CLEANaction

Coalition Linking Energy and Nature for Action

Nature-safe Energy: Linking energy and nature to tackle the climate and biodiversity crises

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WWF is an independent conservation organization, with over 30 million followers and a global network active in nearly 100 countries. Our mission is to stop the degradation of the planet's natural environment and to build a future in which people live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption. Find out more at panda.org/climateenergy

The Biodiversity Consultancy is a consultancy which specialises in biodiversity risk management, helping clients integrate nature into business decision-making and designing practical environmental solutions that deliver nature-positive outcomes. As strategic advisor to some of the world's largest companies, we lead the development of post-2020 corporate strategies, biodiversity metrics, science-based targets, and sustainable supply chains. Our expertise is applied across the renewable energy sector, including hydropower, solar, wind, and geothermal, where we specialise in the interpretation and application of international finance safeguards. www.thebiodiversityconsultancy.com/

Kogarah Council in Sydney has embraced alternative energy sources and installed solar panels and transparent roofing in their state-of-the-art Town Centre. Sydney, Australia

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Preamble

Nature is in freefall. WWF's *Living Planet Report 2022* highlighted the 69 per cent decline in average population sizes of wildlife across the globe over the past 50 years. And according to the World Economic Forum 2020, US$44 trillion of economic value generation – half the world's GDP – is dependent upon nature.[1] Our prosperity depends on us protecting and restoring nature.

Climate change is causing havoc across the globe and, together with habitat loss and overexploitation, is a leading cause of reduced biodiversity worldwide. This loss of biodiversity, and of the natural carbon uptake and storage enabled by healthy ecosystems, exacerbates the climate crisis and threatens the health and wellbeing of humankind around the world. Every fraction of a degree matters when fighting climate change. Restricting global warming to 1.5°C above pre-industrial levels will significantly limit the damaging impact on nature and people.

Fossil fuels are at the centre of the climate and energy crises, and a concerted global effort is needed to achieve the urgently required transition to renewable energy. However, the increased exposure to present and future energy crises, with increased prices and higher supply instability, has refocused attention on national energy security rather than the energy transition.

Despite the pressing global challenge, energy security and the clean energy transition need not be in conflict. The benefits of transitioning to renewable energy sources have never been more apparent. When correctly sited, mature renewable energy technologies such as wind and solar photovoltaics (PV) provide clean and affordable energy solutions with the lowest impacts on nature. In some instances, depending upon local conditions, bioenergy and low-carbon, low-cost, low-impact hydropower can also provide local renewable energy options with relatively low impacts on nature compared with the energy alternatives available. Such renewable energy technologies are also the most affordable energy options, and can build resilience, create energy access, alleviate energy poverty and provide greater energy security than fossil fuels.

The renewable energy transition also offers opportunities to reset our relationship between energy production and nature by increasing the efficiency of how we use energy and decreasing its demand.[2] This can be achieved through behavioural change and enabling technologies such as 'smart' electricity grids that store and deliver energy more efficiently.

However, scaling up the deployment of renewable energy needs to balance the impact on climate and biodiversity. Potentially negative impacts on nature must be carefully managed to ensure that priority is awarded to those renewable energy technologies that cause the least damage. To be sustainable, renewables and energy storage technologies must account for their full impact across the supply chain, including the related resourcing of metals and minerals. Adopting a circular economy model that prioritises material reuse, as well as rigorous implementation of the mitigation hierarchy (avoid, reduce, restore), can help avoid and minimise impacts and contribute to nature-positive outcomes.

The **Coalition Linking Energy And Nature for action (CLEANaction)** was established in recognition of the urgent need for a global and just transition to a low-impact and nature-sensitive renewable energy system. It brings together NGOs, leading businesses, financial institutions and research and governmental bodies to work together to spread knowledge and drive implementation of low-impact renewable energies, enabling best-practice solutions for nature, including appropriate siting, the bridging of data gaps, the development of the most advanced mitigation measures, and much more.

This report is the first step in CLEANaction's mission to highlight the links between energy and nature, and sets out an agenda for its future activities.

CLEANaction
Coalition Linking Energy And Nature for action

WWF · BirdLife International · ICLEI Local Governments for Sustainability · The Nature Conservancy · Alliance for Rural Electrification – Shining a Light for Progress · Nordic Energy Research · PACJA Panafrican Climate Justice Alliance · Ørsted · Iberdrola

Foreword

Linking energy and nature to tackle the climate and biodiversity crises

During the COP26 climate negotiations in Glasgow, we brought together six leading organisations to consider the link between energy and nature. The Coalition Linking Energy And Nature for Action (CLEANaction) was launched as a global platform to address the impact of future energy supplies on the natural environment upon which our lifestyles and livelihoods ultimately depend.

We know that renewable energy is our best option to meet future energy needs without irreparably damaging our climate and nature. But even renewables will be disruptive to the natural environment when they are installed and maintained.

This disruption must be minimised to avoid any further loss of biodiversity (the variety of plant and animal life in the world). CLEANaction aims to ensure that the transition to a renewable energy future, so urgently required, does not compromise our immediate need to restore nature.

Jointly solving the climate crisis, the energy crisis and this crisis in nature is critical if we are to maintain healthy living conditions for future generations. This is the mission of CLEANaction, which seeks to raise awareness of the link between energy and nature, to build capacity and understanding to ensure corrective responses are made, and to demonstrate the type of effective action that must be taken.

As a first step, the CLEANaction partners commissioned The Biodiversity Consultancy to review the issues and measures that must be considered for an effective response to the energy-nature crisis. Unfortunately, emerging and continuing geopolitical shifts have altered the global agenda, including the options for addressing our energy-nature challenge. Energy security has become the leading short-term priority for many countries, often without considering the associated long-term, damaging environmental impacts.

There remain a number of critical issues that must still be prioritised to avoid reaching tipping points where our planet will never again return to a sustainable level of biodiversity. We need an immediate transition from fossil fuels to renewables to avoid the climate balance being irreversibly changed, with unknown consequences. Without urgent action, we will all regret the damage that we are leaving for future generations.

CLEANaction offers a global forum that can co-ordinate related efforts worldwide and achieve the positive energy and nature outcomes that are so essential.

The measures outlined in this report signpost the efforts we must take to avoid a disastrous future. With an immediate, concerted effort, we can still ensure a clean climate and a healthy planet for people and nature, with access to appropriate renewable energy for us all.

Manuel Pulgar-Vidal,
WWF International Lead, Climate and Energy


Monarch Butterfly (Danaus plexippus) at the Piedra Herrada Sanctuary, Mexico. © *Julia Ulreich*

Executive summary

Without accounting for nature and the goods and services it provides, global efforts to transition to a net-zero energy system will not achieve the positive outcome required. Failing to do so could lead to energy pathways that undermine climate, nature, health, and poverty reduction goals, leaving a planet in continual decline. Fortunately, there are energy solutions that can help tackle the climate and biodiversity crises together.

