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Integrating biodiversity conservation into renewable energy development under the European Green Deal: A comparative analysis of national policies in France, Italy and Spain

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A B S T R A C T

This paper examines how France, Italy, and Spain integrate biodiversity conservation into renewable energy development under the European Green Deal (EGD). Based on a qualitative analysis of 46 national policy documents, we provide a comparative assessment of how these countries address the synergies and trade-offs between individual renewable energy sources (RES) and biodiversity, as well as the planned or implemented measures to manage them. Our results reveal that, while national policies address several links between RES and biodiversity, critical areas still require further management. Specific attention should be given to mitigating the impacts of changes in land use associated with bioenergy production and the installation of onshore wind and solar infrastructure on biodiversity and ecosystems. Careful consideration is also needed regarding the environmental impacts caused by marine and geothermal energy installations, as well as by hydropower development on rivers and floodplains. Sound spatial planning, ecosystem-based management, and integrated maritime policy are essential for reconciling renewable energy development with the conservation of terrestrial and marine ecosystems. Although national policies generally align with EGD provisions, strengthening environmental monitoring, and addressing indirect, cumulative, and long-term ecological impacts, particularly on habitats and species, remains a priority. Overall, our study emphasises the need for countries to adopt a holistic approach to renewable energy planning that systematically incorporates biodiversity considerations into energy and cross-sectoral policies.

1. Introduction

In the face of climate change, preventing biodiversity loss and promoting the expansion of renewable energy sources (RES) are two equally important policy objectives. The European Green Deal (EGD) aims to guide the European Union (EU) towards a low-carbon and resource-efficient economy while safeguarding its natural capital (EC, 2019). While RES offer various environmental, social, and economic benefits, their rapid growth may also result in conflicts with nature due to extensive land use, decentralised development, and rising energy demand (Bosch et al., 2020). Certain RES may adversely impact terrestrial and marine biodiversity by altering ecosystem processes, affecting habitats and species, and compromising the delivery of essential ecosystem services (Gasparatos et al., 2017; Hastik et al., 2015). A major challenge in policy formulation is the difference in scale between the local impacts on biodiversity, which usually occur at the level of a site or landscape, and the broader national-level benefits of RES, such as climate change mitigation, enhanced energy security, and economic growth (Gasparatos et al., 2017). This scale mismatch can lead to tensions between local biodiversity conservation and wider national socio-economic and environmental objectives. Other socio-economic factors, such as local community acceptance and competition for land and sea use, can also influence the feasibility and ecological outcomes of RES projects (Bosch et al., 2020; Salak et al., 2022). National policies are therefore essential for effectively managing these trade-offs and fostering synergies between renewable energy and biodiversity objectives.

In this paper, we examine how France, Italy, and Spain integrate biodiversity conservation into renewable energy development under the EGD. These countries are compelling case studies as they represent three

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major renewable energy systems in Southern Europe and share similar climatic and environmental conditions within the Euro-Mediterranean region. In the region, energy-biodiversity interactions are particularly pronounced due to strong pressures on land and sea and high ecological sensitivity. Beyond these shared characteristics, the three countries were selected to compare contrasting governance and spatial planning systems within a common EU policy framework, enabling a systematic assessment of how institutional arrangements influence biodiversity integration into renewable energy transitions. France has a centralised governance model, whereas Italy and Spain have regionally decentralised and multi-level systems, leading to differences in policy coordination and spatial planning approaches. Although all three countries operate under common EU directives and have adopted national climate and energy plans (NECPs), they have each developed their own national strategies, action plans, and legislation with specific objectives and measures. Recent studies show that the implementation of the EGD varies between Member States due to differences in institutional capacity, regulatory frameworks, and national priorities (Tutak and Brodny, 2024). National governments may prioritise the development of renewable energy for various purposes, such as mitigating climate change, ensuring energy security, or fostering economic growth. This can result, for example, in a limited focus on reducing greenhouse gas (GHG) emissions, potentially neglecting broader environmental impacts such as biodiversity loss and ecosystem disruption associated with large-scale RES deployment (Gasparatos et al., 2017). Recent studies emphasise the need for coherent and flexible EU policy guidance that enables national and local authorities to adapt measures to their specific conditions (Hajdukovic and Jessel, 2026; Paleari, 2024). Since national policies are central to translating the EGD into effective action, it is essential to assess how biodiversity considerations are integrated into energy planning at the country level.

The literature has increasingly investigated interlinkages across sectors such as energy, food, water, and resources, as well as wider socio-economic and environmental issues, including biodiversity, climate change, economic development, and the circular economy (e.g., Boas et al., 2016; Estoque, 2023; Hajdukovic and Jessel, 2026; Paleari, 2024). Despite growing research on the biodiversity and ecosystem impacts of RES (see Gasparatos et al., 2017), there are important gaps in understanding how biodiversity considerations are integrated into EU and national policies and translated into spatial planning across terrestrial and marine environments. Existing studies offer valuable insights into specific RES technologies and individual policy instruments (e.g., Jackson, 2011; OECD, 2024), yet comparative cross-country evidence on how biodiversity considerations are integrated across a wider range of RES within spatial planning, and how this varies across governance systems under a shared EU policy framework, remains limited. Although recent research emphasises the need for integrated, cross-sectoral policy development (e.g., Hajdukovic and Jessel, 2026; Rouillard et al., 2016), the mechanisms enabling effective integration across governance levels, sectors, and spatial and temporal scales are not well understood. This also limits the assessment of how consistently EGD provisions are reflected in national renewable energy policies and implemented across Member States.

This paper addresses these gaps by providing a comparative analysis of how biodiversity considerations are integrated into national policies for all RES in France, Italy, and Spain under the EGD, emphasising both terrestrial and marine environments. We use environmental policy integration (EPI) as an analytical framework, which conceptualises the integration of environmental objectives into the design and implementation of sectoral policies (Paleari, 2024) and is therefore well suited to analysing energy-biodiversity interactions (Hajdukovic and Jessel, 2026). EPI is operationalised by assessing the extent to which biodiversity objectives are embedded in renewable energy policies and the mechanisms used to promote synergies and manage trade-offs across different governance levels, sectors, and spatial and temporal scales. Our study draws on the objectives of the EU Biodiversity Strategy (EC, 2020), which guide Member States in aligning national policies with ecosystem protection, restoration, and the conservation of habitats and species. Following the definitions used in prior studies (e.g., Hajdukovic and Jessel, 2026; Pedercini et al., 2019; Rodríguez et al., 2006), we refer to synergies as mutually beneficial relationships in which renewable energy policies promote biodiversity objectives, and trade-offs as relationships in which these policies negatively affect biodiversity.

Against this background, we examine how national policies implement EGD provisions, identify cross-country similarities and differences, and highlight gaps and opportunities to strengthen integrated policy frameworks that better align biodiversity, climate, and energy objectives. We address two main research questions: (1) How are the synergies and trade-offs between individual RES (bioenergy, geothermal, hydropower, marine, solar, and wind) and biodiversity addressed in national policies, and what measures are planned or implemented to manage them? (2) To what extent are biodiversity considerations integrated into renewable energy planning, and what gaps and cross-country differences emerge? To answer these questions, we conduct a qualitative analysis of 46 policy documents from France, Italy, and Spain. Our findings reveal that, although progress has been made, there are important gaps in the management of trade-offs in terrestrial and marine areas, and the assessment of indirect, cumulative, and long-term ecological impacts. Strengthening cross-sectoral policy integration, spatial planning, and environmental monitoring is therefore essential to better align renewable energy development with biodiversity objectives and ensure sustainable energy transitions.

The remainder of the paper is organised as follows. Section 2 presents the methodology. Sections 3 and 4 describe national policies in the selected countries and provide a comparative analysis, respectively. Finally, Section 5 provides concluding remarks and policy implications.

2. Methodology

The methodology of this study consists of three phases: (i) the selection of policy documents, (ii) a structured document review, and (iii) a comparative analysis of national policies. To assess whether and how the links between individual RES and biodiversity are managed, we carry out a qualitative analysis of 46 policy documents: 15 from France, 13 from Italy, and 18 from Spain.

In Phase I, the documents were selected according to their content and relevance to renewable energy and biodiversity, their legal or strategic importance at the national level, and their availability as of March 2026. Only formally adopted national-level documents in force were included, and all materials were in a language accessible to the authors (English, French, Italian, and Spanish). Regional and local policy documents, EU-level instruments not transposed into national frameworks, draft or non-adopted texts, and non-binding guidance documents were excluded. This purposive selection approach ensured relevance to the study objectives while recognising that not all potentially relevant documents were available. Potential selection bias was mitigated through the consistent application of these inclusion criteria across all cases and the systematic coverage of key thematic areas (e.g., energy, environment, and cross-sectoral policy), thereby enhancing comparability and reducing the risk of thematic omission. The documents were then grouped into four policy domains: 19 on climate and energy, 13 on biodiversity and ecosystems, 4 on the circular economy, and 10 on cross-cutting issues (see Tables 1, 3, and 5). The analysis also includes legislative documents that underpin the implementation of national strategies, plans, and actions for renewable energy and biodiversity. Document retrieval and selection were carried out between May 2025 and March 2026.

In Phase II, the documents were reviewed using structured qualitative document analysis as the core analytical method, based on the predetermined analytical categories developed by Hajdukovic and Jessel (2026). The analysis involved a systematic and iterative close reading of all documents across thematic areas, during which relevant policy content was identified, extracted, and organised using these categories. We applied interpretive content analysis, cross-case comparison, and synthesis across RES technologies and policy domains to examine how the renewable energy-biodiversity links are addressed in national policy contexts. Rather than applying a formal coding scheme, the analysis relied on this category-based approach to provide the interpretive flexibility required by the highly heterogeneous nature of the policy texts while maintaining analytical consistency. Consistency was ensured through repeated application of the predetermined categories, systematic cross-checking of extracted statements between researchers, and iterative comparison of interpretations within and across country cases.

