

Renewable energy and implications for protected and conserved area downgrading, downsizing, degazettement, and delisting: guidance to address climate change and biodiversity loss synergistically

Renewable energy development is critical to addressing climate change, but poses emerging risks for protected and conserved areas (PCAs). As the demand for renewables increases to meet climate goals and the number of PCAs increase to meet area-based biodiversity targets, objectives may come into conflict. The three main renewable energy types projected to provide the largest contributions to electricity generation by 2050 are solar photovoltaics (PV), wind, and hydropower, which are the focus of this Technical Note.

With strategic spatial planning, most solar and wind energy infrastructure can be placed on already degraded land, agricultural areas, areas with little biodiversity, and more—avoiding PCAs and hence, reducing the occurrence of PCA downgrading, downsizing, degazettement, and delisting (PADDD and CADDD¹), while also avoiding further loss of other areas important for biodiversity. The siting of related mining operations for renewable energy resources and hydropower, on the other hand, is more difficult to modify.

To prevent the most environmentally-damaging impacts from renewable energy development, **PCAs should not be downgraded, downsized, degazetted, or delisted to enable *large-scale* solar and wind energy development or mining.** In addition, *large-scale* development should not be approved in other areas important for biodiversity that are not currently within PCAs, such as sites with high ecological integrity. For *intermediate-scale, non-industrial* solar and wind developments designed to support local needs, rigorous environmental and social impact assessments (ESIAs) that are independently verified should be conducted to show that the operations do not have a significant impact, in cases where these areas are demonstrated to be unavoidable. *Micro- to small-scale* solar and wind infrastructure, which are less environmentally damaging, can be placed in PCAs to support local needs where required.

However, the same guidance does not apply to hydropower—**PADDD, CADDD, and further hydropower expansion should be avoided for hydropower of *any scale*** as it is difficult to mitigate the severe environmental impacts it has on already highly threatened freshwater ecosystems; marine hydropower is less explored for its risks. In situations where development cannot be avoided, rigorous mitigation measures should be used.

In all cases, the aim should be to avoid PADDD, CADDD, and biodiversity loss as much as possible by avoiding areas of high biodiversity importance and selecting already degraded areas instead, while increasing the use of mitigation, restoration, and transformation measures.

¹ PADDD—protected area downgrading, downsizing, and degazettement—or CADDD—conserved area downgrading, downsizing, and delisting



Bolero PV project, Región de Antofagasta, Chile by Antonio Garcia (Unsplash)



Derby Dam, Sparks, NV, USA by Manny Becerra (Unsplash)

Introduction

As the world moves to phase out fossil fuels in favour of renewable energy sources, there are noteworthy implications for area-based biodiversity conservation and climate goals that need to be considered. The headline goal for climate change urges limiting the temperature increase to 1.5°C above pre-industrial levels, in alignment with the [Paris Agreement](#), which will require achieving net-zero carbon emissions by 2050. According to the International Energy Agency (2021), renewable energy will need to account for over 90% of electricity generation by 2050 to meet net-zero emissions; solar photovoltaics (PV) and wind energy are projected to provide the vast majority of these contributions, and hydropower is projected to comprise the third-largest share.

The demand for renewable energy will increase pressures to convert natural spaces to build infrastructure and mines. Of the global land area that supports nature's contributions to people, 16% of it is also highly suitable for agriculture, renewable energy, oil and gas, mining, and urban expansion, which could lead to conflicts between development and conservation goals (Neugarten et al., 2024). Similar risks exist in the ocean for marine habitats (Paolo et al., 2024). These conflicts apply to protected and conserved areas (PCAs) as well, which includes both protected areas (PAs) and other effective area-based conservation measures (OECMs).

PCAs are known to support biodiversity conservation, but they also support human well-being and climate mitigation and adaptation; hence, PCAs are nature-based solutions to climate change (MacKinnon et al., 2019). PCAs have proven to be one of the most effective tools to tackle both biodiversity loss and climate change, widely acknowledged as twin crises that require combined proactive efforts, within a suitable time-frame (Smith & Young, 2023); this sentiment was reiterated in a powerful [joint statement](#) at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) 28 in 2023. The role of conserving, protecting, and restoring nature in addressing climate change has been highlighted in key global climate frameworks and agreements, the latest of which is the [first global stocktake draft decision](#). This draft decision also calls for tripling renewable energy capacity globally.

