Mainstreaming Biodiversity into Renewable Power Infrastructure

POLICY HIGHLIGHTS

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Biodiversity and renewable power: Context for action

The world faces dual biodiversity and climate crises

Biodiversity loss and climate change have profound implications for human health, societal well-being and the economy. They are intertwined and therefore require a coherent response. Healthy ecosystems regulate the climate and provide adaptation benefits such as flood protection. Climate change is the fastest growing driver of biodiversity loss. Allowing global average temperature to exceed 1.5 °C above preindustrial levels could significantly increase harm to species and ecosystems.

Expanding renewable power is fundamental to tackling climate change

All pathways for achieving the Paris Agreement's temperature goals require electrification of energy end-uses and a large increase in renewably-sourced electricity. In the International Energy Agency's net zero emissions by 2050 scenario, global electricity demand increases 150% by 2050. Renewables generate almost 90% of global electricity in 2050, up from 30% in 2022. The combined capacity of solar photovoltaics and wind power increases more than four-fold from 2022-30 and almost thirteen-fold from 2022-50.

Without careful planning, renewable power expansion could significantly harm biodiversity

Renewable power infrastructure can affect biodiversity in various ways across its lifecycle. If not appropriately mitigated, these effects can lead to significant declines in species' populations, ecosystem integrity and resilience. Furthermore, one-third of areas with high solar and wind power potential globally, and many of the reserves of critical minerals used in renewable power infrastructure, overlap with areas of high biodiversity value. As renewable power expands, its cumulative impacts on biodiversity are of increasing concern.

Mainstreaming biodiversity in renewable power infrastructure is critical for delivering on the Kunming-Montreal Global Biodiversity Framework

Scaling up renewable power while halting and reversing biodiversity loss demands an integrated approach that capitalises on synergies, minimises trade-offs and averts unintended consequences. It requires governments to systematically integrate both climate and biodiversity objectives throughout electricity planning and policy. Effective biodiversity mainstreaming not only mitigates adverse impacts on biodiversity, but can also expedite renewable power permitting, reduce project delays and cancellations, and avoid greenhouse gas emissions from ecosystem conversion.

The report provides guidance to governments on protecting biodiversity when scaling up renewable power

With most renewable power infrastructure yet to be deployed, an opportunity exists to develop electricity systems that deliver better outcomes for both climate and nature. This report synthesises evidence on the biodiversity impacts from renewable power infrastructure, focussing on solar photovoltaics, concentrated solar power, wind power and power lines for electricity distribution and transmission. It also shares insights and good practices for integrating biodiversity considerations into power sector planning and policy.

Recommendations and policy options

Scale up efforts to hold global average temperature increase to 1.5 °C, pursuing low-energy demand pathways that deliver benefits for climate, biodiversity and other well-being objectives

- Adopt ambitious low-emissions development strategies and policies that integrate climate, biodiversity, energy and broader well-being objectives.
- Leverage the full range of demand-side mitigation measures, including technological and social innovations, to improve energy efficiency and change consumer behaviour to reduce energy demand.
- Apply a systems approach to the (re-)design of energy end-use systems, to use less energy and materials.

Consider biodiversity impacts when selecting among power sector technologies and capacity expansion options

- Integrate spatially explicit biodiversity data into power system modelling to identify capacity expansion options that are low cost, low emissions and low risk for biodiversity.
- Evaluate the relative cumulative biodiversity impacts of capacity expansion options through appropriate environmental assessments.
- Integrate ecosystem service values and biodiversity related measures into cost-benefit analysis or multi-criteria decision analysis tools used to appraise technology choices and capacity expansion options.

Prioritise areas of low ecological sensitivity and avoid the most ecologically sensitive areas

- Develop biodiversity-explicit spatial plans for renewable power infrastructure, stipulating no go areas and areas of low ecological risk where renewable power projects should be prioritised.
- Ensure that siting decisions for utility-scale power projects account for potential cumulative impacts.
- Accelerate solar rooftop deployment, e.g. by mandating them for public buildings and new builds.
- Promote research and development of technologies and approaches to co-locate solar, wind and power lines with other infrastructure and activities.
- Adapt land and sea-use regulations to facilitate co-location and the siting of renewable power in areas of low ecological risk, e.g. brownfield sites; abandoned agricultural land.

Develop policies and guidance to ensure that power projects effectively mitigate adverse impacts on biodiversity

- Review requirements, processes and guidance for environmental impact assessment and permitting, to promote efficiency and ensure risks to biodiversity are effectively addressed.
- Ensure renewable power companies and utilities strictly adhere to the Mitigation Hierarchy (avoid, minimise, restore/rehabilitate and where appropriate offset) to address biodiversity impacts.
- Establish "no net loss" (or "net biodiversity gain") requirements for new infrastructure projects, including power sector infrastructure, accompanied by robust metrics and methods for verification.
- Adopt standards to promote infrastructure designs and operational practices with lower-risk to biodiversity (e.g. bird-safe power-line design; minimum cut-in-speed for wind turbines).
- Encourage or require renewable power companies and their investors to conduct due diligence in line with the OECD's Due Diligence Guidance for Responsible Business Conduct.
- Require post-construction monitoring and reporting to ensure that environmental assessment recommendations and permitting requirements are respected and to inform adaptive management.