The analytical categories guided the identification of synergies, trade-offs, and planned or implemented measures for each RES. The measures considered include legislation and other instruments, such as spatial planning tools, financing instruments, research projects, programmes, networking activities, cross-sectoral cooperation, monitoring mechanisms, and environmental assessments. The categories comprise: (i) explicit considerations of biodiversity and ecosystems; (ii) indirect terminology related to biodiversity and ecosystems, such as "ecological connectivity", "ecosystem services", "environmental impact", "habitats", "land/sea use planning", "landscape impact", or "species"; and (iii) planned or implemented measures aimed at managing conflicts or enhancing synergies. The first author conducted the initial review of all documents, after which the research group jointly examined and validated the identified links and their interpretation. Discrepancies were resolved by re-examining the relevant passages in their full policy context and agreeing on the most appropriate interpretation. The qualitative analysis is reproducible through the systematic application of the analytical categories across all documents, enabling consistent identification and comparison of policy content. To ensure transparency and replicability, Tables A.4 and A.5 provide the full list of biodiversity-related terminology searched and examples of how explicit and implicit links between RES and biodiversity were identified. This approach preserves interpretive depth while enabling a systematic comparison of complex policy language, intricate links, and multi-level governance mechanisms, which may not be fully captured by formal coding approaches.

In Phase III, the measures planned and implemented to address potential impacts on biodiversity were mapped for each RES. A comparative analysis of national policies was then conducted to highlight similarities and differences, and evaluate progress and remaining gaps in the integration of biodiversity considerations into renewable energy planning.

This study has some limitations. First, the identified links between RES and biodiversity represent the content and priorities of national policy documents. These links could stem from scientific research, stakeholder perspectives, or the interpretations of policymakers, and may not reflect all the relevant links documented in the scientific literature. Second, evaluating the integration of EGD provisions into national policies is challenging as many measures are in the early stages of implementation or translation. This analysis reflects policies as of March 2026 and may therefore not fully anticipate future legislative revisions or policy developments. In addition, the study does not include regional and local policies, which limits the representation of subnational measures. Finally, comparable quantitative indicators for RES planning are not consistently available due to differences in definitions, governance structures, and reporting systems, which limits quantitative comparison. Despite these limitations, this study contributes to understanding how renewable energy and biodiversity objectives are integrated into national policies under the EGD, thereby supporting more effective policy design and implementation.

3. National policies for renewable energy and biodiversity in France, Italy, and Spain

This section presents the results of the qualitative analysis of national policies in France, Italy, and Spain, focusing on the links between individual RES (bioenergy, geothermal, hydropower, marine, solar, and wind) and biodiversity, as well as the measures planned or implemented to enhance synergies and manage trade-offs.

3.1. France

3.1.1. Policy framework

France has adopted a net-zero target for 2050 in its Energy-Climate Law (République française, 2019), with an interim target of reducing emissions by 55% compared to 1990 levels by 2030. These targets are to be achieved through energy efficiency and renewable energy measures, which are supported by investments under the Multiannual Planning for Energy (MTES, 2020a) and five-year carbon budgets of the National Low-carbon Strategy (MTES, 2020b). The Law on Accelerating Renewable Energy Production (République française, 2023a) establishes a framework for identifying suitable areas for renewable energy development that have minimal environmental impact, in line with national strategies (MTE, 2023; MTEBFMP, 2025; MTECT, 2023; MTES, 2020a; République française, 2024a, 2025b). These renewable acceleration areas (RAAs) cover all RES in France and are designated by municipalities through local authority involvement and public consultations. As mandated by Article 20, an observatory was established in 2024 to monitor the impacts of onshore renewable energy on biodiversity, soils, and landscapes, operating independently from the National Offshore Wind Observatory. However, systematic national monitoring of all RES and data standardisation are still under development. Another important reform was the establishment of the General Secretariat for Ecological Planning in 2022. This body coordinates the development of national strategies, mobilises ministries and stakeholders, and monitors the ecological performance of implemented actions to ensure

Table 1
National policy documents analysed for France.

Policy document	Issuing authority
Climate and energy	
Stratégie Française pour L'énergie et le Climat (French Strategy for Energy and Climate)	MTE (2023)
Programmation Pluriannuelle de l'Énergie 2019–2028 (Multiannual Planning for Energy 2019–2028)	MTES (2020a)
Stratégie Nationale Bas-carbone (National Low-carbon Strategy)	MTES (2020b)
Code de l'Energie (Energy Code)	République française (2011b)
Loi Énergie-Climat (Energy-Climate Law)	République française (2019)
Loi Relative à l'Accélération de la Production d'Énergies Renouvelables (Law on Accelerating Renewable Energy Production)	République française (2023a)
Plan National Intégré Énergie-Climat (National Integrated Energy and Climate Plan)	République française (2024a)
3e Plan National d'Adaptation au Changement Climatique (3rd National Climate Change Adaptation Plan)	République française (2025b)
Biodiversity and ecosystems	
Plan d'Action pour la Préservation des Sols Forestiers (Action Plan for Sustainable Forest Management)	MTEBFMP (2025)
Stratégie Nationale Biodiversité 2030 (National Biodiversity Strategy 2030)	MTECT (2023)
Stratégie Nationale pour la Mer et le Littoral 2024–2030 (National Strategy for the Sea and the Coastline 2024–2030)	République française (2024b)
Circular economy	
Stratégie Nationale de Mobilisation de la Biomasse (National Biomass Mobilisation Strategy)	MTES (2018)
Cross-cutting issues	
Plan Stratégique National de la PAC 2023–2027 (National Strategic Plan for the CAP 2023–2027)	MASA (2022)
Code de l'Environnement (Environmental Code)	République française (2000)
Mise à jour du Plan National de Relance et de Résilience (Update of the National Recovery and Resilience Plan)	République française (2023b)

compliance with EU objectives (République française, 2023b).

3.1.2. National policy for renewable energy and biodiversity

The use of biomass for bioenergy production can result in changes in land use that affect biodiversity through habitat loss and fragmentation, soil, water, and air quality degradation, and altered landscape connectivity (MTES, 2018, 2020a). National strategies (MASA, 2022; MTE, 2023; MTEBFMP, 2025; MTECT, 2023; MTES, 2018, 2020a; République française, 2024a) emphasise the need to meet increasing demand for biomass energy without compromising other priorities, such as food production, carbon sequestration, and biodiversity protection. In line with circular economy principles (MTES, 2018), national energy strategies (MTE, 2023; MTES, 2020a, 2020b; République française, 2024a) prioritise the use of residues and waste from agriculture and forestry as the main feedstock for bioenergy. Building on the Energy Code (Art. L281–1 to L281–13; République française, 2011b), France is transposing the Renewable Energy Directive (EU, 2023) into national law by applying strengthened sustainability and GHG emission reduction criteria to prevent biomass production in carbon-rich or biodiversity-sensitive areas. New forest harvesting rules, such as limits on deadwood extraction and large clear-cuts, aim to minimise impacts on biodiversity and soils (MTEBFMP, 2025). France also applies the cascading principle, prioritising biomass use for human and animal nutrition, carbon sinks, and soil fertility over energy production, while favouring low-carbon alternatives for heating, transport, and electricity generation (MTE, 2023; MTES, 2018; République française, 2024a). Governance is reinforced through regional biomass cells that monitor biomass use, engage with stakeholders, and provide tools (e.g., forest biomass maps) (MTE, 2023; MTES, 2018; République française, 2024a). Nevertheless, the effectiveness of biomass cells is hindered by limited access to data on forest resources, biomass availability, and land-use change.

Solar energy, particularly ground-mounted photovoltaic (PV) panels, can have a negative impact on biodiversity and ecosystems, primarily through habitat loss and fragmentation resulting from changes in land use (MTES, 2020a). To minimise these impacts, national legislation (République française, 2023a) and strategies (MTE, 2023; MTES, 2020a) promote the installation of solar panels on sites of low environmental value, such as rooftops, roadsides, and artificialised areas. In contrast, installations in natural, agricultural, and forest areas are only permitted in designated zones, provided they do not conflict with agricultural production or sustainable forest management, and involve the loss of no >25 hectares of forest (MTE, 2023). In line with Article 54 of the Law on Accelerating Renewable Energy Production (République française, 2023a), national energy strategies (MTE, 2023; République française, 2024a) encourage the installation of agrivoltaic systems that support multiple objectives, such as increasing agricultural productivity and enhancing climate resilience and animal welfare.

Onshore wind energy can affect biodiversity and ecosystems, particularly habitats and avian species, and present challenges for landscape integration (MTES, 2020a). Wind farm projects must undergo an environmental impact assessment (EIA) to evaluate the potential effects on landscapes, wildlife (e.g., birds and bats), and noise, and to propose mitigation measures (e.g., for habitat and species protection). National energy strategies (MTES, 2020b; République française, 2024a) also emphasise the need to increase the circularity of raw material use in RES technologies to reduce pressure on ecosystems. Article 29 of the Decree of 26 August 2011 (République française, 2011a) requires turbine and cable dismantling at end of life, excavation of foundations to specified depths, site restoration, and the reuse or recycling of materials. Careful management is also required for geothermal energy development, as drilling and exploitation can pose environmental risks, such as induced seismicity, groundwater pollution, and resource depletion (MTES, 2020a). Geothermal energy projects are regulated by the Mining Code (Arts. L112-1 to L112-3; République française, 2011c), the Environmental Code (Art. R.122-2; République française, 2000), and Decree

Table 2
Measures planned or implemented to address biodiversity impacts of RES in France.