Efforts to address both biodiversity loss and climate change through renewable energy need to be synergised to avoid area-use conflicts and subsequent PCA downgrading, downsizing, or degazettement (or delisting in the case of OECMs; Cook et al., 2024) to develop renewable energy plants and mines for renewable energy resources. Downgrading is defined as a decrease in legal restrictions on the number, magnitude, or extent of human activities within a PA, downsizing is a decrease in the size of a PA due to the excision of an area through a legal boundary change, and degazettement is the loss of legal protection for a PA; together, these are referred to as PADDD events (Mascia & Pailler, 2011). For OECMs, these definitions differ slightly—recently coined as conserved area downgrading, downsizing, and delisting (CADDD) by Cook et al. (2024)—as not all will have legal measures in place².

² Cook et al. (2024) defined conserved area or OECM downgrading as an increase in human activities authorised within an OECM that could be deemed incompatible with the long-term *in situ* conservation of biodiversity, downsizing as a decrease in the size of an OECM as a result of excision of land, freshwater, or sea area through a boundary change, and delisting as when an area is no longer recognised as an OECM.

Although PADDD and CADDD can be viewed as entirely negative, there could be instances where these events are neutral or positive for social and ecological outcomes, such as when they return areas to Indigenous peoples and local communities or enable systematic conservation planning (Naughton-Treves and Holland, 2019). However, in the case of environmentally-damaging renewable energy development (and any infrastructure), it is likely that PADDD and CADDD events will lead to negative outcomes in and around the site, and as the demand for renewable energy increases, the risks for environmentally-damaging PADDD and CADDD could increase as well.

As UNFCCC COP29 approaches, it is important to emphasise point 7 in [IUCN's position paper for UNFCCC COP29](#): "*IUCN urges Parties to ensure the highest levels of environmental and ecosystem integrity in the operationalisation of Article 6 of the Paris Agreement, and to maintain strong ecological and social safeguards, particularly in the use of any nature-based sinks and removals, including to prevent any adverse impacts on the stability of ecosystem-based carbon reservoirs*", which is related to alleviating this potential conflict between climate and biodiversity objectives, as efforts to lower emissions, as called for in Article 6, will require the use of renewable energy, and this could affect biodiversity.

This Technical Note discusses the risks from this potential conflict and aims to provide guidance on the intersection between renewable energy, PCAs, and other areas important for biodiversity, focusing on solar PV, wind, and hydropower energy, while considering the related impacts of mining, as it is necessary to ensure that efforts to address one crisis do not undermine efforts for the other.

Renewable energy development as an emerging risk for biodiversity and PCAs

PAs already face several risks—over 3,700 PADDD events have been recorded in 73 countries from 1892 to 2018, affecting around 2 million km², mainly driven by large-scale resource extraction and development (Golden Kroner et al., 2019). This includes development for roads, electrical grids, railways, large dams, oil and gas, and large-scale renewable energy fields, all of which can be considered as environmentally harmful types of development. The most common type of PADDD event in both terrestrial and marine PAs is downgrading (Albrecht et al., 2021), and the most common proximate cause is infrastructure (Golden Kroner et al., 2019; CI and WWF, 2021).

A global study by Rehbein et al. (2020) revealed that 1,018 (477 onshore wind, 146 solar PV, and 394 hydropower facilities) out of 12,658 large-scale renewable energy installations (8%) overlap with 634 PAs (289 PAs with wind power, 99 with solar PV, and 246 with hydropower). Of these, 122 are strictly managed PAs under IUCN Categories I–IV, where development is prohibited. Another study (Dunnett et al., 2022) supports these findings, identifying 3,666 wind and solar PV installations, 14.89% of 24,624 total installations, within critical conservation areas, including PAs, Key Biodiversity Areas (KBAs), and wilderness areas. Dunnett et al. (2022) found only eight instances where PADDD events overlapped with renewable energy locations to date, with no clear evidence linking these directly to renewable energy installations. This is likely because the global coverage of PADDD data where spatial data are available (Conservation International and WWF, 2021) greatly differs from the data on the mapped locations of renewables (Dunnett et al., 2022); for instance, there are many renewable energy facilities in China, Europe, Russia, Canada, and the Southern Cone, which are also places with large PADDD data gaps that are a priority for future research. Additionally, the study focused on solar and wind; hence, hydropower, which is the most mature renewable energy type, was not accounted for. Furthermore, Thieme et al. (2020) found 1,249 existing large dams located within 984 PAs across 80 countries, of which 278 were for hydropower; of these, there were 40 confirmed and enacted PADDD events associated with dams, and 11 proposed events.

