure such as access roads and powerlines, can lead to significant loss of natural habitat from the footprint area. A large concentration of wind or solar farms in combination with other developments can increase habitat fragmentation, create barriers for species movement and potentially cause significant cumulative impacts to species' populations. The water demands of solar plants can put strain on local water resources and create ecological change. Of particular concern are developments that are placed in or near to areas recognised for their conservation significance, including sensitive breeding areas, important species migration routes, Key Biodiversity Areas and protected areas. Developments that are incompatible with the objectives or the conservation outcomes of a protected or conserved area must be avoided.

Wind and solar projects can impact species directly. Some birds are at risk from collision with wind turbines or with associated transmission lines, potentially leading to high fatality rates across a wide range of vulnerable species groups including vultures, bustards, cranes and many migratory species. Electrocution due to poorly designed low- and medium-voltage lines continues to pose a significant risk to many birds, particularly threatened raptors.

Bats also face collision risk, although the response of bats to turbines differs widely across species and locations. Studies from the northern temperate zone indicate a large variety of bats are at risk, especially species adapted for foraging insects in open spaces. Without appropriate mitigation in place, turbine collisions can lead to significant declines of local bat populations.

In addition to birds and bats, species vulnerable to offshore wind developments include marine mammals, particularly when exposed to high noise during construction, sea turtles and some fish species. Mammals and sea turtles face risks of collision with associated vessels, while habitat alteration can affect species of the seafloor.

Mitigation approaches

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.

Effective avoidance and minimisation during project construction often require a good understanding of species behaviour, for example to avoid construction during sensitive breeding and migratory periods. For offshore developments, noise impacts can be minimised by implementing strict construction protocols that include acoustic monitoring, soft starts and acoustic deterrent devices.

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.

Key mitigation approaches for wind and solar are summarised in Table 2.

Table 2 Summary of key mitigation approaches during project phases

Project phase	Mitigation Hierarchy	Mitigation approaches include:	Solar	Onshore wind	Offshore wind
Project design phase	Avoidance and Minimisation	Micro-siting: changing the layout of project infrastructure to avoid sensitive areas	X	X	X
		Re-routing, marking or burying powerlines to avoid collision risks and barrier effects	X	X	X
		Scheduling: changing the timing of survey activities during site characterisation to avoid sensitive periods	X	X	X
		Selecting or designing project components to avoid or reduce impacts such as quiet foundations			X
Construction phase	Avoidance	Scheduling: changing the timing of construction activities to avoid disturbing biodiversity during sensitive periods	X	X	X
	Minimisation	Abatement controls to reduce emissions and pollutants (noise, erosion, waste) created during construction	X	X	X
		Operational controls: exclusion fencing around sensitive areas, designated machinery and lay-down areas	X	X	X
		Operational controls: controlling construction/installation vessel movements and reduce lighting			X
	Restoration and rehabilitation	Revegetation of temporary use areas as they come available, using topsoil and indigenous plants from the site	X	X	X
		Restoring coastal intertidal habitats disturbed during export cable installation			X

Operational phase	Minimisation	Physical controls: modifications to solar technology, implementing dry or hybrid cooling systems	X	X	X
Operational phase	Minimisation	Physical controls: shutdown on demand to minimise collision risk	X	X	X
Operational phase	Minimisation	Physical controls: installation of Bird Flight Diverters on transmission lines	X	X	X
Operational phase	Minimisation	Abatement controls: restricting vehicle and vessel movements when sensitive species are present	X	X	X
Operational phase	Minimisation	Operational controls to make sites less suitable for sensitive species: habitat modification, removal of carcasses		X	X
End-of-life	Avoidance	Scheduling: changing the timing of decommissioning activities to avoid disturbing biodiversity during sensitive periods (e.g. during breeding seasons)	X	X	X
End-of-life	Minimisation	Abatement controls to reduce emissions and pollutants (e.g. noise, erosion, waste) created during decommissioning	X	X	X
End-of-life	Minimisation	Operational controls to manage and regulate contractor activity (e.g. exclusion fencing around sensitive areas, designated machinery and lay-down areas, vessel speeds)	X	X	X
End-of-life	Restoration and rehabilitation	Reinstatement of original vegetation, as far as feasible, following decommissioning	X	X	X
End-of-life	Restoration and rehabilitation	Leaving infrastructure in place if there is a biodiversity/ecosystem services benefit such as the reef effect associated with foundation/ scour protection			X

6. How to use the Guidelines

The full report *Mitigating biodiversity impacts associated with solar and wind energy development* is available here: https://doi.org/fw2c.