RES	Biodiversity and ecosystem impacts	Measures planned or implemented	Sources
Bioenergy	Habitat loss and fragmentation; soil, water, and air quality degradation; landscape connectivity alteration	- Promote the use of residues and waste from agriculture and forestry for bioenergy - Apply strengthened sustainability and GHG emission reduction criteria - Set harvesting requirements (e.g., limits on deadwood extraction and large clear-cuts) - Apply cascading principle for biomass use - Strengthen governance through biomass cells	(MTE, 2023; MTEBFMP, 2025; MTES, 2018, 2020a, 2020b; République française, 2024a)
Solar energy	Habitat loss and fragmentation associated with land-use changes	- Prioritise sites of low environmental value (e.g., rooftops, roadsides, artificialised areas) - Allow installations on natural areas only in designated zones without conflicts with agriculture and forest management - Promote the use of agrivoltaic systems	(MTE, 2023; MTES, 2020a; République française, 2023a, 2024a)
Wind energy	Potential impacts on habitats, birds, and bats; landscape integration	- Conduct EIAs for species, noise, and landscape impacts, with mitigation measures - Dismantle turbines and cables at end-of-life, excavate foundations to specified depths, and promote circularity of materials use	(MTES, 2020a, 2020b; République française, 2024a)
Hydropower	Altered hydrological regimes and fish migration downstream; disrupted ecological continuity and sediment transport; fish mortality	- Strengthen regulations to maintain minimum river flows, restore ecological continuity, and install devices that reduce fish mortality - Assess environmental impacts of projects, particularly with regard to aquatic life and the cumulative impacts on biodiversity - Increase hydropower capacity by optimising existing plants and supporting the development of environmentally compatible small-scale hydroelectric plants through calls for tenders	(MTE, 2023; MTES, 2020a; République française, 2023a, 2024a)
Marine energy	Impacts on marine ecosystems,	- Manage environmental	(MTECT, 2023; MTES, 2020a;

(continued on next page)

Table 2 (*continued*)

RES	Biodiversity and ecosystem impacts	Measures planned or implemented	Sources
	habitats, and species	impacts through Environmental Code authorisations, with EIAs and public consultation required - Implement maritime spatial planning based on an ecosystem approach - Map priority maritime and coastal zones for installations, with spatial planning coordinated with local authorities to protect biodiversity - Strengthen environmental monitoring, including cumulative impacts via initiatives such as National Offshore Wind Observatory	République française, 2023a, 2024b)
Geothermal energy	Induced seismicity; groundwater pollution; resource depletion	- Regulate projects under the Mining code and the Environmental code - Conduct EIAs except for low-impact drilling	(MTES, 2020a; République française, 2000)

Table 2 provides an overview of planned and implemented measures in France to address biodiversity and ecosystem impacts of RES, based on national policy documents.

No 2025-852 (République française, 2025a). According to Section 27.a of the Annex to Article R.122–2 of the Environmental Code, projects involving drilling for the exploration or exploitation of geothermal resources must undergo an environmental assessment unless they are deemed to have minimal impact.

The impact of hydropower projects on aquatic ecosystems varies depending on their size and location. For example, small-scale installations can alter hydrological regimes and fish migration downstream, whereas large-scale projects can disrupt ecological continuity and sediment transport (MTES, 2020a). In line with EU directives (EU, 2000, 2014a, 2023), national regulations have been strengthened to ensure that minimum river flows are maintained, ecological continuity is restored, and devices that reduce fish mortality are installed (MTES 2020a). These issues are considered during project reviews under the Water law (République française, 2006), which governs authorisation procedures and concession applications. Article 75 of the Law on Accelerating Renewable Energy Production (République française, 2023a) requires hydropower projects to assess their environmental impacts, particularly with regard to aquatic life and the cumulative impacts on biodiversity. Moreover, national energy strategies (MTE, 2023; République française, 2024a) aim to increase hydropower capacity by optimising existing plants and supporting the development of new small-scale hydroelectric plants through tendering processes, while safeguarding biodiversity, water quality, and ecological continuity.

In France, renewable marine energy includes various technologies that generate electricity from the sea, such as tidal, wave, ocean thermal, osmotic, and offshore wind energy, with the latter being the most advanced (MTE, 2026). The construction and operation of these installations can affect marine ecosystems, habitats, and species (MTES, 2020a), and are subject to authorisation procedures under the Environmental Code (République française, 2000), which require EIAs and public consultation. Article 56 of the Law on Accelerating Renewable Energy Production (République française, 2023a) requires the mapping of priority maritime and coastal zones for marine energy installations over a ten-year horizon. Within this framework, the National Strategy for the Sea and the Coastline 2024–2030 (République française, 2024b) prioritises the implementation of maritime spatial planning based on a holistic ecosystem approach and coordination with local authorities to protect and restore marine biodiversity. National biodiversity strategies (MTECT, 2023; République française, 2024b) further emphasise the need to improve knowledge of marine ecosystems and to strengthen environmental monitoring of marine energy, particularly with regard to cumulative impacts, which is supported by initiatives such as the National Offshore Wind Observatory.

3.2. Italy

3.2.1. Policy framework

Italy aims to achieve carbon neutrality by 2050 and is making progress towards its 2030 greenhouse gas reduction targets, with RES expected to supply 40% of total energy consumption and 65% of electricity generation (MASE, 2024b). National strategies (MASAF, 2022; MASE, 2022, 2023a, 2023b, 2024b; MIPAAF, 2022; MISE and MATTM, 2017) promote the deployment of renewable energy in a way that safeguards landscapes, air and water quality, biodiversity, soils, and carbon-rich ecosystems (e.g., forests and agricultural lands). The National Biodiversity Strategy 2030 (MASE, 2023b) sets the legal commitment to protecting at least 30% of terrestrial and marine areas through an integrated network of protected zones, including sites within the Natura 2000 network. As the primary legal framework for implementing the Renewable Energy Directive (EU, 2018), Decree No 199/2021 (Governo Italiano, 2021a) provides the necessary tools, mechanisms, and regulatory provisions to meet renewable energy targets in line with wider sustainability objectives. Italy adopted the Ministerial Decree of 21 June 2024 ("Suitable Areas") (MASE, 2024a), which establishes criteria for identifying suitable and unsuitable areas for renewable energy installations, and assigns regions responsibility for implementing these classifications to meet national renewable energy targets. Subsequently, Decrees 190/2024 (Governo Italiano, 2024) and 73/2025 (Governo Italiano, 2025a) introduce RAAs and simplified permitting processes. Furthermore, Decree 175/2025 (Governo Italiano, 2025b) provides updates to the provisions for identifying these areas. Nevertheless, some aspects of the Ministerial Decree of 21 June 2024 are still facing legal challenges and require revision, and full implementation depends on regions adopting their own plans in accordance with national criteria and timelines. While individual EIAs are carried out, Italy currently lacks a comprehensive framework for systematically monitoring and assessing the cumulative biodiversity impacts of multiple RES projects across regions.

3.2.2. National policy for renewable energy and biodiversity

National strategies (MASE, 2023b, 2024b; MISE and MATTM, 2017; MIPAAF, 2022; MITE, 2022a; PCM, 2017) promote the use of agricultural and forestry residues and waste for bioenergy to improve resource efficiency and prevent changes to land use that could negatively affect biodiversity and ecosystems. In line with the Renewable Energy Directives (EU, 2018, 2023), Italy enforces sustainability and GHG emission reduction criteria for biomass. According to Article 42 of Decree No 199/2021 (Governo Italiano, 2021a), producing biofuels, bioliquids, and biomass fuels in areas of high biodiversity or carbon stock is prohibited with limited exceptions. By contrast, fuels derived from waste, residues, or sustainably managed forest biomass are allowed only if they meet the sustainability and GHG emission reduction criteria to qualify for national support schemes. The NECP (MASE, 2024b) outlines Italy's planned contribution of advanced biofuels and renewable fuels of non-biological origin to the transport sector. This includes the phasing out of biofuels with a high risk of indirect land use change (ILUC) (e.g., animal fats and palm oil) and the limitation of first-generation biofuels derived from food and feed crops. Moreover, Italy applies the cascading

Table 3
National policy documents analysed for Italy.

Policy document	Issuing authority
Climate and energy	
Decreto Legislativo 8 Novembre 2021, n. 199 (Legislative Decree No 199 of November 8, 2021)	Governo Italiano (2021a)
Piano Nazionale di Adattamento ai Cambiamenti Climatici (National Plan for Climate Change Adaptation)	MASE (2023a)
Piano Nazionale Integrato per l'Energia e il Clima (National Integrated Energy and Climate Plan)	MASE (2024b)
Strategia Energetica Nazionale (National Energy Strategy)	MISE & MATTM (2017)
Piano per la Transizione Ecologica (Ecological Transition Plan)	MITE (2022a)
Biodiversity and ecosystems	
Strategia Nazionale Biodiversità 2030 (National Biodiversity Strategy 2030)	MASE (2023b)
Decreto 21 giugno 2024: Disciplina per l'individuazione di superfici e aree idonee per l'installazione di impianti a fonti rinnovabili [Decree of 21 June 2024: Regulation for the identification of suitable surfaces and areas for renewable energy installations]	MASE (2024a)
Strategia Forestale Nazionale (National Forest Strategy)	MIPAAF (2022)
Circular economy	
Strategia Nazionale per l'Economia Circolare (National Strategy for the Circular Economy)	MITE (2022b)
Cross-cutting issues	
Piano Nazionale di Ripresa e Resilienza (National Recovery and Resilience Plan)	Governo Italiano (2021b)
Piano Strategico della PAC 2023–2027 (CAP Strategic Plan 2023–2027)	MASAF (2022)
Strategia Nazionale per lo Sviluppo Sostenibile (National Strategy for Sustainable Development)	MASE (2022)
Strategia Italiana per la Bioeconomia (Italian Bioeconomy Strategy)	PCM (2017)

principle for biomass, prioritising material use over energy use, but its integration into policy and support mechanisms is still ongoing (MIPAAF, 2022; MISE and MATTM, 2017; MITE, 2022a, 2022b; PCM, 2017).

Solar PV systems, particularly large ground-mounted installations, can affect biodiversity and ecosystems through changes in land-use, whereas onshore wind mainly presents challenges for landscape protection (MASE, 2024b; MISE and MATTM, 2017). In accordance with Article 20 of Decree No. 199/2021 (Governo Italiano, 2021a), the Ministerial Decree of 21 June 2024 (MASE, 2024a) sets out uniform criteria for regions to classify areas as suitable, unsuitable, or ordinary for the installation of renewable energy plants, and to identify areas where ground-mounted PV in agricultural zones is restricted. However, some provisions remain subject to revision, and specific mitigation measures to protect habitats and species from solar and wind energy development have yet to be fully defined. In terms of synergies, national policies (Governo Italiano, 2021b; MASAF, 2022; MASE, 2023b, 2024b) promote the use of agrivoltaic systems, which combine solar energy production with agricultural activities. According to the National Biodiversity Strategy (MASE, 2023b), guidelines and criteria will be established for designing and selecting sites for solar PV and agrivoltaic systems on agricultural land to protect biodiversity, maintain agricultural production, and minimise land-use changes. The National Recovery and Resilience Plan (Governo Italiano, 2021b) includes a specific investment measure (M2C2.1) to support the deployment of agrivoltaic systems and monitor their impact on energy production, agricultural productivity, water use, soil fertility, and microclimate. Furthermore, national energy strategies (MASE, 2024b; MISE and MATTM, 2017) encourage the repowering of wind installations to reduce associated land and material use, but careful mitigation measures are needed to prevent local ecological impacts.