Given the rising demand for renewable energy, infrastructure development for renewable energy is expected to increase substantially over the next few decades, as is the number of PCAs to meet [Target 3](#) of the Kunming-Montreal Global Biodiversity Framework (GBF), and potentially more ambitious targets in the future. Hence, there is a chance that PADDD and now, CADDD, events could increase as well, and renewable energy development could be an emerging risk for PCAs. This development could threaten both biodiversity and climate goals, despite supporting the energy transition away from fossil fuels.

Although it is necessary to minimise climate impacts by reducing greenhouse gas emissions and increasing renewable energy, the impacts of climate action on biodiversity needs to be minimised as well, as called for in GBF [Target 8](#), and emerging risks to biodiversity should be addressed early. The risk is especially uncertain for CADD events as no studies have assessed the impacts of renewable energy development on OECMs yet as they are a relatively new area-based conservation tool. Although OECMs are meant to offer the same level of protection as PAs, if countries do not develop adequate legal or other effective measures to prevent industrial development there, then there could be issues with overlapping development projects. Since there is currently no universal mechanism to track CADD downgrading (Cook et al., 2024), the risk of unreported CADD events could be especially high for OECMs.

The shift towards renewable energy is also increasing the demand for metals and minerals such as nickel, lithium, cobalt, and rare earth elements that need to be mined (IEA, 2021), particularly for solar and wind expansion, and less so for hydropower (IEA, 2022). Mining poses a significant threat to biodiversity and important habitats; for instance, nickel extraction can lead to the destruction of tropical forests, cause air and water pollution, and exterminate threatened wildlife populations (IUCN WCPA, 2023). Additionally, 8% of mining activities overlap with PAs, 7% with KBAs, and 16% with remaining wilderness areas (Sonter et al., 2020). Since the vast majority of mining sites (82%) target materials needed for renewable energy production (Sonter et al., 2020), increases in mining activities for renewable energy resources are another risk for more PADDD and CADD events in the future. There are additional rising concerns surrounding artisanal and small-scale (ASM) mining operations; these expanding operations cause environmental damage and are largely informal, with around 75–80% of ASM not being regulated and permitted, making it difficult to encourage responsible practices (World Bank, 2019; 2021). These operations take place in over 80 countries and employ over 40 million people, comprising the majority of mining operations in some countries based on the number of people involved (World Bank, 2019). Another concern is the growing interest in deep-sea mining, which is expected to severely harm marine biodiversity and ecosystems, but there are limited protection mechanisms for this due to limited knowledge of the deep sea and the potential impacts of mining there (IUCN, 2022). Despite this, renewable energy requires far fewer resources than coal—it is estimated that the total cumulative material requirements for the energy transition up to 2050 are still less than what is required for coal in a single year (Energy Transitions Commission, 2023).