Encourage positive biodiversity outcomes from power generation, transmission and distribution projects

- Integrate biodiversity criteria into tenders for renewable power projects to incentivise companies to go beyond regulatory requirements.
- Establish or endorse certification schemes with science-based criteria to encourage power sector projects to seek positive biodiversity outcomes.
- Encourage power companies to adopt ambitious biodiversity targets, a plan to achieve the targets and a methodology for assessing progress. Collaborate with power companies on proactive conservation actions.

Strengthen the quality and transparency of data on biodiversity and renewable power interactions

- Support development and application of environmental sensitivity mapping tools to inform project siting decisions.
- Develop protocols and guidelines for monitoring biodiversity impacts from renewable power. Encourage coordination across projects to evaluate and address their cumulative impacts.
- Require sharing of data from SEA, EIA, other pre-construction surveys and post-construction monitoring. Establish or support development of open access data platforms to share data.
- Support targeted research to address knowledge gaps on the impacts of renewable power on biodiversity and the effectiveness of mitigation measures.

Promote cross-border collaboration to mitigate adverse biodiversity impacts of the low-emissions transition

- Promote collective ambition across sub-national and national governments to protect species and ecosystems across their entire range and lifecycle.
- Promote cross-border spatial planning and impact assessments, share data on biodiversity affected by renewable power and co-ordinate policy to better understand and address cumulative impacts.
- Harness opportunities presented by cross-border electricity trade for siting renewable power infrastructure in areas of low ecological risk, while managing potential adverse impacts from transmission infrastructure.
- Leverage official development assistance to develop partner country capacity to integrate biodiversity into energy planning, policy and spatial planning, and to establish monitoring and data management systems.

Address upstream biodiversity (and other) adverse impacts from the sourcing and processing of minerals and the manufacturing of parts for renewable power infrastructure

- Prioritise mining in areas of relatively low ecological risk and avoid sites that have particularly high biodiversity values that may be compromised by mining.
- Promote international good practice principles in mining, ensuring full application of the Mitigation Hierarchy by companies extracting or refining minerals.
- Promote supply chain transparency and apply due diligence guidelines to promote sustainable extraction and trade of the minerals required for the low-emissions transition.
- Pursue greater resource efficiency and material circularity for renewable power infrastructure through extended producer responsibility and other policies that promote resource productivity, material recovery, sustainable materials management and the 3Rs (i.e. reduce, reuse, recycle).

Biodiversity impacts of solar power, wind power and power lines

Renewable power infrastructure can adversely affect biodiversity throughout its life cycle

Impacts range from habitat loss and direct species mortality through to complex behavioural shifts and ecosystem service disruption. These impacts may accumulate over projects, time and political boundaries, resulting in potentially significant declines in species' populations and habitats. The nature and extent of impacts depend on the type of infrastructure and its design, where and how critical mineral inputs are mined and processed, where the infrastructure is located and how it is constructed, operated, maintained and decommissioned. In specific contexts, impacts may be positive. For example, solar fields in the UK under biodiversity-minded management were found to support a higher diversity and abundance of plant and animal species than the agricultural or brownfield land where they were sited.

Globally, solar, wind and hydropower projects operate or are being built in 886 Protected Areas, 749 Key Biodiversity Areas and 40 Wilderness Areas

(Rehbein et al. 2020)

Some species and ecosystems are particularly vulnerable

Renewable power affects a variety of marine and terrestrial species, but some species have traits that make them particularly vulnerable to renewable power expansion. For example, large migratory soaring birds and many bat species face an elevated risk of collision with wind turbines. These species also tend to have long lifespans, low fecundity and late ages of maturity, rendering their populations highly sensitive to additional mortality. Some ecosystems may also be more heavily impacted, for example, deserts and xeric shrubland are subject to high concentrations of solar power facilities and mining.