To limit global warming to 1.5°C above pre-industrial levels and avoid the worst risks of climate change, renewable energy will need to account for more than 90 per cent of electricity generation by 2050.[3] While every form of energy technology we use – from solar panels to coal mines – has some impact on nature over its lifecycle, the evidence is clear that we must shift from polluting fossil fuels, such as coal, oil and gas, to renewables, such as wind and solar PV, to help address the climate and biodiversity crises. When considering the full range of environmental impacts, deriving and storing energy from renewables is far less environmentally damaging overall than using fossil fuels.

As we transition to a net-zero world, we must consider that not all low-carbon energy sources are created equal. Supporting those renewable technologies with the lowest impact on nature can have major benefits and also be low-cost. Studies that account for the full range of impacts clearly demonstrate that a transition to renewable energy focused on wind and solar can result in significantly reduced environmental impacts compared to other renewable energy types, although other renewables can be the most appropriate solution depending upon the local circumstances and sustainability principles applied.

Existing global-scale mapping of sites for wind and solar indicates that there is enough energy available on sites with minimal disruption to nature (low-conflict) sites to achieve projections from the International Energy Agency (IEA) for a power system consistent with holding the global average temperature rise to below 1.5°C.[4] This should allow almost all countries to achieve power systems that are low carbon, low cost and low conflict (LowCx3).

Emerging technologies such as floating solar and floating wind can also play a pivotal role in positively reshaping our energy system, although further research is needed to understand their impacts.[5] If properly designed, other emerging solutions, such as agrivoltaics, which combine agriculture and solar PV, could also prove to have positive social and environmental impacts. Improvements in grid management and energy storage technologies will be needed to address the variable supply of many renewable energy systems. Possible solutions to manage this variability include smart grids coupled with energy storage measures that allow reliable response to demand, such as battery storage, heating and cooling storage, and low-impact off-river pumped-storage hydropower. Retrofitting existing hydropower stations is another option that can dramatically improve their efficiency, offering back-up to variable supplies, and reducing the need for additional capacity.

Reforming our financial, economic and regulatory systems to reflect the true cost of environmental and climate impacts can inform sound investment and development decisions, and end energy subsidies that harm nature and jeopardise climate targets. Interconnections between countries can increase energy security, optimise energy yields and minimise impacts, whilst energy decentralisation through micro- and mini-grids can reduce negative impacts on natural resources and empower communities.

Significant changes are also needed in how we source and trace materials for developing our energy infrastructure. A new, circular economic model is essential to reduce environmental impacts. This model should prioritise the reduction of primary materials, as well as reuse and recycling to minimise further extraction and impacts related to the disposal of end-of-life equipment. When mining occurs, rigorous environmental and social safeguards must be in place to mitigate risk, with a focus on avoiding the degradation of natural habitat.

As with all large-scale development, early planning is key to ensure that we develop the right types of renewables in the right places to minimise risks and avoid impacts on communities and nature.[6] Poor placement in areas of intact natural habitat and high community dependency, including protected areas, could lead to a loss of vital ecosystems and reduced access to important provisioning services such as fisheries and agriculture, or could degrade the aesthetic and cultural value of land and waters.

Fortunately, flexibility in siting means wind and solar technologies can be built primarily on sites that would cause far less damage to nature than their fossil fuel-based equivalents, including already developed areas such as rooftops, industrial zones, reservoirs, former mines and pastures. The tools to help identify these low-conflict areas already exist.[7] Where managed for nature, wind and solar energy even offer opportunities to rehabilitate previously degraded habitats and deliver nature-positive outcomes.

Failure to adequately account for nature and people could undermine climate targets. While there are clear synergies between biodiversity protection and climate change mitigation, there are also risks of misalignment, including social and environmental conflict and the release of carbon stocks through the loss of biodiversity.

KEY MESSAGES

- All energy systems, including renewables, have some impact on nature
- When considering the full range of environmental impacts, deriving and storing energy from renewables is far less environmentally damaging overall than using fossil fuels
- To limit global warming to 1.5°C above pre-industrial levels and avoid the worst risks of climate change, renewable energy will need to account for more than 90 per cent of electricity generation by 2050
- Supporting renewable technologies with the lowest impact on nature can have major benefits and also be low-cost
- A transition focused on wind and solar can result in significantly reduced environmental impacts compared with other renewable energy types
- Early planning that is strategic in considering climate and nature goals is key to ensure that we develop the right types of renewables in the right places to minimise risks and avoid impacts on communities and nature. Rigorous implementation of the mitigation hierarchy (avoid, reduce, restore) is fundamental
- Existing global-scale mapping of sites for wind and solar indicates that there is enough energy available on low-conflict sites to achieve projections from the International Energy Agency (IEA) for a power system consistent with holding the global average temperature rise to below 1.5°C
- Greater energy efficiency in all sectors is required to minimise the demand for increased energy supply, and avoid unnecessary additional infrastructure
- Significant changes are needed in how we source and trace materials for developing our energy infrastructure. A new, circular economic model is essential to reduce environmental impacts

KEY RECOMMENDATIONS

The key high-level recommendations from the assessment in this report are listed below (see Section 4 for more detailed recommendations).

Governments should:

1. Undertake *strategic-level energy planning* at national or regional scales to identify potential energy savings, suitable renewable energy sources, and sites for energy expansion in areas of low biodiversity sensitivity
2. Consider the *impact on nature at the earliest stage of integrated clean energy planning*, taking account of the full value chain (from sourcing material to disposal)
3. Develop *national regulatory schemes* that require energy developers to contribute to national conservation targets
4. Invest in timely *nature-sensitivity mapping* to help direct technology siting through proper data, and require industry to avoid protected areas, Key Biodiversity Areas (KBAs), and other areas of particular sensitivity and value[8]
5. Apply stringent *environmental impact assessment processes and required standards* to all new developments according to best practice
6. Adopt a *circular economy approach with optimised energy efficiency*, to maximise reuse of energy materials, and minimise demand for natural resources

Renewable energy investors and developers should:

1. Integrate *biodiversity, social and environmental risks* early into renewable energy planning and investment decisions
2. Apply *effective biodiversity safeguards* and environmental impact assessment procedures to avoid and minimise impacts, and offset any residual impacts to achieve net-positive outcomes
3. Ensure there is traceability of raw materials and *account for supply chain impacts* within corporate commitments to nature
4. Apply a *circular approach* to minimise the use of primary materials and maximise the reuse and recycling of materials
5. Strengthen *corporate disclosure and reporting* on biodiversity, environmental and social impacts