Along with the impacts of habitat degradation and loss, renewable energy infrastructure development and mining can pose other rising threats to terrestrial, freshwater, and marine species, both during construction and after, such as noise pollution, disruption to migration routes, and wildlife mortality (Bennun et al., 2021; TBC & WWF, 2023; see more in Table 1). Hydropower in particular poses a severe threat to freshwater ecosystems, which are already gravely at risk yet receive far less attention than terrestrial and marine ecosystems in global conservation efforts. In the past 50 years, freshwater species have declined by 85% (WWF, 2024), and continued hydropower expansion could be detrimental to these fragile ecosystems since hydropower is a significant cause of river fragmentation and threatens 92% of freshwater megafauna (FLUVIUS et al., 2019; WWF, 2020; Zarfl et al., 2020). Even small-scale hydropower, which has varying definitions but is considered to be a plant with a capacity of less than 10 megawatt (MW) that does not necessarily require a dam, has been shown to disproportionately affect biodiversity loss in freshwater habitats, as it produces little energy for the environmental damage it causes; this means that more small-scale plants need to be built to deliver the same output as a large-scale one, causing further issues (Couto & Olden, 2018; Kuriqi et al., 2021; Lange et al., 2018; Timpe & Kaplan, 2017). Additionally, these smaller plants tend to be in smaller rivers, which are important for connectivity, biodiversity, and ecological integrity; despite this and limited research on their efficacy and further risks, their use has rapidly expanded, partly due to weak regulatory oversight that has encouraged investments (Couto & Olden, 2018). Further, most large-scale facilities have already been built and smaller ones are perceived to be less environmentally damaging than larger ones, despite that not being the case (Kuriqi et al., 2021; Lange et al., 2018).

Although there are several emerging risks associated with renewable energy development and mining, with careful planning, most of these can be avoided or reduced to implement climate and biodiversity goals more synergistically.

Opportunities and recommendations

Studies have shown that there is enough space available to site renewable energy facilities without developing them in ecologically important areas; Baruch-Mordo et al. (2019) note that the planet can source up to 17 times the amount of energy required by current global targets from converted land alone, and that most countries, including the top-ten greenhouse gas emitters, can meet the goals of the Paris Agreement by developing renewable energy facilities on previously cultivated or mined lands, industrialised areas, and within urbanised areas such as on rooftops. Similarly, Adeh et al. (2019) estimate that the global energy demand could be met by solar energy production if less than one percent of cropland were converted to an agrivoltaic system, which involves growing crops under solar panels. These studies did not include considerations for renewables in degraded ocean habitats, including offshore wind energy or floating solar panels, suggesting that the contributions from renewables in converted areas would be higher when considering those.

A similar approach is already taking place in the European Union; under the “renewables acceleration areas” initiative, Member States should adopt plans for these areas by early 2026 and prioritise “...*artificial and built surfaces, such as rooftops and facades of buildings, transport infrastructure and their direct surroundings, parking areas, farms, waste sites, industrial sites, mines, artificial inland water bodies, lakes or reservoirs and, where appropriate, urban waste water treatment sites, as well as degraded land not usable for agriculture*” under Article 15c of [Directive \(EU\) 2023/2413](#). Additionally, a recent study found that for offshore wind in the EU, enough ocean area has been designated for renewables that avoids protected areas in most countries (WWF, 2024).

Hence, it is possible to achieve benefits for both biodiversity and the climate in most countries by incorporating participatory, integrated, and biodiversity-inclusive spatial planning into renewable energy development to ensure that facilities and infrastructure are housed away from ecologically important areas where possible, apart from micro- to small-scale infrastructure that may be needed to support local needs in those areas. These efforts are highly relevant to [Target 1](#) of the GBF as well, which states: “*Ensure that all areas are under **participatory, integrated, and biodiversity inclusive spatial planning** and/or effective management processes addressing land and sea use change, to **bring the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity, close to zero** by 2030, while respecting the rights of indigenous peoples and local communities*” (see [guidance](#) (Grantham et al., 2024) on this topic by the IUCN WCPA Task Force on Spatial Planning). Landscape and seascape assessments, such as Strategic Environmental Assessments, that account for the cumulative impacts of renewable energy projects and related mining operations across landscapes and seascapes should also be conducted to ensure that they are cumulatively not harmful for biodiversity. Additionally, management could play a role in securing sites, as Rehbein et al. (2020) and Dunnett et al. (2022) found that stricter protection (IUCN Categories I–IV) tends to offer more resistance to renewable energy development than areas with less stringent or no classification (IUCN Categories V–VI or uncategorised). Renewable energy projects that conflict with the conservation objectives of PAs, and the conservation outcomes of OECMs, should be avoided.