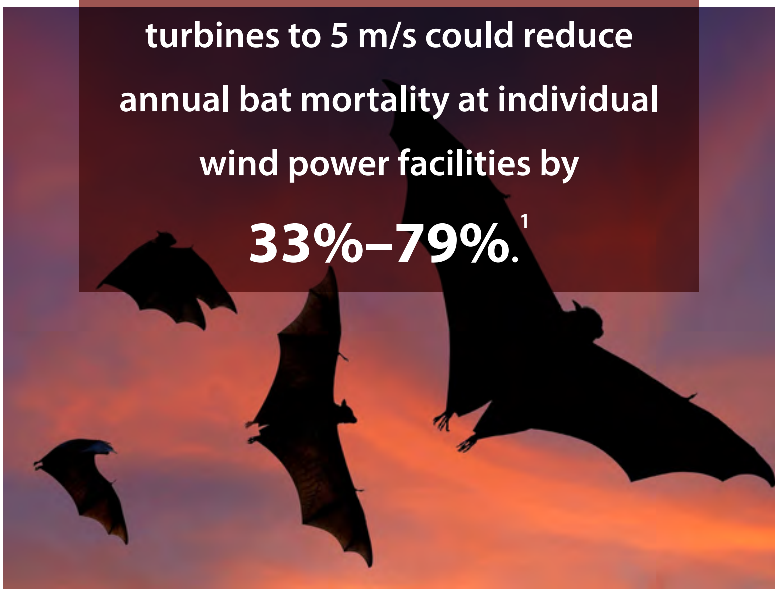
Solutions are emerging for mitigating the adverse impacts of renewable power

Various solutions for mitigating the adverse impacts of renewable power exist, ranging from smart siting to improved project infrastructure design. These solutions continue to be tested and refined, as experience and evidence increase. Digital technologies such as machine learning and artificial intelligence provide new opportunities for the industry to monitor and cost-effectively mitigate impacts on biodiversity. Through strategic planning and effective policies, governments can scale up such solutions.

The knowledge base for renewable power interactions with biodiversity has grown but gaps remain

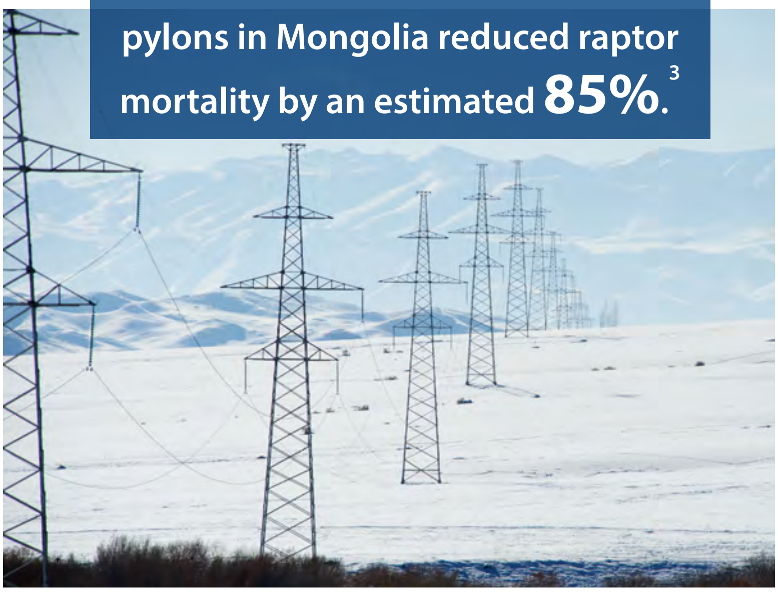
Knowledge is incomplete and uneven across technologies, species, ecosystems and geography. For example, the impacts of onshore wind on terrestrial ecosystems are better understood than those of offshore wind on marine ecosystems. Similarly, the risk factors and consequences for birds are more comprehensively studied than for other groups of species. Most detailed data and insights come from Europe and North America; significant gaps exist in developing countries where most development is projected. Key knowledge gaps and uncertainties common to all renewable power include population-level effects, how impacts on individual species have knock-on effects on ecological communities and ecosystem services, cumulative impacts (e.g. for migratory species or certain habitats), and indirect impacts. Evidence of the effectiveness of some impact mitigation measures used by the industry is still weak or missing.

Increasing the cut-in speed of wind turbines to 5 m/s could reduce annual bat mortality at individual wind power facilities by 33%–79%.[1]

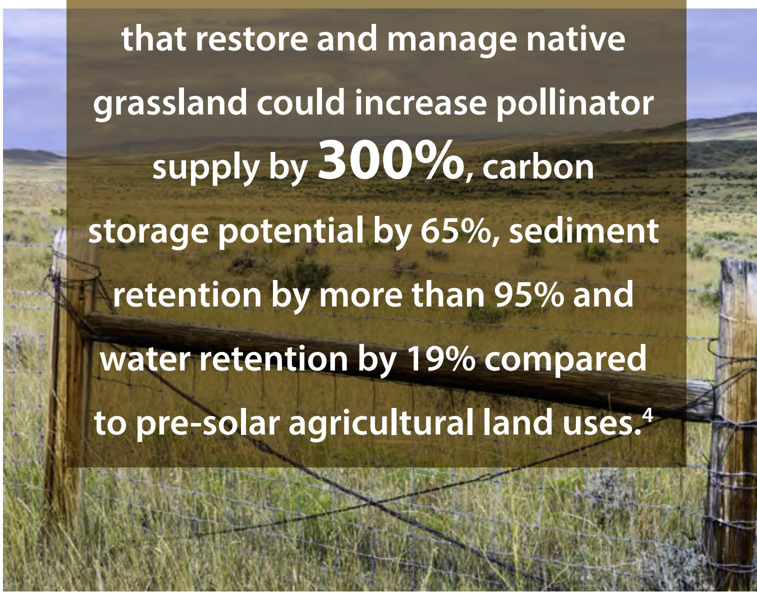


Shutdown on demand measures at twenty wind farms in Spain reduced mortality of soaring birds by 62%, while costing about 0.5% in energy production.[2]