The environmental and landscape impacts of hydropower are primarily addressed through the minimum operational requirements and compliance with the Water Framework Directive (EU, 2000) and EIA

Table 4
Measures planned or implemented to address biodiversity impacts of RES in Italy.

RES	Biodiversity and ecosystem impacts	Measures planned or implemented	Sources
Bioenergy	Biodiversity loss and ecosystem disturbance associated with land use change from biomass use	- Promote the use of agricultural and forest residues and waste for bioenergy production - Apply sustainability and GHG emission reduction criteria - Apply the cascading principle for biomass use - Prohibit biofuels from high-biodiversity or high-carbon-stock areas, with limited exceptions - Incentivise advanced biofuels, while limiting biofuels from food and feed crops, animal fats, and palm oil unless low-ILUC risk certified	(Governo Italiano, 2021a; MASE, 2023b, 2024b; MIPAAF, 2022; MISE and MATTM, 2017; MITE, 2022a, 2022b; PCM, 2017)
Solar energy	The impact of large ground-mounted PV installations on agricultural land, biodiversity, and ecosystems	- Set uniform criteria for designing suitable, unsuitable, ordinary areas, and agricultural zones where ground-mounted PV is restricted - Promote agrivoltaic and solar PV systems through guidelines and criteria for design and siting, as well as targeted investment measures	(Governo Italiano, 2021a, 2021b; MASAF, 2022; MASE, 2023b, 2024a, 2024b; MISE and MATTM, 2017)
Wind energy	Ecosystems and habitat disruption; landscape integration	- Set uniform criteria for designing suitable, unsuitable, and ordinary areas - Promote the repowering of wind installations to reduce associated land and material use	(Governo Italiano, 2021a; MASE, 2024a, 2024b; MISE and MATTM, 2017)
Hydropower	Environmental and landscape impacts on river ecosystems and their surroundings	- Require minimum river basin restoration and environmental improvements in concessions - Allocate a portion of concession revenues to measures that support the protection and restoration of affected water bodies - Prioritise repowering and upgrading existing plants and projects on disused areas	(MASE, 2024b; MISE and MATTM, 2017)
Marine energy	Impacts on marine ecosystems, habitats, and species	- Define technical, legislative, financial, and policy measures to achieve and maintain GES - Implement ecosystem-based maritime spatial planning for the identification of suitable sites	(Governo Italiano, 2010, 2016, 2021a; MASE, 2023b, 2024b)

(continued on next page)

Table 4 (*continued*)

RES	Biodiversity and ecosystem impacts	Measures planned or implemented	Sources
		- Use technical guidelines and working groups to support implementation and monitoring of maritime spatial plans - Support research for the development of low-impact offshore wind technologies	
Geothermal energy	Environmental and landscape impacts	- Prioritise repowering and upgrading of existing plants and projects on disused areas - Apply standard planning requirements and EIA	(MISE and MATTM, 2017)

Table 4 provides an overview of planned and implemented measures in Italy to address biodiversity and ecosystem impacts of RES, based on national policy documents.

Directive (EU, 2014a). Large hydropower concessions, which are managed at a regional level, must ensure that minimum levels of river basin restoration and environmental improvement are met (MASE, 2024b). They are also required to allocate a portion of their revenues to measures that support the protection and restoration of affected water bodies. In line with the Water Framework Directive (EU, 2000), Italy has adopted national river basin management plans for the 2021–2027 planning cycle, although implementation varies by region. To minimise environmental impacts, Italy promotes the repowering and upgrading of hydropower and geothermal plants, and encourages projects in disused areas (MISE and MATTM, 2017). The environmental risks of geothermal energy are addressed through planning requirements and EIAs, even though measures to mitigate biodiversity impacts remain limited.

To promote sustainable maritime development, Italy transposed the Marine Strategy Framework Directive (EU, 2008) into national law through Decree 190/2010 (Governo Italiano, 2010), establishing a framework for setting environmental targets, legislative, technical, policy, and financial measures, and coordinated monitoring to achieve good environmental status (GES). The Maritime Spatial Planning Directive (EU, 2014b) was implemented via Decree No 201/2016 (Governo Italiano, 2016), providing a basis for ecosystem-based maritime spatial planning that balances socio-economic and environmental objectives in line with the National Biodiversity Strategy (MASE, 2023b). Maritime spatial plans for the Adriatic, Ionian-Central Mediterranean, and Tyrrhenian-Western Mediterranean areas were adopted through Ministerial Decree No 237 of 25 September 2024. The implementation and monitoring of these plans is supported by the establishment of technical guidelines and working groups (MASE, 2026). Article 23 of Decree 199/2021 (Governo Italiano, 2021a) sets authorisation procedures for offshore installations and the identification of suitable areas to align with maritime spatial plans while safeguarding marine ecosystems and landscape values. With the growing potential of offshore wind, current research focuses on developing low-impact technologies adapted to Mediterranean conditions to balance energy production with biodiversity objectives (MASE, 2024b). However, challenges remain due to delays in maritime spatial plan implementation, limited integration of cumulative impact assessments, and gaps in biodiversity data availability.

3.3. Spain

3.3.1. Policy framework

The Spanish framework for climate and energy is guided by the 2050 objectives of national climate neutrality, 100% renewable electricity, and 97% renewable energy in the total energy mix, with large-scale deployment of RES and measures to increase energy efficiency (IEA, n. d.). In line with national legislation (Cortes Generales de España, 2021) and strategies (Gobierno de España, 2021; IDAE, 2011; MITECO, 2020, 2020c, 2021a, 2021b, 2022a, 2022b, 2022c, 2022f; MITECO and MCIN, 2022), Measure 1.1 of the NECP (MITECO, 2024) aims to strengthen renewable energy development in a way that is compatible with the conservation of biodiversity by ensuring that projects are appropriately located and integrated with other land and sea uses. Key policy mechanisms under development include territorial zoning, best-practice guidelines, defined environmental criteria for energy planning, enhanced environmental monitoring through research and development (R&D), coordinated regional planning, and stakeholder collaboration. Article 21(2) of the law requires the Ministry for the Ecological Transition and Demographic Challenge (MITECO) to establish and regularly update a zoning tool, in coordination with the Autonomous Communities. This tool uses scientific data to identify areas that should be protected or excluded from the deployment of RES based on their biodiversity value, ecological connectivity, and the provision of ecosystem services. RES projects must avoid disturbing natural habitats, fauna, and flora, and ensure that protected areas and Natura 2000 sites remain unaffected (MITECO, 2024). The NECP emphasises the need to minimise land occupation, apply buffer distances, and prioritise locations of low environmental value or areas that have already been degraded. Projects must also adhere to the principle of no net biodiversity loss, and EIAs must be conducted with preventive, corrective, and compensatory measures in place for construction and operation phases (MITECO, 2024). In compliance with the Renewable Energy Directive (EU, 2023), Spain is designating RAAs to facilitate the faster deployment of RES, although a nationwide set covering all RES has not yet been finalised, with current efforts largely at the regional or draft stage. While individual EIAs are being conducted, a systematic approach to assessing the cumulative and long-term impact of multiple RES projects on both terrestrial and marine biodiversity is still in development.

3.3.2. National policy for renewable energy and biodiversity

In line with national biodiversity strategies (MITECO, 2022b, 2022f, 2023b; MITECO and MCIN, 2022), Spain is promoting the sustainable production of bioenergy from biomass by applying sustainability and GHG emission reduction criteria. The amendments to the Renewable Energy Directive (EU, 2023) are being incorporated into national legislation, with a particular focus on reviewing the sustainability criteria for harvesting biomass and aligning policies with the cascading principle (MITECO, 2024). The State Strategic Plan for Natural Heritage and Biodiversity to 2030 (MITECO, 2023b) and the NECP (MITECO, 2024) state that the sustainability of biomass raw materials and biofuels will be verified, including the impacts of ILUC on biodiversity, although the verification mechanisms have yet to be specified. Consistent with circular economy principles (MITECO, 2020b, 2022d), national strategies (MAPA, 2022; MITECO, 2022b, 2022c, 2024) prioritise the use of residues and waste from biomass as the primary feedstock for bioenergy production to minimise impacts on biodiversity and ecosystems. Spain is also gradually phasing out conventional crop-based biofuels in favour of advanced biofuels, which have lower biodiversity impacts (MITECO, 2023b, 2024).

The development of new solar and wind energy infrastructure can affect biodiversity and ecosystems, primarily due to habitat loss, fragmentation, and collision risks for species such as steppe birds (MITECO, 2021a, 2022a, 2023b, 2024). To mitigate these impacts, solar and wind energy projects must avoid critical areas for steppe birds and apply ecological compatibility criteria. Regional sensitivity maps developed

Table 5
National policy documents analysed for Spain.

Policy document	Issuing authority
Climate and energy	
Ley 7/2021 de Cambio Climático y Transición Energética (Law 7/2021 on Climate Change and Energy Transition)	Cortes Generales de España (2021)
Plan de Energías Renovables 2011–2020 (Renewable Energy Plan 2011–2020)	IDAE (2011)
Plan Nacional de Adaptación al Cambio Climático 2021–2030 (National Climate Change Adaptation Plan 2021–2030)	MITECO (2020c)
Hoja de Ruta para desarrollo de Eólica Marina y Energías del Mar (Roadmap for Offshore Wind and Marine Energy Development)	MITECO (2021b)
Hoja de Ruta del Biogás (Roadmap of Biogas)	MITECO (2022c)
Plan Nacional Integrado de Energía y Clima (National Integrated Energy and Climate Plan)	MITECO (2024)
Biodiversity and ecosystems	
Estrategia Nacional de Infraestructura Verde y de la Conectividad y Restauración Ecológicas (National Strategy for Green Infrastructure and Ecological Connectivity and Restoration)	MITECO (2021a)
Estrategia de Conservación de Aves Amenazadas Ligadas a Medios Agro-esteparios en España (Conservation Strategy for Threatened Birds of Agro-Steppe Habitats in Spain)	MITECO (2022a)
Estrategia Forestal Española Horizonte 2050 (Spanish Forest Strategy Horizon 2050)	MITECO (2022b)
Plan Forestal Español 2022–2032 (Spanish Forest Plan 2022–2032)	MITECO (2022f)
Estrategia de Biodiversidad y Ciencia (2023–2027) (Strategy for Biodiversity and Science (2023–2027))	MITECO & MCIN (2022)
Estrategia Nacional de Restauración de Ríos 2023–2030 (National Strategy for River Restoration 2023–2030)	MITECO (2023a)
Plan Estratégico Estatal del Patrimonio Natural y Biodiversidad a 2030 (State Strategic Plan for Natural Heritage and Biodiversity to 2030)	MITECO (2023b)
Circular economy	
Estrategia Española de Economía Circular: España Circular 2030 (Spanish Circular Economy Strategy: Spain Circular 2030)	MITECO (2020b)
Hoja de Ruta para la Gestión Sostenible de las Materias Primas Minerales (Roadmap for the Sustainable Management of Mineral Raw Materials)	MITECO (2022d)
Cross-cutting issues	
Plan de Recuperación, Transformación y Resiliencia (Recovery, Transformation, and Resilience Plan)	Gobierno de España (2021)
Plan estratégico de la PAC de España 2023–2027 (Spain's CAP Strategic Plan 2023–2027)	MAPA (2022)
Estrategia a Largo Plazo para una Economía Española Moderna, Competitiva y Climáticamente Neutra en 2050 (Long-term Strategy for a Modern, Competitive, and Climate-Neutral Spanish Economy in 2050)	MITECO (2020a)