For solar and wind energy siting, based on existing IUCN guidance that is aligned with [WCC-2016-Rec-102](#) and [WCC-2020-Res-084](#) (originally written for renewable energy development within PAs but here it also applies to OECMs and other important biodiversity areas):

- *“Large-scale, industrial renewable developments likely to have impacts that cannot be fully mitigated: such development should in all circumstances be 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.*
- *Micro to small scale, serving local needs: assess on a case-by-case basis. For World Heritage sites, given their globally significant value, only micro to small 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”* (Bennun et al., 2021).

For some micro- to small-scale sites, adding renewable energy could support income generation as well, which could help support PCA staff or locals in the PCA, or go towards conservation activities. Additionally, for other non-industrial scale sites, some renewable energy infrastructure could even support wildlife, such as marine organisms around offshore wind energy structures that have returned to the site after construction, if sufficient restoration activities have taken place to avoid and mitigate impacts to species and habitats, reduce pollutants, and replenish the biodiversity there—if these sites meet the criteria and have support in place for long-term governance and management, they could be conserved as OECMs (Woodley, 2024), representing an opportunity to co-locate renewable energy with biodiversity conservation objectives.

However, if a site is already an OECM, environmentally-damaging renewable energy operations that are not consistent with delivering long-term conservation outcomes should not be allowed there, as the site would then fail to meet the definition of an OECM³. Hence, some instances of renewable energy in PCAs may be compatible with biodiversity conservation goals. From a longer-term perspective, renewable energy will also help reduce rising climatic impacts on biodiversity by lowering greenhouse gas emissions, aligned with GBF Target 8.

However, hydropower siting should not follow the same approach as solar and wind in terms of scale, since small-scale hydropower is not necessarily less damaging than a large-scale hydropower facility, for the amount of energy produced (Couto & Olden, 2018; Lange et al., 2018; Timpe & Kaplan, 2017). Although certain mitigation measures can still apply for sites in situations where hydropower development cannot be avoided, it is recommended that the use of hydropower should be greatly reduced and solar and wind development should be scaled instead, due to the severe risks hydropower poses to the most threatened habitats—freshwater ecosystems—and because even with mitigation measures, the impacts are difficult to reduce due to siting requirements. Although marine hydropower is being explored, it is still in its early stages, and the impacts have not been carefully assessed yet. Hydropower is also not future-resilient, since it is at risk from increased floods and droughts from climate change (WWF, 2024).

Mining for renewable energy resources is another large challenge that will need further considerations, as it is difficult to avoid overlaps in areas with required resources and areas that are important for biodiversity. Some measures could help, such as strengthening governance and management in PCAs to reduce mining threats there (Sonter et al., 2020), and supporting mining companies with relevant accreditations for responsible mining (Bennun et al., 2021) that include considerations for biodiversity. However, risks with unregulated ASM operations and deep-sea mining still remain and are more difficult to resolve without effective policies and safeguards.

Below are recommendations for site selection and mitigation measures for renewable energy project developers, with considerations for mining (Table 1), as well as recommended actions for other actors (Table 2).

³ As defined under [CBD Decision 14/8](#), an OECM is “a geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio-economic, and other locally relevant values”

Table 1. Recommendations for site selection and mitigation measures for renewable energy project developers (site-level for renewable energy projects, including considerations for associated mining operations for renewable energy resources), based on the [AR3T Hierarchy](#). This is not an exhaustive list and additional considerations should be determined on a site-to-site basis. Important biodiversity area acronyms: KBA: Key Biodiversity Area; EBSA: Ecologically or Biologically Significant Marine Area; ISRA: Important Shark and Ray Area; IMMA: Important Marine Mammal Area.