Section 1 provides an overview of the expected transformation in the energy sector due to the growth in renewable energy sources, the potential implications for biodiversity and ecosystem services and an introduction to the guidelines.

Section 2 introduces and explains the mitigation hierarchy, which provides the overall framework for presenting good practice approaches to managing the impacts of wind and solar developments on biodiversity and ecosystem services.

Section 3 explains the importance of early project planning, and the tools and approaches that can be used to inform the first step (avoidance) of the mitigation hierarchy. This applies to all solar and wind technologies.

Section 4, Section 5 and Section 6 examine potential impacts and mitigation approaches for each of the technology types: solar (both PV and CSP), onshore wind and offshore wind.

Section 7, Section 8, Section 9 and Section 10 cover issues that are general to all the technology types. Section 7 specifically outlines the principles and practical considerations for designing and implementing offsets that compensate for residual project impacts (after rigorous application of avoidance, minimisation and restoration in project design).

Section 8 explains considerations and good practice approaches for assessment, monitoring and adaptive management, and signposts more detailed guidance relevant to specific technologies.

Section 9 provides a summary of key project outputs required for aligning with good biodiversity management throughout the project lifecycle, including for the Environmental and Social Impacts Assessment (ESIA), and key additional sources of guidance and information for each of these.

Section 10 reviews the issue of supply chain stewardship, and how projects can reduce the embedded impacts of materials.

A database with additional tools and resources to supplement information presented in each section is provided in Annex 1. This resource will be updated based on the latest evidence and information.

Annex 2 presents 33 case studies to help illustrate the main points and highlight suitable mitigation approaches.

Finally, Annex 3 provides a list of species groups that are known to be particularly sensitive to solar and wind developments.

Finally, note that although the scope of the guidelines is global, specific project conditions and requirements (from permitting authorities or financers) can vary between locations. Of particular relevance are the requirements for undertaking ESIAs, which vary by country. Hence, this guidance document should be interpreted with reference to the local environmental, social and legislative context. Specialist input and advice will be needed to understand and effectively manage biodiversity and ecosystem services risks related to each development.

References

Beatty, B., Macknick, J., McCall, J., Braus, G. and Buckner, D. (2017). *Native Vegetation Performance under a Solar PV Array at the National Wind Technology Center* (Technical Report No. NREL/TP-1900-66218). Colorado, United States: National Renewable Energy Laboratory (NREL). National Renewable Energy Laboratory (NREL). Available at: https://www.nrel.gov/docs/fy17osti/66218.pdf

Bidaud, C., Schreckenberg, K. and Jones, J.P.G. (2018). 'The local costs of biodiversity offsets: Comparing standards, policy and practice'. *Land Use Policy* 77: 43–50. Available at: https://doi.org/10.1016/j.landusepol.2018.05.003

BSG Ecology (2014). 'BSG Ecology Bat Reasearch In 2014'. BSG Ecology [blogpost], 6 June 2014. Available at: https://www.bsg-ecology.com/bsg-ecology-bat-research-2014/

Campese, J., Center for International Forestry Research, and International Union for Conservation of Nature (eds.). (2009). *Rights-based approaches: exploring issues and opportunities for conservation*. Bogor, Indonesia: Center for International Forestry Research.

Coates, D.A., Deschutter, Y., Vincx, M. and Vanaverbeke, J. (2014). 'Enrichment and shifts in macrobenthic assemblages in an offshore wind farm area in the Belgian part of the North Sea'. *Marine Environmental Research* 95: 1–12. Available at: https://doi.org/10.1016/j.marenvres.2013.12.008

Cross Sector Biodiversity Initiative (CSBI) (2013). *CSBI Timeline Tool. A Tool for Aligning Timelines for Project Execution, Biodiversity Management and Financing*. Available at: http://www.csbi.org.uk/wpcontent/uploads/2015/06/Timeline_Illustrator_V03-011.jpg

de Silva, G.C. de S., Regan, E.C., Pollard, E.H.B. and Addison, P.F.E.A. (2019). 'The evolution of corporate no net loss and net positive impact biodiversity commitments: Understanding appetite and addressing challenges.'. *Business Strategy and the Environment* 1–15. Available at: https://doi.org/10.1002/bse.2379

Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Agard, J., Arneth, A., Balvanera, P.,Brauman, K.A., Butchart, S.H.M., Chan, K.M.A., Garibaldi, L.A. (2019). 'Pervasive human-driven decline of life on Earth points to the need for transformative change'. *Science* 366(6471). Available at: https://doi.org/10.1126/science.aax3100

Dominish, E., Florin, N. and Teske, S. (2019*). Responsible Minerals Sourcing for Renewable Energy*. Available at: https://earthworks.org/cms/assets/uploads/2019/04/MCEC_UTS_Report_lowres-1.pdf