Retrofitting of insulation on pylons in Mongolia reduced raptor mortality by an estimated 85%.[3]

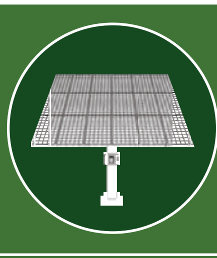


Solar facilities in Midwest US that restore and manage native grassland could increase pollinator supply by 300%, carbon storage potential by 65%, sediment retention by more than 95% and water retention by 19% compared to pre-solar agricultural land uses.[4]



1 Whitby, Shirmacher and Frick, 2021.
2 Ferrer et al., 2022.
3 Dixon et al., 2018.
4 Walston et al., 2021.

Overview of potential biodiversity impacts from renewable power

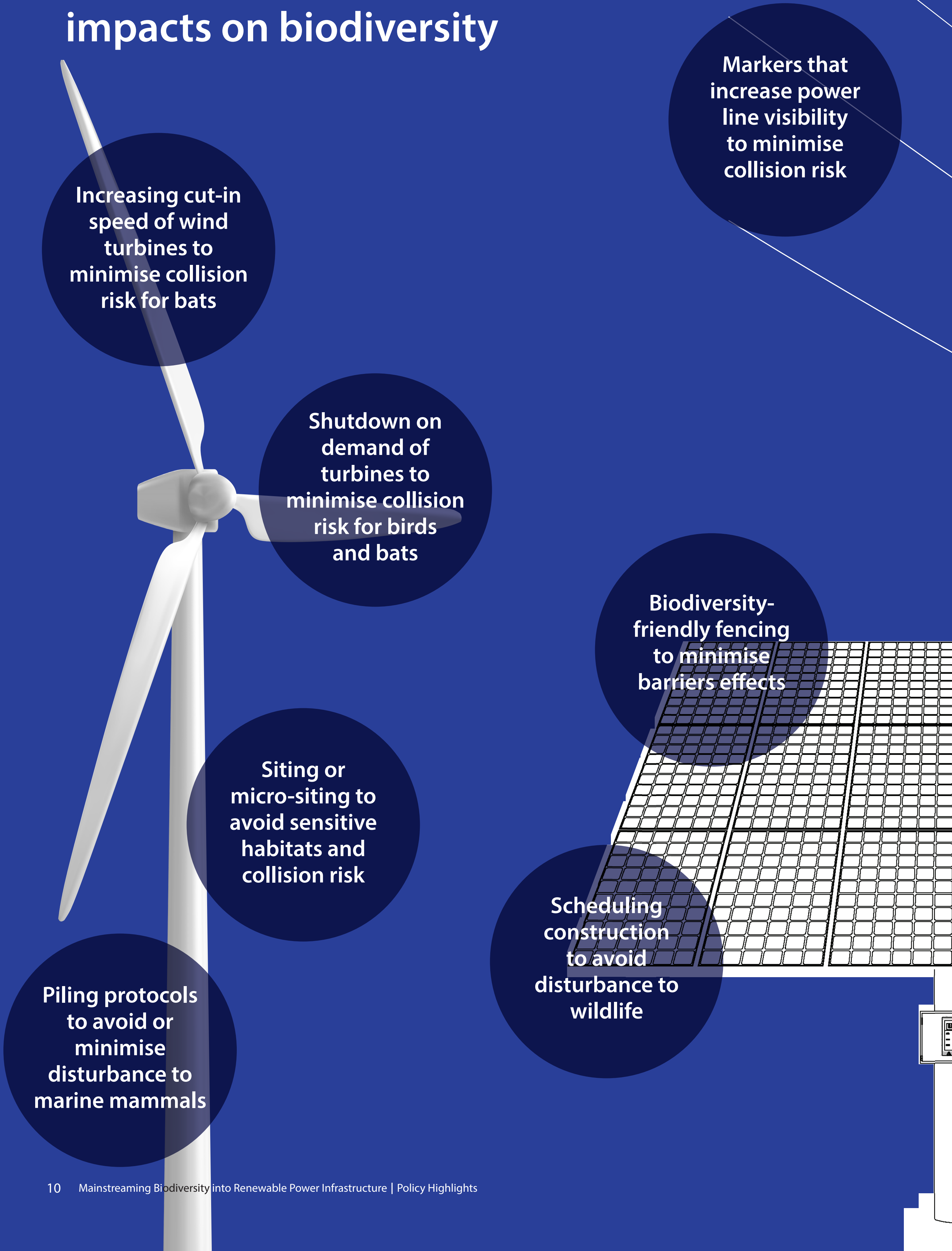
	
Direct wildlife mortality and morbidity	• Avian collision with panels or mirrors • Burning of birds and insects (CSP) • Drowning or poisoning in evaporation ponds (CSP)
Habitat loss and degradation	• Vegetation clearance • Change in surface-water flows • Impacts on freshwater habitats in water-scarce areas (CSP)
Habitat fragmentation and barrier effects	• Physical barrier from fences • Potential edge effects
Habitat alteration / creation (potentially positive or negative)	• Microclimatic changes due to solar panels • Nesting sites/shelter for birds, arthropods and plants
