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Facilitating Policy Responses for Renewable Energy and Biodiversity

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Renewable energy contributes substantially to climate change mitigation, but its expansion can have trade-offs with biodiversity. These trade-offs could be reduced by building a strong evidence base, rationalizing the selection of sites and operational characteristics of renewable energy installations, and coordinating concerted policy efforts at the national and international levels.

Framing the Policy Debate

Energy systems have multiple interactions with biodiversity and ecosystem services. Conventional fossil fuel-based energy generation affects biodiversity through the emission of greenhouse gases (GHGs) and pollutants. Although the expansion of renewable energy will have broadly positive biodiversity outcomes through climate change mitigation, some negative trade-offs exist [1]. This is currently observed with the increasing prevalence of renewable energy infrastructure in and around protected and highly biodiverse areas [2]. To meet the emissions goals of the UNFCCC (The United Nations Framework Convention on Climate Change) Paris Agreement through solar and onshore wind energy, it is estimated that >110 000 km^2 of natural lands would be lost, affecting the ranges of 1574 threatened and endangered species [3].

However, the intersection between renewable energy and biodiversity is complicated (Figure 1). Renewable energy generation options affect biodiversity via multiple mechanisms [1,4] (Table 1). Mining and material sourcing for renewable energy infrastructure such as solar panels and batteries can further affect biodiversity [5]. It is possible that decommissioning and disposal of this infrastructure might have similar effects (Figure 1).

Renewable energy expansion and biodiversity conservation have both become major and legitimate policy goals nationally and internationally. Renewable energy expansion is a major avenue for (i) climate change mitigation under the UNFCCC Paris Agreement, (ii) green economy transitions under the UN Conference on Sustainable Development, and (iii) sustainable development under the UN Sustainable Development Goals (SDGs). Biodiversity conservation is central to many multilateral environmental agreements (MEAs), most prominently the UN Convention on Biological Diversity (CBD).

However, despite a broad consensus on the undeniable biodiversity benefits of renewable energy expansion via climate-change mitigation, there are some negative effects on biodiversity that must be considered. This represents a 'green-versus-green dilemma' that is integral in current sustainability transition efforts [6]. The picture is complicated by the fact that the different renewable energy options have varied and context-specific footprints, operational characteristics, and thus biodiversity trade-offs. Nevertheless, these policy discussions seem to be disjointed, and the possible trade-offs often fall into the cracks between the climate change, energy, and biodiversity conservation communities.

Arguably, scale mismatches create the preconditions for this disjunction. For example, the intended benefits of increased renewable energy production mostly manifest at the national and the global levels, usually as improved energy security, green job generation, and/or climate-change mitigation. However, the negative trade-offs between renewable energy and biodiversity mostly manifest at the local and regional levels through diverse mechanisms associated with the location and operational characteristics of renewable energy installations, as well as the sourcing and disposal of the material used in renewable energy infrastructure (Table 1 and Figure 1).

Facilitating Policy Responses at the Interface of Biodiversity and Renewable Energy

We outline four priority areas to facilitate the design of comprehensive, cohesive, and evidence-based policy responses to ensure that renewable energy expansion does not take place at the expense of biodiversity.

First, a strong evidence-base must guide the design of fit-for-purpose policies that seek to minimize trade-offs between renewable energy and biodiversity. Most major primary knowledge gaps stem from the often-limited focus on (i) renewable energy generation compared with material procurement or disposal, (ii) individual study sites and/or energy pathways, and (iii) drivers of biodiversity loss (e.g., land-use change, pollution) rather than on actual biodiversity impacts (e.g., population decline, species loss) [1]. A new generation of empirical studies must move beyond exploring the drivers of biodiversity loss to quantifying the actual impact on biodiversity. Subsequently, meta-analyses will be necessary to consolidate the literature on drivers and impacts, and to quantify the magnitude of the different mechanisms and their mediating factors. In addition, a new generation of empirical studies that adopt full-lifecycle approaches must focus on poorly understood upstream and downstream activities (Figure 1). These include habitat loss/degradation, pollution, and other