All stakeholders should promote research, knowledge sharing and diffusion of best practice to encourage greater awareness and motivation towards the *expansion of renewable energy with least negative disruption to nature.*

PV modules on the Highmar senior housing carports in Boulder, Colorado. © *Dennis Schroeder*

A participant in the EV event charges his vehicle with the new fast charge EV station at Mt. Hood Skibowl. © Oregon DOT

1. The renewables imperative

Climate change presents an existential risk to humanity and the natural world as we know it.[9] Decisive action this decade is needed if we are to hold global warming below 1.5°C and avert its worst impacts. Biodiversity loss represents a similar existential risk to humanity and the life-support systems on which we depend for our food, water, health and so much more.[10] It is crucial that these two intrinsically linked challenges are tackled together. A healthy living planet is fundamental to a stable climate and the provision of life-sustaining services to nature and the wellbeing of people. Nature-based solutions, such as preserving natural areas with high natural uptake and storage of carbon, can help reduce atmospheric carbon dioxide (CO_2) levels and conserve and restore biodiversity, contributing to ambitious new goals under the UN Convention on Biological Diversity (CBD) and recently agreed 2030 targets at the CBD COP15 in Montreal.[11]

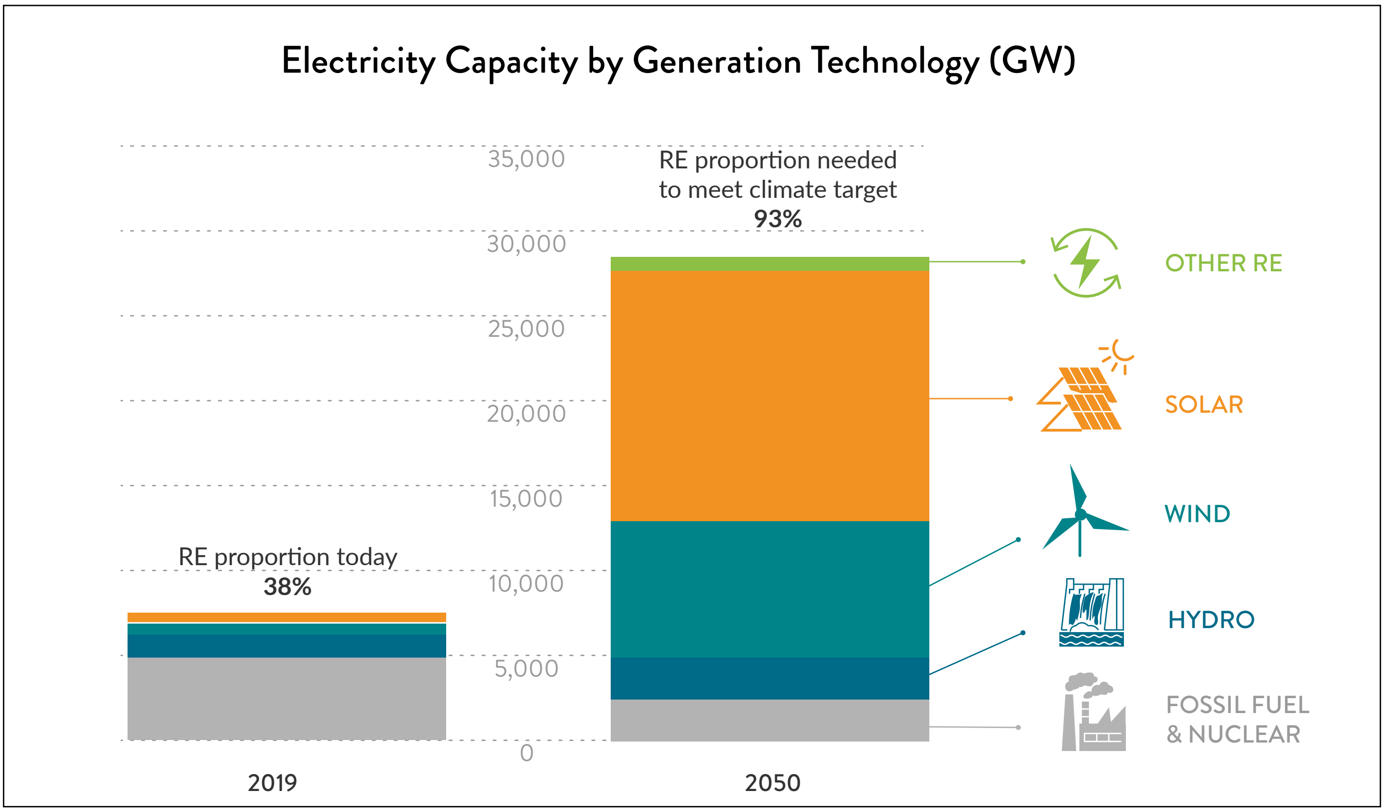


Figure 1: A renewables-based electricity system will be essential to reach net-zero emissions. Source: IEA 2021

A rapid and sustainable transition away from destructive fossil fuel technology and towards low-impact renewable energy, combined with extensive electrification, will be critical to maintaining a liveable planet.[12] Projections by the IEA show that, to meet net-zero carbon emissions by 2050, renewable energy will need to account for more than 90 per cent of electricity generation by 2050, coupled with a drastic reduction in energy consumption.[13] Its projections assume that energy systems are dominated by solar PV and wind, which together will provide 70 per cent of electricity generation by 2050, with other forms of renewable energy, including hydropower (12 per cent)[14] and bioenergy (5 per cent), accounting for smaller shares (Figure 1). Other nascent renewable energy technologies, including tidal and wave energy, are currently not forecasted to play a major role in the energy transition. Scientific understanding of their potential impacts on nature is also more limited at this time.

BOX 1: RENEWABLE ENERGY TYPES OF PARTICULAR IMPORTANCE FOR THE TRANSITION TO NET ZERO

Solar – photovoltaics (PV)

Radiant sunlight excites electrons in PV cells to generate electricity directly. PV cells are connected to form PV panels, which can be aggregated into arrays. The stronger the irradiation, the more electricity can be produced. Solar PV panels can be spatially efficient as they can be installed to co-exist with some agricultural practices, or be mounted on surfaces such as rooftops or floating structures.

Solar – concentrated solar power (CSP) and solar thermal power (STP)

Concentrated solar power (CSP) makes use of the heat of the sun to generate electricity indirectly. CSP technologies use large arrays of mirrors that track the sun to reflect its rays to a single point known as a heliostat. The focused rays heat a liquid that is then used to generate electricity in a conventional turbine. The energy can be stored in a battery or thermal storage system before it is used to generate power. Locations with strong sunlight and clear skies are particularly suited to CSP.