Behavioural changes, species displacement & physiological changes	• Avoidance during construction or operation • Attraction to solar panels (e.g. aquatic insects and birds)
Potential impacts from invasive alien species	• IAS introduced during construction • IAS colonisation and dispersal due to vegetation clearance, mowing etc.
Ecosystem service impacts (potentially positive or negative)	• Aesthetics and recreation • Carbon sequestration, nutrient and water cycles • Pollination
Indirect impacts (potentially positive or negative)	• Displacement of agriculture and associated pressures • Displacement of GHG intensive energy sources • Alternative livelihoods in developing countries
Cumulative and population-level impacts	• Cumulative impacts on populations of sensitive species • Cumulative impacts on ecosystems, e.g. desert and xeric shrubland

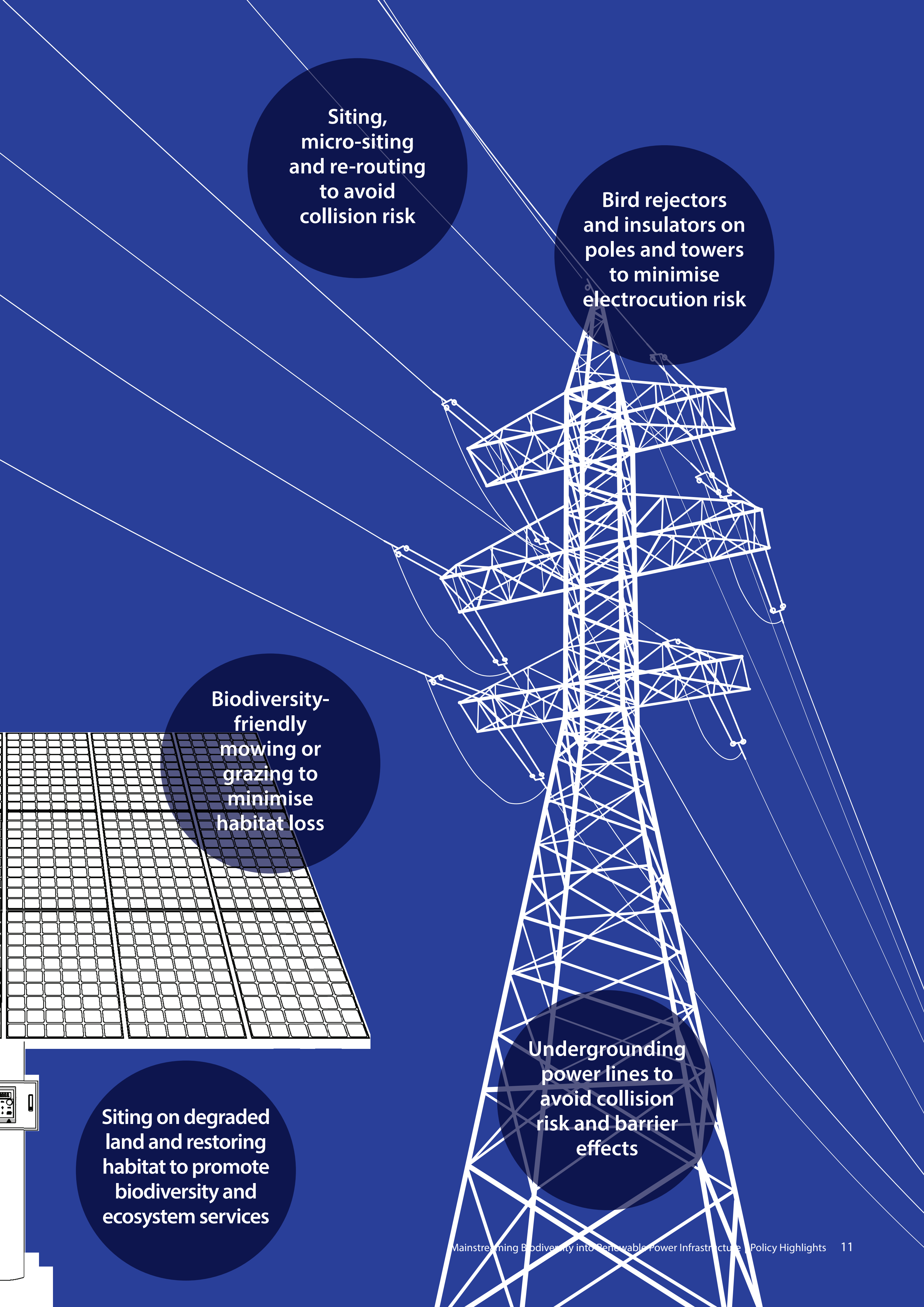
Note: This table provides examples of potential impacts based on empirical evidence and inference. Mitigation measures can avoid or reduce the severity of these impacts. CSP = Concentrated Solar Power. IAS = invasive alien species. RoW = right of way.