European Technology and Innovation Platform on Wind Energy (ETIPWind®) (n.d.). 'How wind is going circular – blade recycling.'. Available at: https://etipwind.eu/files/reports/ETIPWind-How-wind-is-going-circular-blade-recycling.pdf

Global Inventory of Biodiversity Offset Policies (GIBOP) (2020). 'World View – A Snapshot of National Biodiversity Offset Policies'. Available at: https://portals.iucn.org/offsetpolicy/ (Accessed: 1 July 2020)

Hammar, L., Perry, D. and Gullström, M. (2015). 'Offshore wind power for marine conservation'. *Open Journal of Marine Science* 6(1): 66–78. Available at: https://doi.org/10.4236/ojms.2016.61007

Hernandez, R.R., Easter, S.B., Murphy-Mariscal, M.L., Maestre, F.T., Tavassoli, M., Allen, E.B., Barrows, C.W., Belnap, J., Ochoa-Hueso, R., Ravi, S., Allen, M.F. (2014). 'Environmental impacts of utility-scale solar energy'. *Renewable and Sustainable Energy Reviews* 29: 766–779. Available at: https://doi.org/10.1016/j.rser.2013.08.041

Hernandez, R.R., Hoffacker, M.K. and Field, C.B. (2014). 'Land-Use Efficiency of Big Solar'. *Environmental Science & Technology* 48(2): 1315-1323. Available at: https://doi.org/10.1021/es4043726

IUCN World Conservation Congress (WCC) (2012a). WCC-2012-Rec-172-EN Development of renewable energy and biodiversity conservation. IUCN [website]. Available at: https://portals.iucn.org/library/node/44139

____ (2016). *WCC-2016-Res-059-EN IUCN Policy on Biodiversity Offsets*. IUCN[website].https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2016_RES_059_EN.pdf Available at: https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2016_RES_059_EN.pdf

Jenkins, A., van Rooyen, C. S., Smallie, J.J., Diamond, M., Smit-Robinson, H.A. and Ralston, S. (2015). *Birds and Wind-Energy Best-Practice Guidelines. Best-Practice Guidelines for assessing and monitoring the impact of wind energy facilities on birds in southern Africa* [Third Edition]. BirdLife South Africa and the Endangered Wildlife Trust. BirdLife South Africa and the Endangered Wildlife Trust [website]. Available at: https://www.birdlife.org.za/wp-content/uploads/2020/03/BLSA-Guidelines-Birds-and-Wind.pdf

Kamermans, P., Walles, B., Kraan, M., van Duren, L., Kleissen, F., van der Have, T., Smaal, A. and Poelman, M. (2018). 'Offshore Wind Farms as Potential Locations for Flat Oyster (Ostrea edulis) Restoration in the Dutch North Sea'. *Sustainability* 10(11): 3942. Available at: https://doi.org/10.3390/su10113942

Kiesecker, J.M., Baruch-Mordo, S., Kennedy, C.M., Oakleaf, J.R., Baccini, A. and Griscom, B.W. (2019). 'Hitting the Target but Missing the Mark: Unintended Environmental Consequences of the Paris Climate Agreement'. *Frontiers in Environmental Science*.

Krone, R., Gutow, L., Joschko, T.J. and Schröder, A. (2013). 'Epifauna dynamics at an offshore foundation – Implications of future wind power farming in the North Sea'. *Marine Environmental Research* 85(2): 1–12. Available at: https://doi.org/10.1016/j.marenvres.2012.12.004

Lengkeek, W., Didderen, K., Teunis, M., Driessen, F., Coolen, J.W.P., Bos, O.G., Vergouwen, S.A., Raaijmakers, T., de Vries, M.B. and van Koningsveld, M. (2017). 'Eco-friendly design of scour protection: potential enhancement of ecological functioning in offshore wind farms: Towards an implementation guide and experimental set-up'. *Deltares, Wageningen University & Research, Bureau Waardenburg*. Available at: https://research.wur.nl/en/publications/eco-friendly-design-of-scour-protection-potential-enhancement-of- (Accessed: 15 July 2020)

Lindeboom, H.J., Kouwenhoven, H.J., Bergman, M.J.N., Bouma, S., Brasseur, S.M.J.M., Daan, R., van Hal, R., Lambers, R.H.R., ter Hofstede, R., Leopold, M.F., Scheidat, M. (2011). 'Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation'. *Environmental Research Letters* 6(3): 035101. Available at: https://doi.org/10.1088/1748-9326/6/3/035101