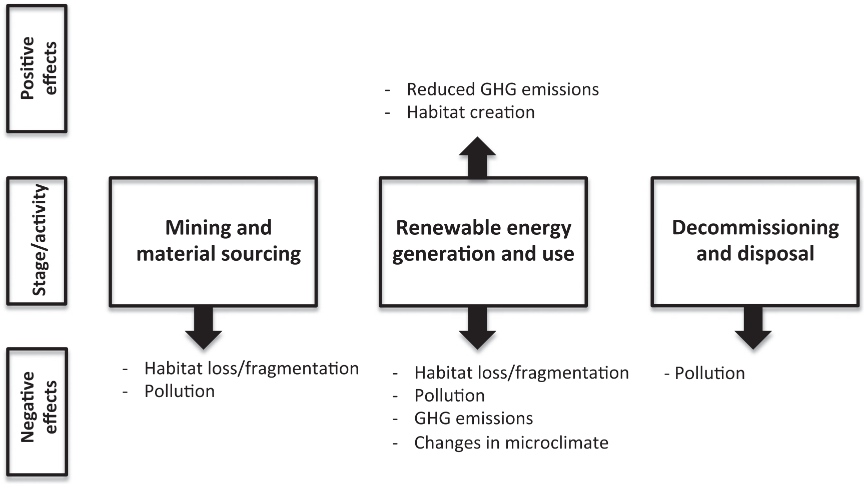

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Figure 1. Main Interactions between Renewable Energy and Biodiversity. Abbreviation: GHG, greenhouse gas.

Table 1. Main Mechanisms of the Effects of Renewable Energy Generation on Biodiversity

Renewable energy option	Mechanism[a]
Solar energy	Habitat loss and fragmentation from installations and ancillary infrastructure (–) Bird and insect attraction, collision, and burn (–) Water overexploitation in dry environments and pollution from toxic chemicals for panel treatment (–) Provision of cover, habitat, and feeding grounds (e.g., for grazing) (+)
Wind energy	Habitat loss and fragmentation from installations and ancillary infrastructure (–) Collision of birds and bats with installations and power lines (–) Disruption of migratory routes and alteration of feeding patterns (–)
Hydropower	Habitat loss and fragmentation from installations, ancillary infrastructure, and upland flooding (–) Alteration of water flows and deterioration of water quality (–) Alteration of migratory routes (–) Habitat generation in flooded areas (+)
Bioenergy	Habitat loss, fragmentation, and simplification through land conversion for agriculture and forestry (–) Water overexploitation and water/air pollution from intensive agricultural activities (–) Invasive behavior of some bioenergy feedstocks (–) Microclimate effects through changes in albedo and evapotranspiration (–) Some bioenergy landscapes provide better habitat options than intensified mono-cultures (+)
Ocean energy	Habitat loss and fragmentation from installations, ancillary infrastructure, and changes in hydrodynamic and sedimentation processes (–) Collision of birds, fish, and aquatic mammals with installations (–) Noise, electromagnetic, and chemical pollution (–) Habitat generation in infrastructure foundations and through the curtailment of vessel movement (+)
Geothermal energy	Habitat loss and fragmentation from installations and ancillary infrastructure (–) Noise, heat, and chemical pollution (–)

[a] Negative and positive effects on biodiversity are denoted by (–) and (+), respectively. For the purposes of this article, the term 'effect' encompasses both drivers of biodiversity loss (e.g., land-use change, pollution) and direct impacts on population decline and species loss. Ocean energy encompasses very diverse energy-generation options, including tidal barrages, wave energy, ocean thermal energy, and offshore wind energy. Source [1,4].

context-specific impact pathways from mining and material sourcing for batteries and renewable energy infrastructure, as well as their decommissioning and disposal [7].

Subsequently, large-scale modeling studies and comprehensive environmental impact assessments will be necessary to explore the effects of different renewable energy scenarios/pathways on biodiversity in a spatially and temporally explicit manner. This would require a step improvement from current modeling approaches that lack the necessary spatial/data resolution or ability to operationalize the diverse impact mechanisms, especially for non-land-intensive renewable energy pathways. Such constraints create large uncertainties about the actual biodiversity effects of large-scale renewable energy expansion [8].