Wind – onshore and offshore

Wind power is generated from turbines powered by large blades rotated by the wind. Turbines can be located onshore or offshore. Offshore turbines are typically made with fixed foundations but can also be mounted on floating structures anchored to the seabed. Individual wind turbines have increased significantly in size and power output since their introduction in the 1980s.

Hydropower

Hydropower harnesses the power of flowing fresh water to power turbines that generate electricity. Hydropower design varies depending on geographical constraints and energy demand patterns. The two broad categories are conventional hydropower (subdivided into reservoir and run-of-river hydropower) and pumped-storage hydropower. Larger projects tend to include a large reservoir and dam, while smaller ones might have no storage component. In contrast to wind and solar, storage plants and pumped storage plants can also store energy. Hydropower dams with reservoirs can also be used for other purposes, such as irrigation, transport and water storage.

Bioenergy

Bioenergy uses organic material to generate energy. This energy can be used to generate electricity, or directly as a heat source. Bioenergy sources are diverse and can include wood and residues from the forestry/arboricultural sector, crops, residues and livestock waste from the agricultural sector, waste from the manufacturing sector, food, domestic and municipal waste from the residential sector, and microalgae. To generate power, dry combustible materials are burned to heat water, creating steam which drives a turbine to produce electricity. Alternatively, wet materials are stored in tanks where they break down, forming biogas, which consists of 40-60% methane. This gas is then burned to heat water, creating steam which drives a turbine to generate energy.

Hydrogen

Hydrogen is an energy carrier (rather than an energy source) that can be used to store, move and deliver energy produced from other sources. Hydrogen can be produced from a variety of methods. 'Blue hydrogen' is produced by splitting methane to create CO2 as a by-product, which is stored and not emitted. An alternative method of reforming natural gas produces what is known as 'grey hydrogen', which is not emission-free and does not contribute to the decarbonisation of the economy. Conversely, 'green hydrogen' is made via the electrolysis of water powered solely by renewable energy. Hydrogen can play a role in a variety of applications across the economy, including as a fuel for transportation, as a feedstock for chemical production and for power generation or electricity storage.[15,]

Further details of these and other types of energy sources and their impacts on nature are provided in section 2.2.

One of the staff of Dulas Ltd arriving at the office by bicycle. Dulas have a large PV solar panel as the roof of their bike shed that generates electricity for the building. Machynlleth, Powys, Wales.
© *Andy Aitchinson / Ashden*

2. Tackling the climate crisis while considering nature

Meeting the Paris Agreement goal of limiting global warming to 1.5°C above pre-industrial levels requires reaching net-zero CO_2 emissions in the middle of the century. As well as changing the way we use and reuse natural resources and energy (see Chapter 3), massive global economy-wide decarbonisation is needed, through a rapid transition from a fossil-fuel energy system to one with global electrification based on renewable energy. All pathways to 1.5°C see energy efficiency and the shift to renewable energy as central to achieving net-zero by 2050 or sooner.[16] To set us on a path to net zero, a quadrupling of wind and solar expansion is needed this decade. It is hugely challenging – roughly equivalent to installing the world's largest solar park every day.[17]

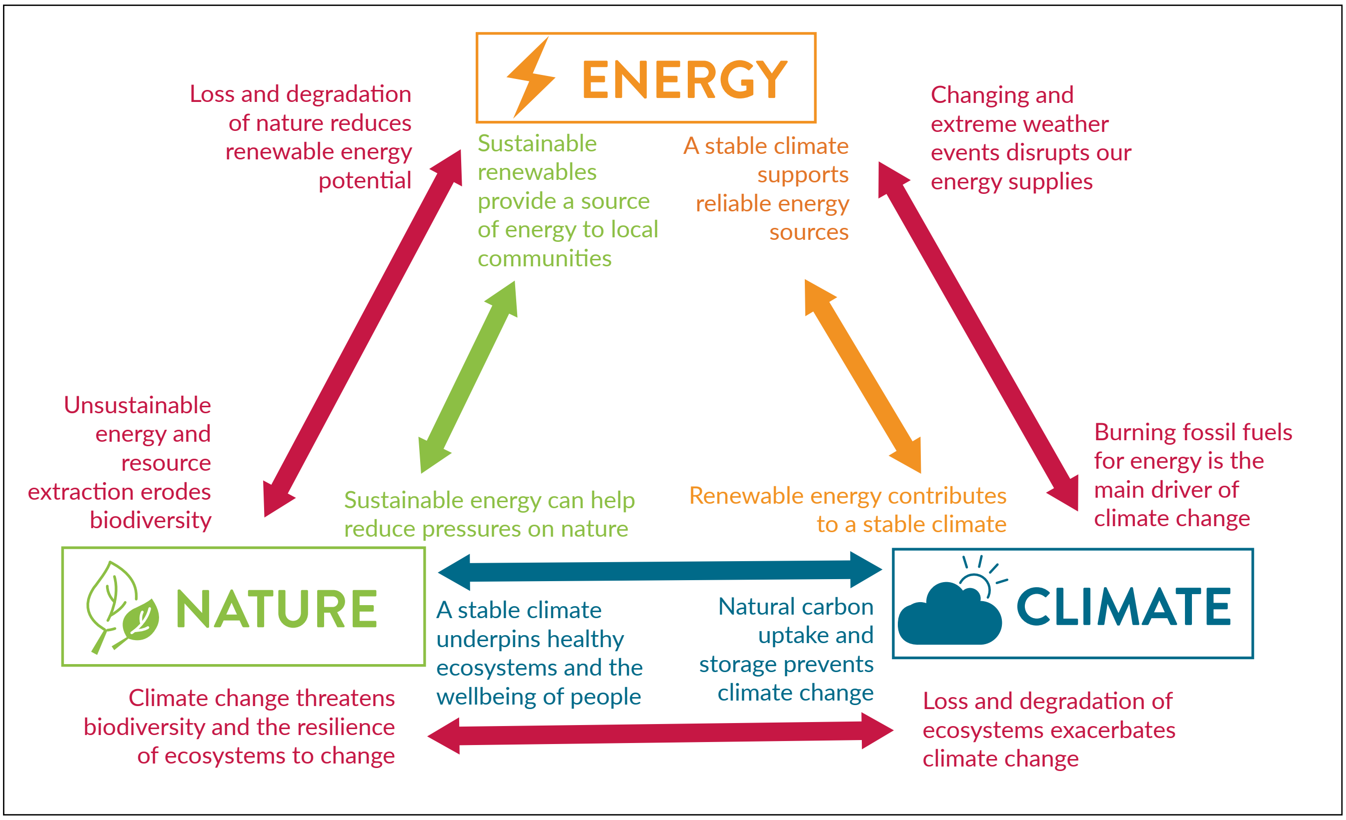


Figure 1a: The positive and negative relationships between nature, climate and energy Source: CLEANaction