	Solar photovoltaics (PV)	Wind (onshore and offshore)	Hydropower	Sources
Description	Electricity produced from solar PV cells	Onshore: Electricity produced by wind turbines from the kinetic energy of wind, installed on land Offshore: Electricity produced by wind turbines that are installed in open water, usually in the ocean	Hydropower, or hydroelectric power, uses the natural flow of moving water to generate electricity. In most cases, it will involve a dam, but some smaller hydropower facilities do not require one (diversions or “run-of-river” facilities)	IEA (2021) Office of Energy Efficiency & Renewable Energy (2024)
Main threats to biodiversity	Habitat loss and degradation Barrier to species movement, including migration routes Bird collisions with transmission lines, particularly for larger birds Associated pollution and destruction from mining for the renewable energy resources required	Habitat loss and degradation Barrier to species movement, including migration routes Bird collisions with transmission lines, particularly for larger birds Bird and bat collisions with turbines Seabed disturbance (offshore) Disturbance from marine noise and ship traffic during construction and maintenance (offshore) Marine/freshwater life collisions with infrastructure and maintenance vessels (offshore) Associated pollution and destruction from mining for the renewable energy resources required	Habitat loss and degradation Barrier to species movement, including migration routes, as well as sediment movement Bird collisions with transmission lines, particularly for larger birds Connectivity loss Water quality deterioration Downstream water depletion Changes to flow regimes Aquatic species mortality and injuries Disturbance to wildlife from construction and maintenance Threatens the most vulnerable and at-risk ecosystem type (freshwater)	Bennun et al. (2021) IUCN WCPA (2023) Kuriqi et al. (2021) TBC (2018) TBC & WWF (2023) WWF (2024)
Avoid threats	Avoid large-scale development and mining in or near PCAs (while avoiding PADDD and CADDD), critical habitats, primary forests, sites with high ecological integrity, KBAs, EBSAs, World Heritage Sites, sites important for migration and connectivity, and other areas important for biodiversity , including ones that are a priority for PCA expansion —prioritise siting in already degraded areas, buildings, agricultural areas, and other areas with little biodiversity instead	Avoid large-scale development or mining in or near PCAs (while avoiding PADDD and CADDD), critical habitats, primary forests, sites with high ecological integrity, KBAs, EBSAs, ISRAs, IMMAs, World Heritage Sites, sites important for migration and connectivity, freshwater areas (for offshore), and other areas important for biodiversity , including ones that are a priority for PCA expansion —prioritise siting in already degraded areas, agricultural areas, and other areas with little biodiversity instead	Avoid hydropower development of any scale where possible to protect freshwater ecosystems, and prioritise solar or wind energy instead; in cases where that is not possible, avoid hydropower development within or near PCAs (while avoiding PADDD and CADDD), critical habitats, sites with high ecological integrity, KBAs, Ramsar sites, World Heritage Sites, and other areas important for biodiversity , including ones that are a priority for PCA expansion —prioritise siting hydropower facilities on rivers that are already degraded or fragmented to maintain free-flowing rivers	Bennun et al. (2021) IUCN (2022) Thieme et al. (2020) Grill et al. (2019) Watson et al. (2023)