Source: Author based on numerous references (see text below for specific references).

	
• Avian and bat collision with turbines • Secondary entanglement of marine species with cables and anchors (floating offshore)	• Avian collision with powerlines • Electrocution of birds, reptiles, bats and other mammals
• Vegetation clearance or disturbance for foundations, access roads etc. (onshore) • Loss of benthic habitat from anchors, foundations and cables (offshore)	• Vegetation clearance of RoW under over-ground cables • Vegetation clearance and earth removal for underground cables
• Barrier effects for birds and bats	• Barrier effects for volant and non-volant species • Edge effects
• "Reef effect" of wind turbine foundations (offshore)	• Pylons and RoWs used for avian nesting and foraging • RoWs used as corridors
• Avoidance during construction or operation • Attraction to wind facilities • Physiological stress from operation of facilities	• Avoidance of power lines by birds and some mammals • Electromagnetic field effects on behaviour and physiology
• IAS introduced during construction • IAS colonisation and dispersal due to roads, offshore turbine foundations etc.	• IAS colonisation and dispersal along RoW and under pylons
• Aesthetics and recreation • Carbon sequestration	• Aesthetics and recreation • Carbon sequestration • Pollination
• Displacement of fisheries and associated pressures (offshore) • Displacement of GHG intensive energy sources • Alternative livelihoods in developing countries	• Increased fire risk • Increased deforestation and hunting by facilitating access • Alternative livelihoods in developing countries
• Cumulative impacts on populations of sensitive bird and bat species due to collision • Cumulative impacts on marine species and ecosystems (offshore)	• Cumulative impacts on populations of sensitive species due to collision and electrocution • Cumulative habitat loss and fragmentation

Emerging solutions for mitigating impacts on biodiversity




Siting, micro-siting and re-routing to avoid collision risk
Bird rejectors and insulators on poles and towers to minimise electrocution risk
Biodiversity-friendly mowing or grazing to minimise habitat loss
Undergrounding power lines to avoid collision risk and barrier effects
Siting on degraded land and restoring habitat to promote biodiversity and ecosystem services

Mainstreaming biodiversity into low-emissions pathways and power sector planning

Strategic planning is crucial for developing power systems that deliver better outcomes for both climate and biodiversity

Decisions on which electricity generation technologies to invest in and where to locate them, have significant biodiversity implications. By addressing biodiversity concerns upfront in planning, governments can help avoid the most significant adverse impacts of renewable power infrastructure. Despite emerging good practices, biodiversity considerations are often not fully and effectively integrated into power sector planning.

Countries should identify electricity expansion options that are low cost, low emissions and low risk to biodiversity

Energy models that inform long-term planning decisions on which electricity generation technologies to invest in and when, tend to be too spatially coarse to account for the potential conflicts between renewable power projects and biodiversity. Incorporating spatially-explicit biodiversity data into energy planning models can help identify electricity capacity expansion options that strike a balance between cost, carbon emissions and biodiversity protection.

Spatial planning can reduce risk to biodiversity while facilitating renewable power deployment

Biodiversity-explict spatial planning is fundamental for steering projects away from high-risk areas, such as Key Biodiversity Areas and migratory routes. Environmental sensitivity mapping tools can inform spatial planning for renewable power and initial project siting decisions. Designating no-go and low-risk areas based on science can provide certainty to developers, regulators and stakeholders, facilitating swift deployment of renewable power and reducing project costs.