Infrastructure developments typically come with inherent environmental costs. Energy, nature and climate are all closely interrelated (Figure 1a). Successfully addressing climate change must not be done at the expense of the integrity of ecosystems and the conservation of biodiversity.[18] Avoiding the loss or degradation of natural habitat is key. Failure to do so could significantly undermine climate mitigation. With poor siting, more than 10 million hectares of natural lands worldwide (an area the size of Iceland) could be cleared for wind and solar development as countries seek to meet their climate commitments under the Paris Agreement.[19] The accompanying roads and transmission lines could also convert and fragment natural habitats. These impacts conflict with the goals of SDG 15 to halt and reverse habitat degradation and loss. It has also been estimated that poorly sited renewable energy developments could release around 4 billion tonnes of CO_2 held in land and soils, equivalent to about 8 per cent of the overall emission reduction needed to meet the Paris Agreement goals.[20]

Fortunately, there are effective mechanisms for mitigating impacts on nature when applied at the earliest development planning stages (see section 2.3). Approaches that integrate biodiversity and climate targets can avoid energy pathways that address greenhouse gas emissions but undermine nature conservation.

To avoid contributing to a further erosion of nature, the renewable energy transition must also address the impacts caused by supply chains and at the end of a project's life. The global electrification effort calls for the massive deployment of clean energy technologies which require metals and minerals such as steel, aluminium, copper, lithium, zinc, nickel and rare earth elements. There are already significant environmental and social impacts from the mining of these elements. The expansion of demand will exacerbate these unless there is careful strategic planning and rigorous mechanisms put in place to ensure the renewables sector only purchases materials that have been ethically sourced in a biodiversity neutral or positive manner, and that all resource use is increasingly circular.

2.1 ENERGY COSTS, TRADE-OFFS AND COMPARISON BETWEEN ENERGY SOURCES

Adopting the right mix of low-carbon technologies to meet energy demand brings multiple benefits to human and ecosystem health, while having the potential to stabilise global temperatures. Identifying which energy mix is the best fit for any given area will depend on a range of factors. These include financial, technical (e.g. resource availability, reliability, connectivity to the grid, generation and storage capacity, etc.), social (e.g. access to energy) and environmental factors. In most places, a renewables-based electricity mix will likely consist of a combination of variable technologies, such as solar PV and wind, and less variable sources, such as bioenergy, CSP with storage, geothermal, and hydropower. These can be developed through careful siting and best practices to ensure low impact, supported by storage technologies (gravity-based, chemical, thermal), and integrated into 'smart' electricity grids that store and deliver energy more efficiently.[21]

All energy pathways carry environmental and social costs. There will be trade-offs between the area of land, seawater or freshwater required, material resourcing and the scale of site-specific impacts (see Figure 2). When comparing energy types, it is important to look at the full range and significance of potential biodiversity impacts, including conversion or degradation of natural habitats, pollution and species impacts. A life-cycle assessment (LCA) applies a standardised method to account for the full range of potential impacts across a project's lifecycle, from extraction of raw materials through development, energy production and storage, transportation and use, to waste management and recycling after closure. LCAs provide an appropriate tool for comparing impacts to identify potential trade-offs between development strategies.

LCA findings show that the choice of technologies strongly affects how much energy strategies impact the environment. When considering the full range of environmental impacts, deriving and storing energy from renewables is far less environmentally damaging overall than using fossil fuels.[22] In addition to its climate and health benefits, a transition to renewable energy focused on wind and solar can result in significantly reduced environmental impacts.[23] These include reduced species impacts and significantly less pollution, ecotoxicity and freshwater impacts overall. In any case, wind and solar energy impacts are largely limited to particular ecosystems or species; fossil fuel-induced climate change, on the other hand, not only threatens humanity but will have irreversible impacts on many of our planet's ecosystems and species.[24]

The abundance and global geographic distribution of solar and wind energy also means that, unlike fossil fuels, there is often flexibility in siting, allowing the use of already converted or disturbed land or offshore locations away from areas of high sensitivity, such as marine mammal habitats and bird migration routes. Where managed for nature, wind and solar developments can contribute to enhancing local biodiversity around the turbines or solar panels. For example, solar farms placed in already converted agricultural lands can provide opportunities to restore native flower meadows around solar arrays.

Wind and solar also tend to have lower overall impacts than other renewable energy types such as hydropower and bioenergy. Construction of hydropower dams and associated reservoirs often leads to flooding of large areas of natural habitat and creates changes to natural flow regimes, altering downstream habitats. Hydropower, including run-of-river schemes, also leads to fragmentation of freshwater ecosystems, often with severe consequences for migratory and other species. It also impedes sediment transport, causing a massive impact to deltas that shrink and sink. Planned large-scale dam projects risk fragmenting some of the world's last free-flowing rivers (see Box 2).[25, 26]

Bioenergy in all its forms, including biomass, biofuel and biogas, has a larger biodiversity impact per unit of energy than that of wind and solar PV. In the case of bioenergy from crops, this has been estimated at one hundred times larger.[27] However, the impact of bioenergy cannot easily be generalised, since this depends on the feedstock involved. Bioenergy can be generated from organic waste, which is likely to reduce some of the pressure on ecosystems. There is however a need to differentiate between solid biomass for combined heat and power, liquid biofuel for transportation, and biogas. Capturing biogas, from wastewater treatment works for example, typically builds upon existing infrastructure and captures harmful green house gases (GHGs), making the impact on nature relatively low. Bioenergy may be a more expensive option than solar or wind, but its range of cost and impact on nature depends upon the feedstock and treatment methods used.

It is also important to recognise that much of the global production potential of bioenergy is concentrated within areas of high biodiversity value.[28] Bioenergy can provide low-cost energy solutions at a local level, but the low energy density of biomass often leads to a large footprint when deployed at scale.[29] This means any climate mitigation benefits from bioenergy risk being outweighed by the carbon released due to habitat conversion.[30] These factors underline the need to assess the environmental and climate costs and benefits of different bioenergy types.