by MITECO and regional administrations should be used to maintain ecological connectivity, particularly for migratory species (MITECO, 2022a, 2024). Installations within special protection areas for birds (ZEPA) are restricted and require the avoidance of sensitive habitats and the implementation of compensation measures for any habitat loss (MITECO, 2022a), in compliance with the Habitats Directive (EU, 1992) and the Birds Directive (EU, 2009). Public administrations are also encouraged to mitigate the threat posed to birds and bats by infrastructure barriers such as wind farms and power lines (MITECO, 2021a). Where EIAs are required, projects must implement standardised monitoring of fauna, flora, habitats, and geological sites, in accordance with national guidelines (e.g., the methodological guide for assessing the impact of solar installations on steppe avian species) (MITECO, 2024). The Circular Repowering Programme (Order TED/1071/2022) (MITECO, 2022e) also promotes the repowering of wind farms to improve their environmental integration and enhance their coexistence with local natural ecosystems. By contrast, the development of geothermal energy is subject to fragmented environmental legislation (e.g., Law 21/2013 on Environmental Assessment, Mining Law 22/1973, Water Act 1/2001) and lacks specific biodiversity protection guidelines. Consequently, its potential ecological impacts are assessed on a case-by-case basis through standard permitting and EIA procedures (MITECO, 2024).

In hydropower systems, transverse structures such as dams and weirs can fragment river habitats, restricting the movement of migratory fish and altering sediment dynamics (MITECO, 2023a). In line with national biodiversity strategies (MITECO, 2021a, 2023a), the NECP (MITECO, 2024) emphasises the importance of maintaining ecological flows and river connectivity. This requires careful consideration of rivers and their surrounding habitats, as well as the application of compensatory mechanisms where necessary, to mitigate impacts on river ecosystems. According to Article 7 of the Law on Climate Change and Energy Transition (Cortes Generales de España, 2021), reversible hydropower plants must be developed in accordance with the environmental objectives of water bodies and the ecological flow regimes specified in river basin management plans. The National Strategy for Green Infrastructure, Ecological Connectivity and Restoration (MITECO, 2021a) promotes mechanisms to design, construct, and operate hydropower plants that are compatible with ecological connectivity. These mechanisms are further specified in the National Strategy for River Restoration 2023–2030 (MITECO, 2023a), with examples including the improvement of river permeability via fishways or bypass channels. Furthermore, the Circular Repowering Programme (Order TED/1071/2022) establishes a regulatory basis for investment aid programmes supporting the environmental and technological renovation of mini-hydropower plants (MITECO, 2024).

In Spain, national strategies (IDAE, 2011; MITECO, 2021b, 2023b, 2024; MITECO and MCIN, 2022) emphasise the need to carefully plan the development of marine energy to prevent negative environmental impacts on marine ecosystems. The ecosystem-based approach to maritime spatial planning provides a framework for organising sea uses and identifying offshore sites for energy production that safeguard biodiversity, with EIAs ensuring site viability on a case-by-case basis (MITECO, 2021b, 2024). Maritime zoning translates planning objectives into action by designating specific areas and prioritising the protection of ZEPA sites, habitats of community interest, and critical areas for seabirds and other sensitive species, while also identifying areas with high biodiversity conservation potential (MITECO, 2021b, 2024). In line with the SEA of the PNIEC, a guide will be developed to define criteria and best practices for the design, siting, installation, and maintenance of marine energy projects, making use of environmental monitoring, indicators, and international standards (MITECO, 2021b). The Roadmap for Offshore Wind and Marine Energy Development (MITECO, 2021b) emphasises the importance of improving our understanding of the marine environment and the impact of marine energy technologies through R&D. This is expected to support EIAs, future maritime spatial planning, and the exploration of multiple sea uses (e.g., the co-location of offshore wind and aquaculture). Finally, the deployment of marine energy requires continuous biodiversity monitoring and assessment of the interactions and impacts of multiple sea uses, which can provide a technical and data basis for decision-making (MITECO, 2021b).

4. A comparative analysis of national policies on renewable energy and biodiversity

This section provides a comparative analysis of national policies on renewable energy and biodiversity in France, Italy, and Spain. Section 4.1 outlines the similarities and differences in national approaches and Section 4.2 assesses progress and remaining gaps in the integration of biodiversity considerations into renewable energy planning and implementation.

4.1. Similarities and differences across national policies

The analysis of national policies reveals that France, Italy, and Spain

Table 6
Measures planned or implemented to address biodiversity impacts of RES in Spain.

RES	Biodiversity and ecosystem impacts	Measures planned or implemented	Sources
Bioenergy	Biodiversity loss and ecosystem disturbance due to land use change from biomass use	- Promote the use of residues and waste from biomass as the primary feedstock for bioenergy production - Apply sustainability and GHG emission reduction criteria - Verify sustainability of biomass raw materials and biofuels, including ILUC impacts - Align biomass policies with the cascading principle - Promote advanced biofuels and limit conventional crop-based biofuels	(MAPA, 2022; MITECO, 2020b, 2022b, 2022c, 2022d, 2022f, 2023b, 2024; MITECO and MCIN, 2022)
Solar energy	Habitat loss and fragmentation; ecosystem disturbance; collision risks for species	- Avoid and restrict installations in critical areas for steppe birds, ZEPA, and other sensitive areas, with compensatory measures for habitat loss - Apply ecological compatibility criteria, including regional sensitivity maps - Where required, implement standardised monitoring of fauna, flora, habitats, and geological sites	(MITECO, 2021a, 2022a, 2023b, 2024)
Wind energy	Habitat loss and fragmentation; ecosystem disturbance; collision risks for species; landscape impacts; ecological continuity disruption	- Avoid and restrict installations in critical areas for steppe birds, ZEPA, and other sensitive areas, with compensatory measures for habitat loss - Apply ecological compatibility criteria, including regional sensitivity maps - Mitigate infrastructure barriers (e.g., wind farms, power lines) that threaten birds and bats - Promote repowering of wind farms - Where required, implement standardised monitoring of fauna, flora, habitats, and geological sites	(MITECO, 2021a, 2022a, 2022e, 2023b, 2024)
Hydropower	River and habitat fragmentation; alteration of migratory fish movement and sediment dynamics	- Apply compensatory measures where necessary to mitigate impacts on river ecosystems - Promote the development of reversible hydropower plants compliant with the ecological flow regimes - Promote mechanisms to design, construct, and operate hydropower plants that are compatible with ecological connectivity - Develop investment aid programmes that support the environmental and technological renovation of mini-hydropower plants	(Cortes Generales de España, 2021; MITECO, 2021a, 2023a, 2024)
Marine energy	Impacts on marine ecosystems, habitats, and species	- Use maritime spatial planning, guided by an ecosystem-based approach, to identify suitable sites - Protect ZEPA sites, habitats of community interest, and critical areas for seabirds and sensitive species, and identify areas with high biodiversity potential - Apply criteria and best-practices for project design, siting, installation, and maintenance - Improve knowledge of the marine environment and marine energy impacts through R&D and monitoring	(IDAE, 2011; MITECO, 2021b, 2023b, 2024; MITECO and MCIN, 2022)
Geothermal energy	Environmental and landscape impacts	- Conduct standard permitting and EIA procedures on a case-by-case basis	(MITECO, 2024)

Table 6 provides an overview of planned and implemented measures in Spain to address biodiversity and ecosystem impacts of RES, based on national policy documents.

are increasingly committed to balancing biodiversity, climate, and energy objectives. These countries share common principles, including the protection of areas with high biodiversity, the reinforcement of the sustainability criteria for biomass use, the integration of terrestrial and ecosystem-based maritime spatial planning, and the promotion of multiple land and sea uses through nature-compatible solutions. These principles are in line with the EU Biodiversity Strategy 2030 (EC, 2020) and key EU directives, such as the Water Framework Directive (EU, 2000), SEA Directive (EU, 2001), Marine Strategy Framework Directive (EU, 2008), EIA Directive (EU, 2014a), Maritime Spatial Planning Directive (EU, 2014b), and Renewable Energy Directive (EU, 2023). Furthermore, circular economy principles, SEA/EIA procedures, stakeholder engagement, and legally protected areas are embedded in all national policy frameworks.

Despite operating under the same EU directives, France, Italy, and Spain have different governance structures and implementation mechanisms. France has a central planning system that incorporates a bottom-up process, whereby municipalities identify suitable areas for RES deployment. Italy has a national regulatory framework with multilevel governance, in which the regions play a central role in planning, granting permits, and implementing RES projects. Spain emphasises data-driven ecological spatial planning, which requires close coordination between national authorities and the autonomous communities. This approach aligns with spatial suitability methods such as those proposed by Akbari et al. (2022), which integrate Land Evaluation and Site Assessment (LESA) and Geographic Information Systems (GIS) to assess and map land capability. This provides a methodological parallel to Spain's use of zoning tools and sensitivity maps to identify areas of low environmental value for RES deployment.