Planners should evaluate the biodiversity impacts of policy scenarios and plans

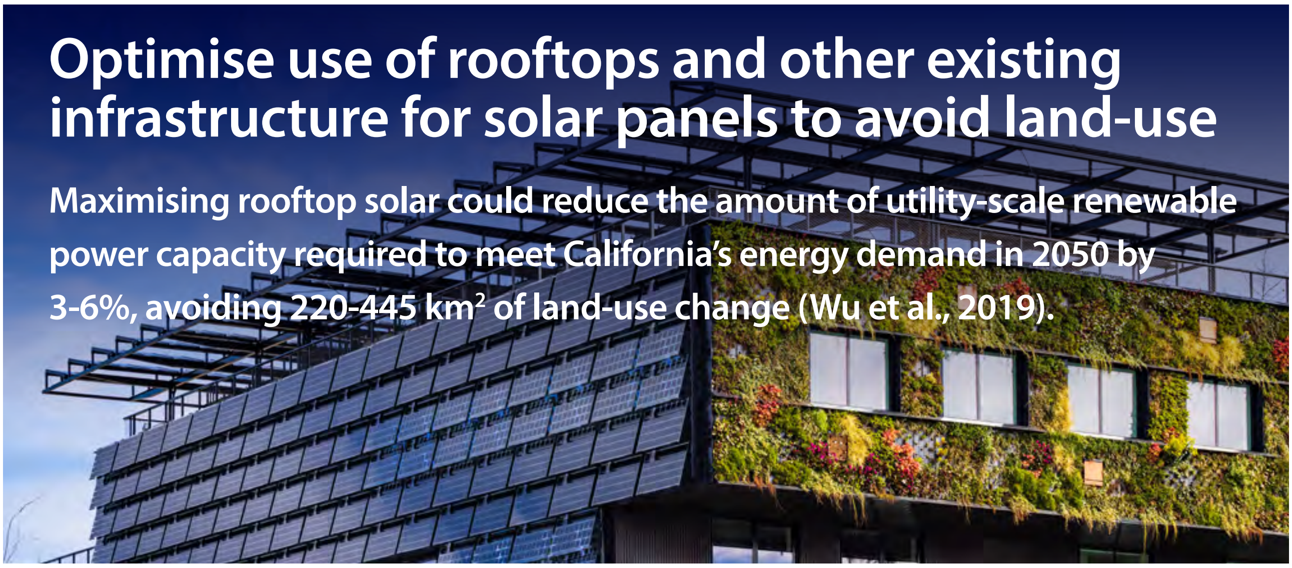
Appraisal of policy scenarios and plans should assess the cumulative impacts on biodiversity, for example through strategic environmental assessments. While cumulative impacts should be considered by individual projects, they are best assessed and addressed at the strategic planning level. Multi-criteria and cost-benefit analysis can help planners to understand trade-offs across policy priorities and to make socially-optimal choices. These tools should seek to integrate biodiversity and ecosystem service values as far as practical.

Intergovernmental collaboration can help align renewable power and biodiversity objectives

Key measures include joint spatial planning, knowledge and data exchange, coordinated monitoring, and development co-operation to strengthen countries' capacities to mainstream biodiversity. Connecting grids across national or state borders could increase opportunities for low-cost, low-risk siting of renewables, but countries must assess and mitigate potential adverse impacts from extending transmission infrastructure.

A study of solar power projects in California concluded that integrating biodiversity into siting decisions reduces permitting time and the costs of biodiversity impact mitigation, with overall project cost savings of up to 14%

(Dashiell, Buckley and Mulvaney, 2019).



Optimise use of rooftops and other existing infrastructure for solar panels to avoid land-use

Maximising rooftop solar could reduce the amount of utility-scale renewable power capacity required to meet California's energy demand in 2050 by 3-6%, avoiding 220-445 km^2 of land-use change (Wu et al., 2019).

Capitalise on already converted lands such as brownfields and abandoned agricultural areas

Globally, sufficient converted land with renewable power resource potential exists to deliver 17 times the required renewable power to meet emission reduction targets based on NDCs in 2016 (Baruch-Mordo et al., 2019).

Co-locate renewable power infrastructure to reduce overall land-use

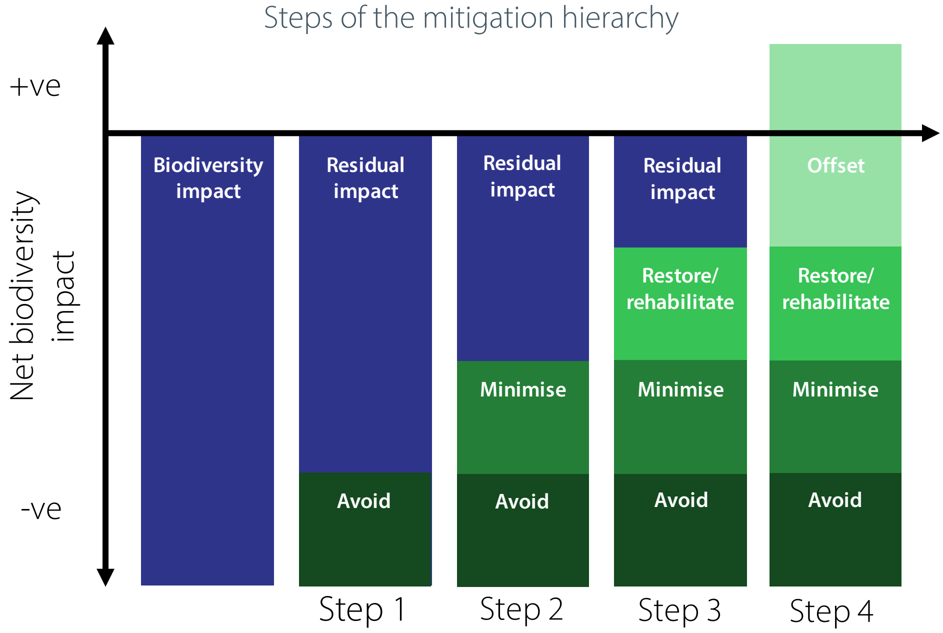
Various forms of co-location or multi-use spaces are emerging such as integrated solar and wind power facilities, solar panels in crop and livestock farms, and artificial reef development at offshore wind facilities to support shellfish.