BOX 2: RISKS OF HYDROPOWER AS A RENEWABLE ENERGY SOURCE

Hydropower has long been a major component of the world's overall renewable energy capacity as a reliable source and store of energy, and is likely to continue to play a role in decarbonising the global economy. However, hydropower would only account for around 12 per cent of the world's future energy generation under a net-zero pathway.[31] Although additional planned dams on free-flowing rivers would provide less than 2 per cent of the projected worldwide power needed to stay within the 1.5°C temperature limit, the associated expansion risks the loss of the free-flowing status of the Amazon, Congo, Irrawaddy and Salween mainstem rivers, and the fragmentation of an additional 260,000 km of free-flowing rivers globally.[32]

Free-flowing rivers are uniquely important but disappearing: only about one-third of the world's rivers longer than 1,000 km are still free-flowing, with dams as the primary driver of this decline. Intact rivers are essential for healthy functional ecosystems and support the livelihoods of millions of people, for example, indigenous and traditional people of the Amazon rainforest.[33] Hydropower dams disrupt the flow regime of the river, decreasing aquatic connectivity and permanently altering natural water flows, directly impacting people's livelihoods, security and wellbeing. Hydropower dams also have a dramatic impact on sediment flow, causing riverbed incision and delta sinking and shrinking.[34]

Including biodiversity values within the watershed as part of early planning is critical to maintaining environmental flows and avoiding developments that dam intact rivers and disrupt areas of high conservation value. The most effective and important mitigation opportunities are during early planning. The consideration of non-hydropower renewable energy options and siting of needed infrastructure in locations that minimise impacts on river corridors of high biodiversity or ecosystem service value is critical. Retrofitting and modernisation of existing hydropower plants and strategically designed new projects, including off-channel pumped storage in degraded areas, can provide sustainable energy alternatives at a lower cost to nature and people and, in some cases, can have a role to play as a backup technology to enable the integration of other renewable energy systems.[35] Internationally recognised tools have been developed to provide good practice guidance for managing biodiversity risks associated with hydropower development.[36]

WWF and The Nature Conservancy have been working to protect the world's few remaining long intact rivers from proposed hydropower development. This work has highlighted the need for power systems that are 'LowCx3' - low carbon, low cost and low conflict – focused around avoiding dams on free-flowing rivers and identifying the right energy types for people and planet.[37] In Europe, WWF and more than 150 NGOs are advocating against the construction of new greenfield hydropower plants, since around 75 per cent of the technical potential of hydropower in Europe has already been exploited, populations of migratory freshwater fish species have plummeted by 93 per cent on average in Europe since 1970, and 33 per cent of all planned hydropower in the EU is in protected areas.[38]

2.2 FOCUS ON WIND AND SOLAR

A transition to net-zero emissions based on scaling up wind and solar PV would be significantly less damaging than other energy pathways. However, it could still have considerable environmental impacts, and deploying best practices is crucial to reduce harm to biodiversity. Three common areas of concern are the additional space required to develop solar PV and wind power plants, their impacts on vulnerable species, particularly birds and bats, and the need for metals and minerals to manufacture them.

Solar and wind land take

Although wind and solar PV are relatively space efficient compared to other renewables in terms of the power that can be generated per unit area, the sheer amount of energy to be produced means that the total area of land and sea required is substantial. The estimated total area needed to provide all the world's renewable energy is nearly 1 million km^2, almost twice the size of the state of California.[39] The area required is also highly variable, depending on resource potential. For example, the estimated land area required to meet national solar requirements ranges from 0.1 per cent in much of Africa to over five per cent in Northern Europe.[40] Managing the space between wind turbines in low-conflict areas for other uses, such as for solar PV, nature or food production, could significantly reduce the footprint needed for renewables and provide significant co-benefits.[41] This is highlighting the importance of land-use planning both to optimise land use and to minimise the risk of displacement of activities into undisturbed areas.

A review of studies that compare lifecycle assessments of various energy sources, including their impacts on nature from land transformation and climate change, finds that a transition focused on wind and solar will minimise any damage to nature. Individual lifecycle assessments that account for the full range of land transformation impacts from energy sources have drawn different conclusions[42]. Some find that the converted area of natural land and sea for wind energy is less per unit of energy than for all other forms of energy. Others indicate that solar PV and concentrated solar power impact a larger area, but are still within the range of natural gas extraction and significantly lower than coal. Studies also show the majority of countries can meet their required energy targets by expanding renewable energy on already converted lands.[43] Studies for the US show that the area of land required for renewables is an order of magnitude less than the current area taken up by fossil fuels,[44] offering opportunities to repurpose land currently used for fossil fuels. For example, obsolete coal mines and power stations could be covered with solar panels and co-managed for food production or biodiversity. However, a recent study has suggested that, for various decarbonization scenarios, the land required for electricity generation will at least double in the future, with potential for serious environmental consequences - especially habitat loss and associated biodiversity loss.[45]

A key factor explaining this range of estimates for the area of land affected by energy sources is whether or not the space between the sources is included. The impact on this land will depend upon its use after the energy systems are installed. For example, solar panels built on already-existing infrastructure will most likely have minimal impact on the space inbetween. In contrast, placing these panels in wilderness areas with high biodiversity may fragment the associated habitats. Similarly, if wind turbines are constructed on agricultural land alongside a road, the impact on the space between them will be much less detrimental than turbines located in areas of untouched nature with high biodiversity. This comparison indicates that the smallest land-use footprint from new renewables results from systems built on land that is already converted.

Impacts on species

Wind energy, in particular, is often criticised for its negative impacts on birds and bats. However, when considering the impacts from pollution and climate change, bird impacts associated with wind and solar are less significant overall than other key energy technologies, including fossil fuels, bioenergy and nuclear energy.[46] Another critical driver of biodiversity loss and degradation is the destruction of habitat and ecosystems, which presents an additional, although related, challenge. This undermines nature's ability to regulate greenhouse gas emissions and protect against extreme weather. The two crises must therefore be tackled together with holistic policies that address both issues simultaneously and recognise their interconnections.[47]

Wind energy technology in its current configuration does present a particular risk to a subset of vulnerable bird species. Such impacts can accumulate where multiple wind farms overlap a species' range. This can lead to elevated extinction risk to threatened birds, particularly species vulnerable to colliding with turbine blades and/or transmission lines, or electrocution on distribution lines, such as large soaring birds, vultures, bustards, cranes and migratory birds.[48] Bats can also be highly vulnerable; poorly planned developments can decimate local bat populations through collisions with turbines.

In addition, species vulnerable to offshore wind developments include whales, dolphins, sea turtles and some fish species, particularly when exposed to high noise levels during construction. Mammals and sea turtles also face risks of collision with construction and maintenance vessels, while habitat alteration can affect species living on the seafloor. Fortunately, effective approaches for addressing many types of species impact already exist, and new mitigation strategies continue to be tested and applied. The most effective and important mitigation opportunities are during early planning. Careful siting of wind projects and associated infrastructure away from sensitive areas, such as migration routes, can minimise impacts on vulnerable species (see Section 3).