Macknick, Jordan, Beatty, B. and Hill, G. (2013). *Overview of Opportunities for Co-Location of Solar Energy Technologies and Vegetation* (No. NREL/TP-6A20-60240). Golden, CO, USA: National Renewable Energy Laboratory (NREL). National Renewable Energy Laboratory (NREL) [website]. Available at: 10.2172/1115798

McDonald, R.I., Fargione, J., Kiesecker, J.M., Miller, W.M. and Powell, J. (2009). 'Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America'. *PLoS ONE* 4(8): e6802. Availsable at: https://doi.org/10.1371/journal.pone.0006802

Montag, H., Parker, D.G. and Clarkson, T. (2016). 'The Effects of Solar Farms on Local Biodiversity: a comparative study'. *Clarkson and Woods and Wychwood Biodiversity*. Available at: https://www.solar-trade.org.uk/wp-content/uploads/2016/04/The-effects-of-solar-farms-on-local-biodiversity-study.pdf

Pollard, E. and Bennun, L. (2016). 'Who are Biodiversity and Ecosystem Services Stakeholders?'. Society of Petroleum Engineers (SPE) *International Conference and Exhibition on Health, Safety, Security, Environment, and Social Responsibility*, 11-13 April 2016. Presented at the Stavanger, Norway. Stavanger, Norway: Society of Petroleum Engineers. Available at: https://doi.org/10.2118/179458-MS

Rehbein, J., Watson, J., Lane, J., Sonter, L., Venter, O., Atkinson, S. and Allan, J. (2020). 'Renewable energy development threatens many globally important biodiversity areas'. *Global Change Biology* 26(5): 3040–3051. Available at: https://doi.org/10.1111/gcb.15067

Sánchez, R.G., Pehlken, A. and Lewandowski, M. (2014). 'On the sustainability of wind energy regarding material usage.'. *Acta Technica Corviniensis-Bulletin of Engineering*. 7(1): 72. Available at: http://acta.fih.upt.ro/pdf/2014-1/ACTA-2014-1-06.pdf

Sonter, L.J., Ali, S.H. and Watson, J.E.M. (2018). 'Mining and biodiversity: key issues and research needs in conservation science'. *Proceedings of the Royal Society B*: Biological Sciences 285(1892): 20181926. Available at: https://doi.org/10.1098/rspb.2018.1926

Sonter, L.J., Dade, M.C., Watson, J.E.M. and Valenta, R.K. (2020). 'Renewable energy production will exacerbate mining threats to biodiversity'. *Nature Communications* 11(1): 4174. Available at: https://doi.org/10.1038/s41467-020-17928-5

Szabó, S., Bódis, K., Kougias, I., Moner-Girona, M., Jäger-Waldau, A., Barton, G. and Szabó, L. (2017). 'A methodology for maximizing the benefits of solar landfills on closed sites'. *Renewable and Sustainable Energy Reviews* 76: 1291–1300. Available at: https://doi.org/10.1016/j.rser.2017.03.117

Visser, E., Perold, V., Ralston-Paton, S., Cardenal, A.C. and Ryan, P.G. (2019). 'Assessing the impacts of a utility-scale photovoltaic solar energy facility on birds in the Northern Cape, South Africa'. *Renewable Energy* 133: 1285–1294. Available at: https://doi.org/10.1016/j.renene.2018.08.106

Vrooman, J., Schild, G., Rodriguez, A.G. and van Hest, F. (2018). *Windparken op de Noordzee: kansen en risico's voor de natuur*. Stichting De Noordzee, Utrecht.

Welstead, J., Hirst, R., Keogh, D., Robb, G. and Bainsfair, R. (2013). *Research and guidance on restoration and decommissioning of onshore wind farms* (No. 591; p. 112). Scottish Natural Heritage Commissioned Report. Scottish Natural Heritage Commissioned Report [website]. Available at: https://www.nature.scot/snh-commissioned-report-591-research-and-guidance-restoration-and-decommissioning-onshore-wind-farms

Wilson, J.C. and Elliott, M. (2009). 'The habitat-creation potential of offshore wind farms'. *Wind Energy* 12(2): 203-212. Available at: https://doi.org/10.1002/we.324

Yeld, J. (2019). 'Watson wind farm stopped - for now. Acting Minister upholds appeal of environmental groups'. *GroundUp* [online article], 16 April 2019. Available at: https://www.groundup.org.za/article/watson-wind-farm-stopped-now/

INTERNATIONAL UNION
FOR CONSERVATION OF NATURE

GLOBAL BUSINESS AND
BIODIVERSITY PROGRAMME
Rue Mauverney 28
1196 Gland
Switzerland
Tel +41 22 999 0000
Fax +41 22 999 0002
www.iucn.org