Second, strong policy provisions must guide the selection of the sites and operational characteristics of renewable energy installations [1,4]. Many installations are currently located in areas of critical biodiversity [2]; however, despite the accumulated expertise and experience of impact mitigation through environmental impact assessments (EIAs), many controversial aspects remain. These include the unclear definition of what constitutes 'significant biodiversity impacts' for each distinct renewable energy pathway. In this sense, current EIA practices must be improved to reduce practitioner discretion in these aspects, and to promote the assessment of cumulative impacts rather than individual one-off project-level impacts. However, again we must be mindful of context-specificity. For example, for marine energy in the UK, the effective promotion of cumulative impact assessments must include the development of appropriate guidelines and alignment between the objectives and responsibilities when multiple national and international processes are involved [9].

Furthermore, site selection could be further improved through zoning informed by renewable energy potential and land characteristics, as well as by criteria reflecting the distinct mechanisms of each renewable energy technology (Table 1) [10]. This can facilitate the development of more-nuanced maps to identify areas conducive to the deployment of individual renewable energy technologies with minimal biodiversity trade-offs [11]. Promising examples towards this direction include the Nature Conservancy 'Site Wind Right' initiative for wind energy development in central USA [12].

In any case, national policy frameworks need to encourage integrated planning and landscape-based approaches that search for the combination of renewable energy sources that has the fewest biodiversity trade-offs. Such approaches must consider the possible effects of ancillary infrastructure (e.g., roads, power lines) that contribute to landscape fragmentation and compound some of the negative effects of renewable energy installations [3]. Tools and approaches such as power sector planning and capacity-expansion models are widely used by governments and utilities, and could thus help to determine these combinations – for example, the Clean Energy Pathways (Power of Place initiative) of the Nature Conservancy for California.

Third, at the national policy level, concerted efforts must eliminate misalignment between renewable energy expansion and biodiversity conservation policies. Institutional fragmentation and policy incoherence is often a reality [6] because, in many countries, these domains are regulated and coordinated by different agencies (often at different spatial levels). Reconciling such policies would require country-specific approaches, but would likely entail serious efforts to mainstream biodiversity in the energy and mining sectors, which is currently far from reality in most countries [13]. Promising examples include the facilitation of industry standards/tools through multi-stakeholder consultations (e.g., South African Mining and Biodiversity Guideline), and National Development Plans that explicitly recognize biodiversity (e.g., Uganda, Ghana) or promote/require land-use planning that integrates biodiversity (e.g., Costa Rica) [14]. Furthermore, it would also require tackling specific contentious issues in some national contexts, such as the location of renewable energy installations on degraded or marginal land, which often has high biodiversity value [1]. This would likely open controversial debates about how to define and target such land for renewable energy generation, considering the different definitions and criteria that are used to delineate marginal land in different contexts. Coordinated cross-sectoral policy actions could boost the adoption of technological solutions that reduce trade-offs between renewable energy and biodiversity – for example, sustainable pastureland intensification for bioenergy crop expansion in South America, eco-innovation in the UK wind-energy sector, and agrophotovoltaics in China and Japan. We should acknowledge, however, the necessity of ensuring the fitness and ability of these measures to prevent negative biodiversity outcomes.

Fourth, at the international policy level, MEAs (e.g., CBD and UNFCCC) should frame the policy debate and possible responses given their international visibility, despite their enforcement constraints, differentiated capacity among signatories, and national heterogeneities. We argue that better coordination between such MEAs would delineate the major policy elements of the biodiversity and renewable energy interface and provide a common language. The ongoing efforts of the CBD to promote biodiversity mainstreaming in all major economic sectors may offer the most comprehensive opportunity to achieve this [14,15]. Biodiversity mainstreaming in the energy and mining sectors, apart from being a dedicated CBD decision, features in early discussions of the post-2020 agenda negotiated for the 15th Meeting of the Conference of the Parties (COP15) to the CBD. At the same time, the UN climate regime recognizes the need to address biodiversity loss and climate change in an integrated manner. In this international context, multilateral development banks and funds, that are instrumental in renewable energy finance, need to include strong biodiversity provisions and safeguards.