Further on-site mitigation may be required to address collision and electrocution risk. Effective mitigation strategies include temporarily stopping turbines during sensitive periods or when species at risk fly into the wind farm area, while measures to deter bats and birds from flying into turbine blades are being tested.[49] The risk of collision with power lines can be reduced through careful siting or by making them more visible through bird flight deflectors or eliminated by burying them, while there are well-established and straightforward methods to prevent electrocutions through wildlife-safe design. For marine mammals and sea turtles, proven methods to reduce risk of injury or death during construction include seasonal avoidance, acoustic monitoring, pre-piling searches and delays, soft-start piling procedures, breaks in piling activity, acoustic deterrent devices and creation of noise barriers such as bubble curtains.[50]

Nevertheless, considerable gaps remain in our understanding of renewable energy impacts and how to mitigate them. As the pace of renewable energy expansion increases, our ability to assess and manage the risks is falling behind. This is particularly so for emerging renewable energy technologies and in less-researched areas of high conservation significance, including much of the tropical and subtropical regions of the world. Urgent research and ongoing standardised monitoring and data sharing are needed to understand the interactions between local biodiversity and renewable energy, and to identify effective strategies to mitigate risks.

Mineral resourcing

While current fossil fuels and nuclear energy require significant mining of critical raw materials, the transition to a wind and solar-based economy is expected to greatly increase demand for metals and minerals needed to develop energy infrastructure, including lithium, cobalt, graphite, nickel, aluminium and rare earth minerals (see also Box 3, page 16, on copper extraction).[51] Many of these commodities are found within some of the world's most biodiverse regions, such as the Congo Basin, posing serious threats to nature and to people whose livelihoods are directly connected to it.[52]

The development of a circular approach to how we use these resources, including the establishment of advanced recycling capacity, end-of-life management, and promoting technological innovation for mineral substitution, are all critical to minimising the need for mining these resources. A recent report outlines the potential to reduce the need for these critical minerals by 58 percent between now and 2050, provided investments are made in recycling, circular economy practices, and in technologies requiring less new material.[53]

However, where mining is unavoidable, strategic planning and adhering to best-practice environmental and social safeguards are needed to avoid unnecessary negative impacts on nature. Extraction from the deep ocean floor is being proposed to source some of these minerals, but with as-yet unknown costs to sensitive deep-sea environments and their carbon storage functions (see Box 4 on page 16).

There is an urgent need to improve the understanding of the scale of mining required to support a transition to renewable energy, and to explicitly account for the risks and trade-offs in spatial planning, corporate and financial sector safeguards and policy development.[54] Full material traceability and environmental risk management along supply chains are needed to understand the risks and minimise the impacts of raw material extraction to both people and nature.[55] Careful strategic planning at the national or even global scale is needed to identify the least damaging extraction methods and locations for land-based mining, away from sensitive sites including protected areas, Key Biodiversity Areas, and other areas of conservation significance.

Where impacts cannot be avoided, the impact hierarchy needs to be implemented to first reduce, then mitigate and finally offset them. This includes actions to reduce and fully restore the footprint of mining, address indirect impacts beyond the mine site, and work with regional developers to identify and address cumulative impacts.[56] Where unavoidable residual impacts remain, developers should look for site alternatives.

BOX 3: MITIGATING THE IMPACTS OF COPPER MINING

Renewable energy will require significant quantities of metals and minerals, with copper being one of the most important. Demand for copper is expected to rise by 40 per cent over the next two decades, driven largely by the offshore wind industry, followed by onshore wind and solar.[57] It is well recognised, not least by the International Copper Association, that there is potential to massively scale up recycling and reuse of copper[58], although mining will remain an important component of copper supply in the near term.

The world's largest suppliers of copper are Chile and Peru, followed by China, the Democratic Republic of Congo (DRC) and the United States.[59] Countries like Chile, Peru and the DRC are also highly biodiverse, with large areas of remaining natural habitat. Copper mining in these countries will have inevitable impacts on biodiversity. The industry not only has a large footprint, but the processes involved and the associated infrastructure also disrupt biodiversity through direct mortality, habitat loss and fragmentation.

Fortunately, there are proven mitigation practices to minimise impacts.[60] As with renewable energy development, early strategic planning is key to avoid the conversion of natural habitat and other impacts on biodiversity and the climate.[61] An emphasis on avoiding and minimising impacts is particularly relevant to mining, as successful restoration and offsetting is often challenging, uncertain and expensive.[62]

BOX 4: THE RISKS TO NATURE FROM DEEP SEABED MINING

Some metals and minerals that are essential for the renewable energy transition can be found in the deep sea, at several kilometres of depth. These include copper, cobalt, nickel, lithium, silver, speciality metals (e.g., tellurium), and rare earths (e.g., neodymium and dysprosium).[63] These deposits can take various forms, such as polymetallic nodules[64] on the deep-sea plains, cobalt crusts[65] on seamounts, and sulphide deposits associated with hydrothermal vents, underwater volcanic chains and island arcs.[66] These systems and the mineral deposits themselves provide critical habitats for a multitude of species that play important roles in the marine ecosystem and the carbon and nutrient cycles. They include migratory species such as whales and tunas, as well as microorganisms, corals and sponges, to name a few.

One area earmarked for commercial mining is the Clarion-Clipperton Fracture Zone in the central Pacific Ocean. Nodules found here form over thousands of years and have a unique set of associated biota. Mining, if permitted, would directly remove benthic (seabed) communities and permanently destroy the seabed habitat.[67] Mining would also cause underwater noise and light pollution, which can be highly disruptive in this naturally low-light environment, and be detrimental both for seafloor species and for fish and whales. Sediment plumes would form through disruption of the seabed or waste-water discharge back into the water column, smothering benthic communities across hundreds of kilometres or more.

In addition to these known risks, there are a plethora of unknown risks posed by deep seabed mining. The impact of deep-sea disturbance on broader ocean functioning and nutrient and carbon cycles is also largely unknown, with potential knock-on effects to climate regulation, fisheries and human well-being. The extent and distribution of deep-sea biodiversity is poorly understood, impacts are difficult to monitor, and very challenging – perhaps impossible – to mitigate.

How deep seabed mining would be regulated and regulations and guidelines enforced is still unclear. There are also unresolved issues around the sharing of benefits by all states of any seabed mining. Only a handful of western companies and a few states are involved in developing this nascent industry.

Civil society organisations, governments, the European Parliament, fishing organisations, and over 650 scientists, as well as a growing number of companies such as BMW Group, Volvo Group, Renault, Google and Samsung SDI, are calling for a moratorium on deep sea mining unless and until scientific certainty and good environmental rules are in place, as well as assurance that significant damage to the marine environment will be avoided; a social licence has been secured; governance issues are addressed; and adequate investments have been made in identifying alternatives to opening a vast new extractive frontier in one of our planet's last wildernesses.[68]

Adding to this resistance, UNEP FI advises that "there is no foreseeable way in which deep seabed mining can be viewed as consistent with the Sustainable Blue Economy Finance Principles" and recommends financial institutions do not invest in such activities.[69] Similarly, WWF believes that seabed mining could have disastrous consequences and therefore should not be allowed; related offsets should not be contemplated in the context of massive uncertainty about the impacts of deep-sea mining (if the impact cannot be properly quantified, then it cannot be confidently compensated for).