These differing approaches are closely linked to underlying political and institutional factors, particularly with regard to administrative coordination and the distribution of competences in environmental governance. They reflect distinct constitutional traditions, rooted in France's historically centralised state model and the more regionally decentralised systems of Italy and Spain. More centralised systems tend to be associated with stronger national coordination and more uniform implementation timelines. Conversely, decentralised systems rely more on regional capacity and multi-level coordination, which may result in greater variation in policy coordination and implementation of environmental objectives. For example, in the designation of RAAs, France has established a comprehensive legal framework and municipal identification process for all RES, whereas Italy and Spain are still finalising regional mapping in order to meet the EU deadline of February 2026. Ultimately, the effectiveness of national policies depends not only on planning instruments but also on the capacity of governments to enforce rules and monitor compliance. Weak or uneven enforcement of rules at regional and local levels can undermine biodiversity safeguards, even when national legislation is robust.

4.1.1. Strategic and environmental impact assessments (SEAs and EIAs)

SEAs provide the initial level of environmental oversight for renewable energy development. France, Italy, and Spain carry out SEAs of their NECPs in accordance with the SEA Directive (EU, 2001). SEAs evaluate the environmental impacts of plans and programmes, ensuring that considerations such as population, human health, biodiversity, land, soil, water, air, climate, and landscape, as well as their interactions, are systematically incorporated into planning and decision-making. These assessments should also address indirect, cumulative, and long-term ecological impacts, which are often limited by the availability of biodiversity data and robust monitoring methodologies, and consider how RES deployment interacts with other land and sea uses. The three countries increasingly integrate biodiversity criteria, data, and monitoring tools into spatial planning. However, current SEA frameworks are not sufficiently aligned with ecosystem-scale planning, particularly with regard to addressing cumulative ecological impacts across spatial and temporal scales, which limits their effectiveness in guiding decision-making.

EIAs are required for all large-scale RES projects (e.g., major onshore and offshore wind farms), while smaller projects may be exempted from a full assessment following a screening process, provided that adequate mitigation measures prevent significant environmental impacts. In line with key EU directives (EU, 1992, 2000, 2009, 2014a), EIAs evaluate the direct, site-specific impacts of RES projects on biodiversity and ecosystems. Despite these requirements, the combined effect of multiple RES projects is not systematically integrated into SEAs and EIAs. This may be due to the institutional separation between planning and permitting authorities, as well as the methodological limitations of project-based assessment tools, which do not effectively capture system-wide ecological interactions. Furthermore, conflicts over the use of land, sea, or rivers can indirectly affect biodiversity, an issue that is not sufficiently addressed by SEAs and EIAs, which underlines the need for cross-sectoral policy coordination.

4.1.2. Environmental monitoring

Environmental monitoring complements SEAs and EIAs, providing a multi-level framework that supports the sustainable deployment of RES. France has set up national observatories to monitor the impact of onshore and offshore renewable energy on biodiversity, although national monitoring and data standardisation are still under development. In Italy and Spain, monitoring of RES projects is fragmented across regional authorities, with most information confined to individual project-level EIAs rather than collated in a unified national database, which limits their capacity to assess cumulative ecological impacts. Therefore, strengthening monitoring frameworks, harmonising data collection, and integrating monitoring results with SEA and EIA findings is critical to ensure that biodiversity considerations effectively guide RES deployment. The cross-sectoral use of monitoring data can also support coordinated planning, mitigate conflicts over land and sea use, and improve the implementation of mitigation measures.

Table 7 provides a comparative overview of national policy frameworks for renewable energy and biodiversity in France, Italy, and Spain, based on national policy documents.

4.1.3. Renewable acceleration areas (RAAs)

In accordance with the Renewable Energy Directive (EU, 2023), Member States must designate RAAs by February 2026. These areas must exclude sites of high biodiversity, such as protected areas, Natura 2000 sites, and migratory routes for birds and marine mammals. RAA plans undergo SEAs to identify potential environmental impacts at an early stage, ensure public consultation, and define mitigation measures. Spatial planning for RAAs involves a coordinated mapping process to select suitable areas on land and at sea, prioritising sites that have low environmental value, such as artificial surfaces, industrial areas, and degraded land. The Directive recommends using spatial data and planning tools, such as wildlife sensitivity maps and data on biodiversity areas and threatened species. As set out in the Nature Restoration Law (EU, 2024), this mapping exercise must align with national restoration plans to ensure RES development supports broader conservation objectives. The implementation and monitoring of RAAs should rely on SEAs to enable adaptive management and address cumulative impacts.

Countries have different approaches to designing RAAs. For example, French municipalities select locations that enable RES projects to receive simplified approval while complying with environmental regulations. Spain uses spatial planning tools (e.g., territorial and maritime zoning) to identify sites with low sensitivity. Italian regions implement fast-track permitting for suitable RES areas following the binding criteria set out in the "Suitable Area" Decree, although these are still subject to legal revision. The effectiveness of RAAs ultimately depends on the design and implementation of these areas, in particular the extent to which simplified approval procedures are connected to suitable mitigation measures and minimum biodiversity safeguards are enforced (Hajdukovic and Jessel, 2026). Social acceptance and potential conflicts regarding the use of land, sea, or rivers can also influence effectiveness since opposition from the public and competing demands for resources can delay project implementation and affect biodiversity outcomes. Early public consultation and participatory planning are therefore essential to reducing conflicts and ensuring that RAAs deliver both energy and biodiversity objectives.

4.2. Biodiversity integration into RES development: progress and gaps

National policies integrate biodiversity considerations into renewable energy planning, but gaps remain, in particular in environmental monitoring, cross-sectoral coordination, and the mitigation of indirect, cumulative, and long-term ecological impacts, particularly on habitats

Table 7
Overview of national policy frameworks for renewable energy and biodiversity.

Country	Legal and policy basis	Governance and implementation	Strengths	Gaps
France	Energy Code; Law on Accelerating Renewable Energy Production; National Biodiversity Strategy 2030; NECP	Central planning system that incorporates a bottom-up process, whereby municipalities designate suitable areas for RES deployment	Legal framework with area designation by municipalities (RAAs); ecosystem-based maritime spatial planning; national biodiversity observatories and regional biomass monitoring; multiple land- and sea-use solutions; integration of SEA/EIA in RES planning	Indirect, cumulative, and long-term ecological impacts not fully assessed; limited cross-sectoral coordination; monitoring and data gaps; habitat- and species-specific impacts require further mitigation; biodiversity safeguards vary across RES
Italy	Legislative Decree No 199/2021; Ministerial Decree of 21 June 2024 ("Suitable Areas"); National Biodiversity Strategy 2030; NECP	Multilevel governance under national regulatory framework; regions identify suitable areas and manage permit granting	Binding national criteria for defining suitable and unsuitable areas for RES deployment; ecosystem-based maritime spatial planning; multiple land- and sea-use solutions; integration of SEA/EIA in RES planning	RAA mapping faces legal challenges; fragmented monitoring and data gaps; indirect, cumulative, and long-term ecological impacts not fully assessed; limited cross-sectoral coordination; habitat- and species-specific impacts require further mitigation; biodiversity safeguards vary across RES
Spain	Law 7/2021 on Climate Change and Energy Transition; National Strategy for Green Infrastructure and Ecological Connectivity and Restoration; NECP; State Strategic Plan for Natural Heritage and Biodiversity to 2030	Data-driven ecological spatial planning; coordination between national authorities and autonomous communities	Advanced data-based spatial planning tools (e.g., territorial and maritime zoning, regional sensitivity maps); guidelines for biodiversity impact assessment; ecosystem-based maritime spatial planning; multiple land- and sea-use solutions; integration of SEA/EIA in RES planning	RAAs not yet fully designated; fragmented monitoring and data gaps; indirect, cumulative, and long-term ecological impacts not fully assessed; limited cross-sectoral coordination; biodiversity safeguards vary across RES

and species. While SEAs and EIAs provide environmental oversight, guidelines and robust mechanisms for systematically monitoring biodiversity outcomes are still under development.

To minimise impacts on biodiversity, France, Italy, and Spain promote the use of residues and waste from biomass as the primary feedstock for bioenergy production. In line with the Renewable Energy Directive (EU, 2023), these countries are transposing strengthened sustainability criteria for biomass into their national legislation and implementing the cascading principle, although further efforts are needed to effectively integrate these instruments into policy and support mechanisms. Successful implementation also requires the development of standardised monitoring methodologies and indicators to assess local ecological impacts. These should include life-cycle assessments (LCA) of land-use changes and metrics for habitat alteration and species-specific effects, such as changes to habitats near harvesting sites and species mortality rates (Hajdukovic and Jessel, 2026). National environmental authorities should monitor these impacts within the existing EU-level monitoring and reporting framework.

The development of solar and onshore wind energy can harm biodiversity and ecosystems, particularly habitats and species. To mitigate these impacts, the three countries prioritise installing these technologies in areas of low environmental value and promote multiple land uses (e.g., agrivoltaics). They also conduct EIAs covering fauna, flora, and landscape, and promote the circularity of raw materials in RES technologies. In France, solar installations are permitted only in designated zones within natural areas, in order to avoid conflicts with agriculture or forest management. In Italy, uniform criteria are used to identify suitable areas, and ground-mounted PV installations are restricted on agricultural land. In Spain, critical areas and species (e.g., ZEPA and steppe birds) are protected through ecological zoning, sensitivity mapping, and compensatory measures. Compared to France and Italy, Spain has developed more advanced data-based spatial planning tools for protecting habitats and species. However, further mitigation measures and cross-sectoral coordination (e.g., between energy and agriculture) are needed to minimise the species-specific and cumulative ecological impacts.

Hydropower development can create a trade-off between the local biodiversity impacts in rivers and floodplains and the expected long-term benefits, including renewable electricity generation and climate change mitigation. In line with the European Union (2000) and the European Union (2014a), France, Italy, and Spain have strengthened regulations and introduced mitigation measures to ensure minimum river flows and ecological continuity. However, important gaps remain in assessing cumulative impacts across entire river systems. While repowering hydropower plants can enhance energy efficiency, careful mitigation measures are required to prevent habitat disturbance and safeguard local wildlife. Recent innovations, such as the Slot-Weir-Orifice combined fishway developed by Zhang et al. (2026), can enhance fish passage by increasing the number of migration channels and reducing flow velocity and turbulence. This type of innovation aligns with national strategies aimed at restoring ecological continuity and improving river permeability in hydropower systems. Emerging computational tools can also contribute to ecosystem-based management in aquatic systems by addressing monitoring and data gaps. For example, hybrid machine learning frameworks for modelling non-linear dynamics provide a scalable basis for the systematic monitoring of aquatic systems and can support the assessment of cumulative impacts on water quality (Azma et al., 2026). Similarly, flood susceptibility models can help identify flood-prone floodplain areas (Eslaminezhad et al., 2022), supporting more targeted protection of riverine ecosystem functions (e.g., water retention) in areas affected by hydropower development.