Policy instruments for reconciling biodiversity protection and renewable power expansion

Increasing the use and effectiveness of policy instruments could help ensure power system transitions benefit both climate and nature

Governments employ a variety of policy instruments to help ensure renewable power companies mitigate adverse biodiversity impacts effectively and encourage them to seek positive biodiversity outcomes. Some instruments, such as environmental impact assessment and permitting, are widely used but their application and effectiveness vary considerably. Other instruments, such as biodiversity-explicit tender processes for renewable power projects, are yet to be widely adopted but hold promise. An effective policy mix may comprise regulatory, economic, information and voluntary instruments. Power sector planning and policy should promote and adhere to the mitigation hierarchy.

Steps of the mitigation hierarchy



The **mitigation hierarchy** provides a structured approach to development planning and the implementation of infrastructure projects with the aim of limiting the negative impacts on biodiversity. The mitigation hierarchy involves four sequential and iterative steps:

1

Avoid: Avoidance measures tend to be the most effective and least expensive way of mitigating adverse impacts on biodiversity. Examples include careful siting of renewable power infrastructure to avoid sensitive areas and constructing infrastructure outside breeding seasons to avoid disturbance.

2

Minimise: Minimisation measures reduce the duration, intensity and extent of impacts that cannot be completely avoided. Examples include physical controls (e.g. bird diverters on power lines), operational (e.g. wind turbine shutdown during migration) and abatement controls (e.g. pile-driving noise reduction).

3

Rehabilitate/restore onsite: Impacts that cannot be completely avoided or minimised can be partly addressed through rehabilitation or restoration. Rehabilitation aims to return basic ecological functions and ecosystem services. Restoration aims to return an area to its original state.

4

Offset: Residual impacts may occur after full implementation of the previous three steps. Offsetting aims to compensate for any residual adverse impacts through actions taken elsewhere to achieve positive biodiversity outcomes for the affected species or habitats. Effectively designed offsets may result in no net loss or net gains in biodiversity.

Regulatory (command-and control)

- Spatial planning (e.g. renewable energy zones) based on biodiversity values
- Environmental licensing and permitting requirements
- Strategic environmental assessment and environmental impact assessment requirements
- Standards for infrastructure design (e.g. power line designs with low risk of electrocution) and operation (e.g. minimum cut-in speeds for wind turbines)
- Monitoring, data-sharing and disclosure requirements
- Due diligence and responsible business conduct requirements

Economic instruments

- Biodiversity offsets to compensate for residual impacts on biodiversity
- Subsidies (e.g. to support research on biodiversity impacts and R&D of mitigation solutions)

Information instruments and voluntary approaches

- Procurement policies, tender processes and power purchase agreements that integrate biodiversity criteria
- Voluntary industry guidelines on assessing and mitigating impacts on biodiversity
- Ecolabelling (e.g. for solar facilities that enhance habitat for pollinators)
- Voluntary corporate commitments such as “no net loss” or “net gain”
- Investor performance standards

Mainstreaming Biodiversity into Renewable Power Infrastructure

This Policy Highlights is based on the OECD publication *Mainstreaming Biodiversity into Renewable Power Infrastructure*.

As countries scale up climate action, they face the challenge of expanding renewable power while tackling biodiversity loss. Transitioning away from fossil fuels can reduce climate-related pressure on biodiversity, but brings its own risks. Unless carefully managed, the expansion of renewable power could compromise biodiversity. This report synthesises evidence on biodiversity impacts from renewable power infrastructure, with a focus on solar power, wind power and powerlines. It identifies opportunities for mainstreaming biodiversity into power sector planning and policy to deliver better outcomes for nature and the climate. Drawing on good practice insights from across the globe, the report offers governments recommendations to align renewable power expansion with biodiversity goals.

Access the full report:

OECD (2024), *Mainstreaming Biodiversity into Renewable Power Infrastructure*, OECD Publishing, Paris, https://doi.org/10.1787/357ac474-en.

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oe.cd/biodiversity

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