	Avoid deep-sea mining operations or supporting companies that will conduct operations there unless activities are aligned with WCC-2020-Res-122	Avoid deep-sea mining operations or supporting companies that will conduct operations there unless activities are aligned with WCC-2020-Res-122		
	Avoid renewable energy development and related mining operations along species migration routes	Avoid renewable energy development or related mining along species migration routes		
	Avoid project development and related mining operations during sensitive periods for wildlife, such as migration and breeding	Avoid project development, turbine operations, and related mining operations during sensitive periods for wildlife, such as migration and breeding		
Reduce threats	<p>Conduct rigorous environmental and social impact assessments (ESIAs) that are independently verified during the planning stage for intermediate-scale, non-industrial renewable energy development in important biodiversity areas</p> <p>Adopt voluntary standards to support nature and climate goals, including adherence to best practice principles (UN Global Compact Principles [Principles 7–9]; International Council on Mining and Metals (ICCM) Mining Principles), target setting (Science Based Targets Network [SBTN], Science Based Targets Initiative Forest, Land Use, and Agriculture [SBTI FLAG]), and disclosure (Taskforce on Nature-Related Financial disclosures [TNFD]; Global Reporting Initiative (GRI) Standards (sector and topic-specific standards available: GRI 14: Mining Sector 2024 used with GRI 101: Biodiversity 2024); Sustainability Accounting Standards Board (SASB) Standards (Solar Technology & Project Developers SASB Standard))</p> <p>Minimise the size of construction facilities</p> <p>Use low-impact construction methods that cause the least environmental damage</p> <p>Place solar PV panels on previously developed land, such as rooftops, agricultural areas, or industrial areas</p> <p>Provide connectivity access to species with bridges and other routes, especially to provide a clear alternative if migration routes are disrupted</p> <p>Route linear infrastructure and power lines away from ecologically important areas</p>	<p>Conduct rigorous environmental and social impact assessments (ESIAs) that are independently verified during the planning stage for intermediate-scale, non-industrial renewable energy development in important biodiversity areas</p> <p>Adopt voluntary standards to support nature and climate goals, including adherence to best practice principles (UN Global Compact Principles [Principles 7–9]; International Council on Mining and Metals (ICCM) Mining Principles), target setting (Science Based Targets Network [SBTN], Science Based Targets Initiative Forest, Land Use, and Agriculture [SBTI FLAG]), and disclosure (Taskforce on Nature-Related Financial disclosures [TNFD]; Global Reporting Initiative (GRI) Standards (sector and topic-specific standards available: GRI 14: Mining Sector 2024 used with GRI 101: Biodiversity 2024); Sustainability Accounting Standards Board (SASB) Standards (Wind Technology & Project Developers SASB Standard))</p> <p>Minimise the size of construction facilities</p> <p>Use low-impact construction methods that cause the least environmental damage</p> <p>Increase wind turbine visibility to reduce collisions</p> <p>Halt power generation and maintenance activities during critical migration periods and times of high activity</p> <p>Use Bird Flight Diverters and other tools that reduce collisions</p> <p>Use adaptive lighting that can be reduced or turned off as needed to reduce light pollution</p> <p>Reroute, mark, or bury power lines where possible</p>	<p>Conduct rigorous environmental and social impact assessments (ESIAs) that are independently verified during the planning stage</p> <p>Adopt voluntary standards to support nature and climate goals, including adherence to best practice principles (UN Global Compact Principles [Principles 7–9]), target setting (Science Based Targets Network [SBTN]), and disclosure (Taskforce on Nature-Related Financial disclosures [TNFD]; Global Reporting Initiative (GRI) Standards (topic-specific standards available: GRI 101: Biodiversity 2024); the Hydropower Sustainability Standard)</p> <p>Minimise the size of construction facilities</p> <p>Use low-impact construction methods that cause the least environmental damage</p> <p>Implement environmental flow regimes to maintain or mimic important natural patterns, ensuring there are no periods of zero flow during construction or operation</p> <p>Establish effective fish passes to support migration</p> <p>Select fish-friendly turbines or add fish screens on turbines</p> <p>Install silt-trap fences to minimise the effects of reduced sedimentation</p> <p>Reroute, mark, or bury power lines where possible</p>	<p>Bennun et al. (2021)</p> <p>Gasparatos et al. (2017)</p> <p>IUCN WCPA (2023)</p> <p>TBC (2016)</p> <p>TBC (2018)</p> <p>TBC & WWF (2023)</p> <p>Thieme et al. (2020)</p> <p>WWF (2023)</p>

	Reroute, mark, or bury power lines where possible	Employ measures to reduce damage to seabeds ahead of construction (offshore)		
	Reduce emissions and pollutants during development and mining	Employ technology to reduce noise pollution during installation		
		Reduce emissions and pollutants during development and mining		
Restore and regenerate	Restore degraded areas used for development and/or mining with native vegetation	Restore degraded areas used for development and/or mining with native vegetation	Restore degraded areas used for development with native vegetation	Bennun et al. (2021)
			Remove dams to restore free-flowing rivers	
Transform	Repurpose materials following a circular economy approach	Repurpose materials following a circular economy approach	Increase energy efficiency to reduce demand	WWF and BCG (2023)
	Increase energy efficiency to reduce demand	Increase energy efficiency to reduce demand	Greatly reduce the use of hydropower and expand solar and wind operations	WWF (2023)
	Invest in research and development for new materials that reduce the need for mining and the environmental impacts of existing methods	Invest in research and development for new materials that reduce the need for mining and the environmental impacts of existing methods		

Table 2. Recommendations for different actors to reduce environmentally-damaging renewable energy operations and PADD/CADD events