Geothermal energy can also pose environmental risks, including induced seismicity, groundwater pollution, and habitat changes (Gasparatos et al., 2017). These impacts are mainly addressed through energy, mining, and water laws, and project-specific EIAs rather than targeted biodiversity mitigation measures. Compared with other RES, the biodiversity impacts of geothermal energy are less well researched and recognised in national policies. No geothermal-specific biodiversity guidelines were identified in any of the three countries, indicating a clear policy gap. This may reflect the localised nature of geothermal impacts, overlapping responsibilities of different authorities (e.g., energy, land use, water), and varying political priorities, which contribute to fragmented oversight and limited policy coordination (Hajdukovic and Jessel, 2026). As an illustration of emerging approaches relevant to these risks, recent machine learning applications for assessing groundwater quality in aquifer systems, including sensitivity analyses to identify key influencing parameters, demonstrate how data-driven methods can support more standardised monitoring and assessment frameworks (Azma et al., 2026). These approaches are particularly relevant for improving the evaluation of drilling impacts on aquifers and groundwater systems.

Maritime spatial planning involves balancing the interrelated but often competing biodiversity, climate, energy, and economic objectives at sea. France, Italy, and Spain aim to develop marine energy, particularly offshore wind, by taking an ecosystem-based approach to maritime spatial planning. This approach is promoted by the European Commission (EC, 2021) and in line with the Marine Strategy Framework Directive (EU, 2008) and the Maritime Spatial Planning Directive (EU, 2014b). However, despite these countries having officially adopted their national maritime spatial plans, certain marine areas in the Mediterranean and Atlantic regions still lack fully operational frameworks for the deployment of marine energy. Maritime spatial planning can serve as a practical application of the ecosystem-based approach, illustrating how coordination across sectors, multi-use sea planning, and EIAs can help to reconcile marine energy development with marine biodiversity objectives (Hajdukovic and Jessel, 2026). However, further progress is needed to systematically monitor and assess the combined effects of marine energy development on ecosystems, habitats, and species. Finally, cross-border cooperation is essential for sharing data, methods, and best practices in order to support the coordinated planning and management of the seas and protect marine biodiversity.

The scientific literature shows that RES can also have positive effects on biodiversity. For example, certain bioenergy landscapes, such as those involving perennial biomass, can provide habitats and food sources, as well as other ecosystem services (Werling et al., 2014). Offshore wind farms can enhance benthic and fish populations through sheltering effects (Coates et al., 2014) and the formation of artificial reefs (Galparsoro et al., 2022). Hydropower can also create new habitats for certain species (Palmeirim et al., 2014). While national policies primarily address trade-offs, the biodiversity benefits of RES that could be realised through effective project planning and implementation should be more fully integrated into policy frameworks.

5. Conclusions and discussion

This paper examines whether and how national policies in France, Italy, and Spain integrate biodiversity conservation into renewable energy development under the EGD. We conduct a qualitative analysis of 46 national policy documents (15 from France, 13 from Italy, and 18 from Spain). RES provide environmental, social, and economic benefits, but they can also positively or negatively influence biodiversity and ecosystems, depending on how projects are designed and implemented. Given the central role of national policies in translating EGD provisions into country-specific legislation and measures, it is essential to assess how biodiversity considerations are integrated into renewable energy planning and implementation.

Our analysis reveals that France, Italy, and Spain recognise and manage several links between RES and biodiversity, although critical policy gaps remain. National policies promote synergies, such as using biomass residues and waste for bioenergy and integrating multiple land and sea uses (e.g., agrivoltaic systems and the colocation of offshore wind with aquaculture). However, significant trade-offs exist in both terrestrial and maritime spatial planning, in which reconciling biodiversity, climate, energy, and economic objectives is particularly challenging. Specific attention should be given to mitigating the impacts of changes in land use associated with bioenergy and the installation of onshore wind and solar infrastructure on biodiversity and ecosystems. The environmental risks arising from marine energy installations and hydropower development on rivers and floodplains also require careful consideration. Overall, our findings emphasise the limited capacity of national policy frameworks to systematically manage these trade-offs across sectors, and spatial and temporal scales, particularly when ambitious climate and energy targets put significant pressure on decisions regarding land, sea, and river use.

Several measures are implemented by countries to manage these potential conflicts. For biomass, the strengthened sustainability criteria and cascading use principle are being applied to ensure its sustainable harvesting and use for bioenergy production. To be effective, these measures must be more explicitly incorporated into policy design and underpinned by robust indicators and monitoring methodologies. As regards solar and wind energy, careful project siting, including installation on sites of low environmental value, promotion of multiple land uses such as agrivoltaics, and avoidance of sensitive ecological areas can help minimise biodiversity loss and ecosystem disruption. Policy measures for hydropower mainly focus on maintaining minimum river flows to ensure ecological continuity and improving the efficiency of existing plants, although cumulative impacts across the entire river system require further attention. While repowering wind and hydropower installations can improve energy efficiency, mitigation measures must be implemented to prevent potential local ecological impacts. The environmental risks of marine energy development on marine ecosystems are mainly addressed through an ecosystem-based approach to maritime spatial planning that prioritises the multiple uses of the seas, and through governance and monitoring frameworks. However, the monitoring and assessment of cumulative ecological impacts are still in development, and while the ecosystem-based approach is a good starting point, it requires full implementation. Although geothermal energy is considered to have lower ecological impacts than other RES, it can still pose environmental risks and requires more targeted mitigation measures for biodiversity.

National policies provide various tools and mechanisms to address the discrepancy between the local biodiversity impacts of RES and their wider, long-term benefits, such as climate change mitigation, economic growth, and enhanced energy security. These include, for example, SEAs, EIAs, strengthened sustainability criteria, integrated terrestrial and maritime spatial planning, RAAs, stakeholder engagement, and cross-sectoral coordination. However, many of these are still under development and not fully operational. The designation of RAAs, for example, is a formal mechanism for incorporating biodiversity objectives into energy planning. Their effectiveness depends on the design and implementation of these areas, the adoption of suitable mitigation measures, and the enforcement of biodiversity safeguards.

Specific attention must also be given to the potential indirect and time-lagged effects of RES deployment (e.g., land-use changes driven by increased demand for bioenergy or changes in hydrological regimes resulting from hydropower). These effects are currently not consistently monitored and need to be more explicitly incorporated into the design of both EU and national policies. Our analysis emphasises the need to develop comprehensive guidelines and targets, and to systematically monitor and evaluate the cumulative and long-term ecological effects of RES projects. These guidelines should inform the integration of biodiversity considerations into project development and impact assessments, particularly with regard to habitats and species. Measurable targets must be set to protect the integrity of natural habitats (e.g., high-biodiversity areas), preserve populations of vulnerable species (e.g., birds, marine mammals), and maintain ecosystem functions (e.g., water retention, carbon storage) and connectivity (e.g., ecological corridors, migration routes) in the face of cumulative effects of RES development.

While the policies of France, Italy, and Spain align with EU legislation and policy objectives, differences in governance structures and implementation capacity may lead to variation in the implementation of biodiversity safeguards. These differences are reflected in the varying ways in which biodiversity considerations are incorporated into renewable energy permitting processes, spatial planning instruments, and environmental monitoring systems in the three countries. Maintaining a balance between policy coherence and complexity can enable the EGD to provide clear guidance through EU-level objectives and minimum standards while allowing national authorities the flexibility to adapt measures to their specific conditions and address local challenges (Hajdukovic and Jessel, 2026). Closer alignment with EU directives could also help EU countries to harmonise cross-sectoral approaches and integrate national biodiversity, climate, and energy objectives more effectively. However, significant gaps remain, in particular, in environmental monitoring, cross-sectoral coordination, and the assessment of cumulative and long-term ecological impacts. Furthermore, national policies primarily address the trade-offs between renewable energy development and biodiversity conservation. At the same time, the positive biodiversity outcomes (e.g., provision of habitat and food sources in perennial biomass) that could be realised through effective RES project planning and implementation are often overlooked and should be better integrated into policy frameworks.

Based on our findings, several policy recommendations can be drawn:

First, France, Italy, and Spain should adopt a holistic approach to renewable energy planning to incorporate biodiversity conservation into their energy and cross-sectoral policies. This would help ensure that biodiversity considerations are systematically integrated into spatial planning and the design, permitting, and implementation of RES projects. Strong coordination is needed between energy, biodiversity, land use, and water policies, as well as between national, regional, and local authorities. Formal coordination mechanisms, such as inter-ministerial working groups or cross-sectoral task forces jointly led by environmental ministries, with clearly defined mandates, decision-making responsibilities, and reporting obligations, could operationalise this approach. Site selection for RES projects should be guided by robust spatial planning tools and datasets (e.g., species distribution, ecological sensitivity maps, data on ecosystem services) to identify sites with the least environmental impact, following Spain's example of data-driven spatial planning. The Renewable Energy Directive (EU, 2023) requires prioritising areas of low environmental value, such as artificialised or degraded land, while excluding ecologically sensitive areas, migration corridors, and protected sites. Project approvals should be conditional on compliance with ecological spatial planning, and adaptive management measures should be applied based on project-level monitoring results. However, the effectiveness of this approach depends on addressing key practical constraints, including administrative fragmentation, limited technical capacity, and competing land-use priorities. In practice, these challenges may lead to uneven implementation across governance levels and countries, particularly where coordination between sectoral authorities is weak and administrative or financial resources for spatial planning and enforcement are limited.

Second, the cumulative impacts of RES projects, including those in RAAs, must be fully considered in SEAs and EIAs, particularly in regions with high biodiversity value and sensitive ecosystems. These assessments should be supported by standardised monitoring methodologies and robust indicators for both onshore and offshore projects. The results of SEAs and EIAs should inform the spatial planning and site selection of RES projects, including the implementation of adaptive management and impact mitigation measures, rather than being used solely for compliance purposes. Finally, the monitoring of the biodiversity outcomes of RES deployment should be integrated into national biodiversity monitoring programmes and not treated as an isolated activity. Germany is taking this approach, for example, by establishing a monitoring centre at the Federal Agency for Nature Conservation to coordinate the various programmes and actors involved in nationwide biodiversity monitoring. The Environmental Research Centre Halle-Leipzig also has an EE-Monitor that uses indicators assigned to RES technologies and target areas, with monitoring results feeding into national biodiversity targets. However, there are limitations in the proposed monitoring approach, particularly with regard to data availability, economic feasibility, and institutional sustainability. This means that large-scale implementation may require phased deployment and reliance on existing monitoring infrastructures and environmental data systems to ensure cost-efficiency and feasibility.