Ways Forward

At present the post-2020 agenda of the CBD is under development, biodiversity has recently been included in UNFCCC-COP25, and uptake of SDGs is broadening. There is thus currently a golden opportunity to enable policy provisions that actively seek to reconcile renewable energy expansion and biodiversity conservation goals. However, this requires (i) higher visibility of the renewable energy sector in the CBD, (ii) a stronger focus on biodiversity conservation in the climate regime, and (iii) a more integrated and coordinated interaction between relevant MEAs to explore potential constraints and synergies. These can be explored through joint task forces or work programs, knowledge syntheses coordinated by their science-policy interfaces (i.e., the Intergovernmental Panel on Climate Change, IPCC; and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES), or through elaboration by the UNFCCC of clear guidance on relevant large-scale CO_2-removal projects (e.g., forest plantations for bioenergy production).

Such efforts at the international level can kick-start the development of comprehensive and cohesive policy frameworks at the national level. These efforts will ensure that renewable energy expansion, a very worthy goal, does not come at the expense of biodiversity conservation.

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Declaration of Interests

No interests are declared.

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Book Review

On Sustainable Pollinator Diversity and Pollination Service

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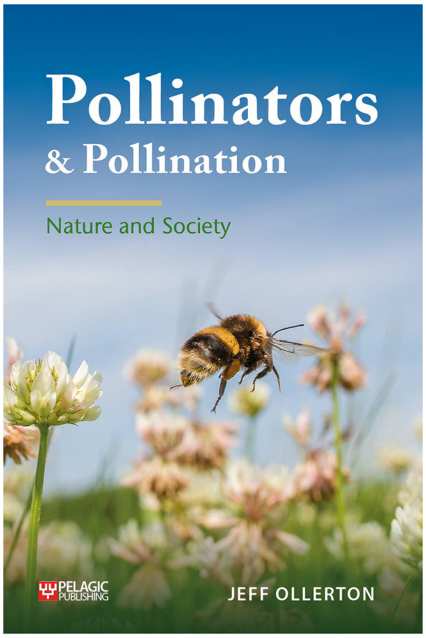

In his new book, *Pollinators & Pollination: Nature and Society*, Jeff Ollerton introduces a PhD project on the impact of city settings on urban bee pollinators like a chat with neighbors in his backyard: 'It made sense to choose Northampton as a case study and focus on this one area in depth…we developed a sampling strategy (of bees) that encompassed a detailed survey of the centre of the town'. I quote this sentence from Chapter 8: *Urban Environments*, as an example of his style of telling stories of scientific projects for readers.

The book is a comprehensive introduction to the critical ecological role of pollinators in both natural and agricultural ecosystems. Compared with previous volumes on the subject of pollination ecology [1,2] that contain >600 pages each, this monograph is much slimmer, with 300 pages. The first six of the 14 chapters mainly focus on ecological functions of pollinators in natural ecosystems; the following seven chapters mainly on practical views of managing pollinators and their sustainable use.

Readers will quickly realize that the book is definitely written by one of the world's leading pollination ecologists, because the author presents state-of-the-art perspectives of the current status of pollinator diversity and importance, inputting his thought-provoking views. In Chapter 2, the fundamental question of what the major and minor groups of pollinators from different animal taxa are is answered in detail. Some miscellaneous pollinators, such as lizards, birds, and bats and other mammals reported in recent literature are discussed. Again, readers without a background in biology can easily grasp the main ideas of plant–pollinator interactions, because the author is ready to expose his logic flow and critical thinking and presents some unsolved problems within each chapter.

For instance, to understand 'All flowers are the same (at the function of sexual reproduction and basic *Bauplan*), all flowers are different (at the floral traits)' in Chapter 3, Jeff used one of his favorite groups of plant (Apocynaceae) to illustrate how flowers manipulate pollinator behavior to attract and trap fly pollinators. The concept of plant–pollinator coevolution is not