Actor	Recommended actions
Governments	<p>Avoid PADD and CADD decisions that enable environmentally-damaging (large-scale solar and wind, large-scale mining for renewable energy resources, and hydropower of any scale) renewable energy development</p> <p>Develop policies and safeguards for deep-sea mining, aligned with WCC-2020-Res-122</p> <p>Large-scale development should not be approved in other areas important for biodiversity that are not currently within PCAs either, such as sites with high ecological integrity, as there are many areas important for biodiversity that are outside of PCAs or not currently identified in biodiversity databases</p> <p>Hydropower projects should only make up a small percentage of the renewable energy portfolio, if at all, with efforts to remove dams for freshwater species recovery, and solar and wind should be expanded instead</p> <p>Develop policies and incentives to maintain free-flowing rivers (Grill et al., 2019)</p> <p>Develop and include considerations for renewable energy in participatory, integrated, and biodiversity-inclusive spatial plans, aligned with Target 1 of the Kunming-Montreal Global Biodiversity Framework (GBF)</p>

Lead processes to conduct inclusive landscape and seascape assessments, such as Strategic Environmental Assessments, that account for the cumulative impacts of renewable energy projects and related mining operations across landscapes and seascapes to ensure that they are cumulatively not harmful for biodiversity

Include mechanisms to implement [Target 15](#) of the GBF and [SGD 12.6](#) with relevant legal, administrative, or policy measures, such as mandating renewable energy project developers, including projects that mine for the resources used in renewables, to adhere to relevant well-established standards for the private sector that include considerations for biodiversity (see Table 1 for examples)

Incorporate renewable energy guidance into Nationally Determined Contributions (NDCs), National Adaptation Plans (NAPs), Long-Term Low Emission Development Strategies (LT-LEDS), Land Degradation Neutrality (LDN) targets of the UN Convention to Combat Desertification (UNCCD) for land-based renewables, and other relevant targets, plans, policies, and legislation

For non-industrial renewable energy development and related mining operations in or near important biodiversity areas, mandate thorough and transparent environmental and social impact assessments (ESIAs) that should be completed during the planning stage, as well as associated environmental and social management plans (ESMPs) that should be completed before any development begins. Both should be verified independently, open to public consultation upon dissemination, and approved by the government before the project is given permission to start. For projects in areas where Indigenous peoples and local communities live, free, prior, and informed consent (FPIC) must be provided as well, following a rights-based approach, including equitable benefit-sharing (e.g. [Toledano et al. 2023](#)). Additionally, the approval should be conditional on the impacts reported—if the impacts turn out to be different or greater than expected (after monitoring them), the ESIAs and ESMPs should be updated and subject to further approval (UNCTAD & The World Bank, 2018)

Develop policies to enforce environmentally and socially responsible artisanal and small-scale mining (ASM) and formalise their work for renewable energy resources, such as requiring permits (World Bank, 2021), and support ESIAs or other relevant processes and frameworks for necessary renewable energy resources for groups that may not have the capacity or funding for it (e.g., formalised artisanal miners)

Increase transparency by reporting PADDD and CADDD data to UNEP-WCMC as a complementary indicator for GBF Target 3

Renewable energy project developers (private sector)	Follow the guidance in Table 1, particularly to avoid creating environmentally-damaging developments in ecologically important areas (e.g., PCAs, KBAs, and sites with high ecological integrity) while avoiding PADDD and CADDD, and prioritising already degraded areas for development
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NGOs	Develop and advocate for a standardised mechanism for governments to track PADDD and CADDD
	Track PADDD and CADDD events and conduct research on the risks and impacts of renewable energy
	Track the expansion of renewable energy operations into other important biodiversity areas that are not currently PCAs
	Lead advocacy efforts for relevant policies and legislation for halting and reversing environmentally-damaging PADDD and CADDD events
	Provide guidance to other actors

Communities	Participate in consultation processes related to ESIAs and ESMPs for renewable energy projects
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Support advocacy efforts to halt and reverse environmentally-damaging PADDD and CADDD events

PCA managers	Strengthen management in alignment with a stricter IUCN category where possible (for PAs) or to the management quality expected for the existing category
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Alert NGOs of potential PADDD and CADDD attempts and proposals by renewable energy developers

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Rampion Offshore Wind Farm, United Kingdom, by Nicholas Doherty (Unsplash)

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