While the findings and recommendations of our study are based on France, Italy, and Spain, they can also provide valuable insights for other EU countries facing similar challenges in integrating energy and biodiversity objectives. Ultimately, policy effectiveness depends on implementation. Further research is needed to assess the implementation of planned measures within different policy areas, timeframes, and spatial scales. Particular attention should be given to how municipal and regional authorities balance renewable energy development with local biodiversity conservation objectives. To reconcile mismatches in spatial and temporal scales, clear guidelines and effective coordination mechanisms are essential. Creating a map of policy shortcomings, recommended measures, monitoring indicators, and responsible authorities for all RES could provide national policymakers with more practical guidance. Combining qualitative and quantitative approaches could also help evaluate the impact of planned measures (e.g., sustainability criteria, RAAs, spatial planning, SEAs, EIAs) on ecosystems, habitats, and species. Such assessments are necessary to ensure that policy-driven renewable energy expansion contributes to national biodiversity, climate, energy, and economic objectives and to refine policy instruments so that they respond more effectively to country-specific challenges.

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CRediT authorship contribution statement

Ivan Hajdukovic: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Beate Jessel:** Writing – review & editing, Supervision, Resources, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A1, Table A2, Table A3, Table A4, Table A5

Table A1
French ministries and authorities: acronyms and full names.

Acronym	Full name
MASA	Ministère de l'Agriculture et de la Souveraineté Alimentaire (Ministry of Agriculture and Food Sovereignty)
MTEBFMP	Ministère de la Transition Écologique, de la Biodiversité, de la Forêt, de la Mer et de la Pêche (Ministry of Ecological Transition, Biodiversity, Forestry, the Sea, and Fisheries)
MTECT	Ministère de la Transition Écologique et de la Cohésion des Territoires (Ministry of Ecological Transition and Territorial Cohesion)
MTES	Ministère de la Transition Écologique et Solidaire (Ministry of Ecological Transition and Solidarity)
MTE	Ministère de la Transition Écologique (Ministry of Ecological Transition)

Table A2
Italian ministries and authorities: Acronyms and full names.

Acronym	Full name
MASAF	Ministero dell'Agricoltura, della Sovranità Alimentare e delle Foreste (Ministry of Agriculture, Food Sovereignty, and Forests)
MASE	Ministero dell'Ambiente e della Sicurezza Energetica (Ministry of the Environment and Energy Security)
MATTM	Ministero dell'Ambiente e della Tutela del Territorio e del Mare (Ministry of the Environment and Protection of Land and Sea)
MIPAAF	Ministero delle Politiche Agricole, Alimentari e Forestali (Ministry of Agricultural, Food, and Forestry Policies)
MISE	Ministero dello Sviluppo Economico (Ministry of Economic Development)
MITE	Ministero della Transizione Ecologica (Ministry of Ecological Transition)

Table A3
Spanish ministries and authorities: Acronyms and full names.

Acronym	Full name
MAPA	Ministerio de Agricultura, Pesca y Alimentación (Ministry of Agriculture, Fisheries, and Food)
MITECO	Ministerio para la Transición Ecológica y el Reto Demográfico (Ministry for the Ecological Transition and Demographic Challenge)

Table A4
Biodiversity-related terms searched in national policy documents.

Aquatic ecosystems	Aquatic species	Biodiversity loss
Biomass	Bird species	Coastal ecosystems
Conservation status	Cumulative impacts	Ecosystem change
Ecosystem disturbance	Ecosystem impacts	Ecosystem resilience
Ecosystem services	Ecological connectivity	Ecological impacts
Environmental footprint	Environmental impact	Environmental protection
Fauna	Flora	Forests
Freshwater ecosystems	Green infrastructure	Habitats
Habitat degradation	Habitat fragmentation	Habitat loss
Landscape impact	Land-use change	Land-use planning
Marine ecosystems	Marine environment	Migratory routes
Natura 2000 sites	Natural capital	Nature protection
Offshore ecosystems	Protected areas	River ecosystems
River fragmentation	Sea-use planning	Soils
Species	Sustainable resource use	Water resources
Wildlife		

The biodiversity-related terminology searched for in national policy documents comes from the same list that was developed and used by Hajdukovic and Jessel (2026).

Table A5
Examples of explicit and implicit links between RES and biodiversity identified in national policy documents.

Source	Page	Quote	Link type
Multiannual Planning for Energy 2019–2028) (MTES, 2020a)	97	*Original:* "En particulier, l'utilisation de terres cultivées existantes aux fins de la production de biocarburants et le déplacement consécutif de la production alimentaire (ou autre) vers de nouvelles terres arables peut entrainer de la **déforestation** et la **disparition d'importants réservoirs de carbone et de biodiversité**. Cet effet créant des émissions non intentionnelles de carbone est appelé **changement d'affectation des sols indirect**, ou **ILUC (Indirect Land Use Change)**, et est très difficile à mesurer ou calculer directement." *English translation:* "In particular, the use of existing croplands for biofuel production and the consequent displacement of food (or other) production to new arable lands can lead to **deforestation** and the **loss of important carbon and biodiversity reservoirs**. This effect, which creates unintended carbon emissions, is called **indirect land use change (ILUC)** and is very difficult to measure or calculate directly."	Explicit
Multiannual Planning for Energy 2019–2028) (MTES, 2020a)	78	*Original:* "C'est principalement en phase d'exploration qu'on note certains **risques et nuisances**, notamment lors des opérations de forage (risque de mise en communication possible de plusieurs aquifères, circulation de camions,	Implicit

(*continued on next page*)

Table A5 (*continued*)

Source	Page	Quote	Link type
		etc.) Le dispositif réglementaire existant (code minier, loi sur l'eau) encadre la réalisation des opérations pour **minimiser les nuisances**. En phase d'exploitation, les opérations de géothermie présentent peu ou pas d'impact. L'enjeu principal porte alors sur la possibilité **d'épuisement de la ressource**, ce qui pourrait être atténué par des productions alternées de chaud et de froid ou par une recharge du sous-sol (rafraîchissement des bâtiments, injection en été d'énergie solaire ou fatale excédentaire)." *English translation:* "It is mainly during the exploration phase that certain **risks and nuisances** are observed, particularly during drilling operations (possible connection of multiple aquifers, truck traffic, etc.). The existing regulatory framework (Mining Code, Water Law) governs these operations to **minimise nuisances**. During the exploitation phase, geothermal operations have little or no impact. The main issue then concerns the potential **depletion of the resource**, which could be mitigated through alternating heat and cold production or by recharging the subsurface (e.g., building cooling, injection in summer of excess solar or waste energy)."	
National Biodiversity Strategy 2030 (MASE, 2023b)	70	*Original:* "Sotto-Azione B13.3.g) Definire linee guida e criteri per la progettazione e localizzazione di impianti fotovoltaici e agri-fotovoltaici sui terreni agricoli al fine di garantire la **tutela della biodiversità** e il mantenimento delle produzioni agricole **limitando il cambiamento dell'uso del suolo**." *English translation:* "Sub-Action B13.3.g) Define guidelines and criteria for the design and siting of photovoltaic and agrivoltaic installations on agricultural land in order to ensure **biodiversity protection** and the maintenance of agricultural production while **limiting land-use change**."	Explicit
NECP (MASE (2024b))	184	*Original:* "In particolare, per quanto riguarda l'eolico a mare si punterà allo sviluppo di soluzioni tecnologiche affidabili e con un **ridotto impatto ambientale**, così da consentire un'applicazione **ambientalmente compatibile** ed energeticamente significativa, tenuto conto delle condizioni tipiche del Mediterraneononché delle capacità della *catena* del valore dell'industria italiana nel settore." *English translation:* "In particular, regarding offshore wind, efforts will focus on developing reliable technological solutions with a **reduced environmental impact**, thereby enabling **environmentally compatible** and energetically significant applications, taking into account the typical conditions of the Mediterranean as well as the capacities of the Italian industry value chain in the sector."	Implicit
NECP (MITECO, 2024)	126	*Original:* "Se trabajará para completar la **zonificación territorial** con la mejor información disponible, especialmente aquella relevante para la **conservación de la biodiversidad** frente al despliegue de instalaciones de generación de energía a partir de fuentes renovables. En particular, incluirá la información que se vaya generando de los **seguimientos de biodiversidad**, e incluirá datos relevantes para áreas de interés para la **biodiversidad**, tales como áreas importantes para las **aves esteparias**, así como de **otros grupos y especies** especialmente vulnerables frente a la implantación de infraestructuras para la generación de este tipo de energías. *English translation:* Work will be carried out to complete **territorial zoning** using the best available information, especially information relevant for **biodiversity conservation** as opposed to the deployment of renewable energy generation facilities. In particular, it will include information generated from **biodiversity monitoring** and relevant data for areas of **biodiversity** interest, such as areas important for **steppe birds**, as well as **other groups and species** particularly vulnerable to the deployment of infrastructure for the generation of these types of energy."	Explicit
Spanish Forest Plan 2022–2032 (MITECO, 2022f)	8	*Original:* "OG7: Participar en las políticas de transición energética y descarbonización, pro- mocionando el **uso y aprovechamiento sostenible de la biomasa forestal** como fuente de energía renovable bajo el **principio del uso en cascada**, sobre todo en zonas rurales próximas a áreas forestales de montaña, así como la ganadería extensiva como herramienta de **gestión del paisaje**, de prevención de incendios forestales y de mitigación del cambio climático en entornos agroforestales." *English translation:* "OG7: Participate in energy transition and decarbonization policies by promoting the **sustainable use and exploitation of forest biomass** as a renewable energy source under the **cascading use principle**, particularly in rural areas near mountain forest areas, as well as extensive livestock farming as a tool for **landscape management**, wildfire prevention, and climate change mitigation in agroforestry environments."	Implicit

Implicit links denote policy measures where the connection to biodiversity is not explicitly stated, but may be deduced from the mechanisms involved, which could have a positive or negative impact on biodiversity or ecosystems (e.g., environmental pressures, changes in land use, or natural resource management).

Data availability

No data was used for the research described in the article.

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