A laborer is seen working at diesel-powered crusher in front of a wind turbine. This is a 17.5 MW wind project, consisting of eighteen wind farm sites in the Indian states of Tamil Nadu, Maharashtra, Rajasthan and Karnataka. © Land Rover Our Planet

3. Key impacts and mitigation measures for different energy types

Recognising that all energy sources, including the wide range of renewables, will have some impact on nature, it is important to understand the comparative costs. Only then can any decision-maker select the most appropriate energy supply balance for any given location. Every situation will be different, with many factors based upon local conditions. However, there are a range of key impacts that can be associated with different energy sources, providing an indication of the most suitable application. Figure 2 below provides an overview of this impact comparison.

● = Relative scale of impact

Relative impact
▼ = Low impact
▼▼ = Medium impact
▼▼▼ = High impact

Relative mitigation potential
▲ = Some potential
▲▲ = Medium potential
▲▲▲ = Good potential

	KEY IMPACTS	SOLAR PV AND CSP	ONSHORE WIND	OFFSHORE WIND	HYDRO-POWER	BIOENERGY	GEOTHERMAL	NUCLEAR	OIL AND GAS	COAL
Impacts	Changes in land and sea use	▼▼	▼	▼	▼▼▼	▼▼▼▼	▼▼	▼▼	▼▼	▼▼▼
	Species overexploitation	▼	▼	▼	▼▼	▼▼▼	▼▼	▼▼	▼▼	▼▼
	Invasive species and disease	▼	▼	▼▼	▼▼	▼▼	▼▼	▼▼	▼▼▼	▼▼
	Pollution	▼	▼	▼	▼▼	▼▼	▼▼▼	▼▼	▼▼▼	▼▼▼▼
	Climate change	▼	▼	▼	▼▼	▼▼	▼	▼▼	▼▼▼▼	▼▼▼▼
	Comparative life-cycle results* - **natural land transformation**	●	●	●	●	●	●	●	●	●
	Comparative life-cycle results* - **ecotoxicity**	●	●	●	●	●		●	●	●
Mitigation potential	Potential to address - **project-level impacts**	▲▲	▲▲	▲▲	▲		▲▲	▲▲	▲	▲
	Potential for achieving **nature-positive outcomes**	▲▲	▲▲	▲▲	▲		▲▲	▲▲	▲	

Notes: Solar includes PV and CSP. Wind includes onshore and offshore. Impact categories based on the WWF classification from the 2020 Living Planet report. Relative impact categories ranges: '▼' low, '▼▼' medium, '▼▼▼' high, '▼▼▼▼' very high . Relative scale of impacts from life-cycle assessment results ranges: low, medium, high, very high. Relative indicative mitigation potential applies to addressing project-level impacts only, based on broad literature review. Scale: '▲▲▲' good potential, '▲▲', Medium potential, '▲' Some potential, '_' limited to no potential.

Figure 2: Comparative assessment of the impacts of key renewable energy types and the potential to mitigate them. Source: Hertwich et al. 2015; UNEP 2016; Gibon et al. 2017; Luderer et al. 2019

The figure also summarises potential for on-site mitigation and for nature-positive outcomes at the project level. Findings are based on lifecycle assessments of different energy types. Further details on impacts and mitigation opportunities are provided in the sector-specific sections below.

The sections presented below provide a synthesis of the current state of knowledge (and gaps) of biodiversity impacts and effective mitigation associated with different energy types and their associated infrastructure.

3.1 RENEWABLE ENERGY TECHNOLOGIES

SOLAR – PHOTOVOLTAICS (PV)

Key biodiversity impacts: habitat loss, barrier effects

Biodiversity most at risk: arid ecosystems

Potential to address project impacts: *high* - avoidance through site selection and micro-siting of panels in already converted lands. Vegetation restoration and enhancement. Careful planning for associated infrastructure linked to the site such as power lines and roads

Potential for achieving nature-positive outcomes at project level: *high* - often opportunities to undertake on-site habitat enhancement if placed on previously modified land (with assessment of the appropriateness of such land for this conversion over the long term)

Summary: developing utility-scale solar PV usually requires large areas of land, which can lead to significant habitat loss if poorly planned. Other impacts include barrier effects and cumulative population impacts. Placement on previously degraded lands or buildings can avoid most biodiversity impacts. There are often opportunities to undertake restoration and enhancement around solar arrays, providing potential to achieve positive biodiversity outcomes, especially in previously degraded lands. Little is known about the potential impacts of solar PV on birds, bats and other species groups (UNEP 2016; Bennun et al. 2021).

Potential impacts from floating solar PV remain largely unstudied and are likely to be very context dependent. Potential impacts include habitat alteration due to shading effects from the panels, and congregation (with possible entanglement, though the risks seem very low and are unstudied). Biodiversity values most likely to be at risk are sensitive freshwater and coastal ecosystems, including coral reefs and seagrass beds. Such risks can be avoided through placement of panels away from particularly sensitive areas and on to man-made water bodies such as hydropower reservoirs. On-site mitigation, as well as opportunities to enhance biodiversity, such as through the creation of artificial substrates underneath the panels, require further study (Hooper et al. 2021). While the direct impacts on water bodies should not be discounted, and need continued attention such as through standard environmental review processes, the indirect impacts on flow releases (particularly from hybrid hydro-floating PV plants) can be even more important.

Information gaps: significance of impacts on species groups, particularly bats and insects.

Resources for further information: UNEP 2016; Bennun et al. 2021

SOLAR - CONCENTRATED SOLAR POWER (CSP)

Renewable energy for unelectrified villages in Bangladesh © Sarah Butler-Sloss / Ashden

Key biodiversity impacts: habitat loss and hydrological changes due to water use

Biodiversity most at risk: arid ecosystems and birds

Potential to address project impacts: *medium* - avoidance through site selection

Potential for achieving nature-positive outcomes at project level: *medium* – sometimes opportunities to undertake on-site habitat enhancement if placed in previously modified land

Summary: as with PV, most of the impacts from CSP can be avoided through placement in previously degraded lands away from sensitive areas. This also presents opportunities for achieving nature-positive outcomes through on-site habitat rehabilitation of degraded areas, although these opportunities are restricted in most cases due to limited space between infrastructure. Biodiversity values most at risk include arid ecosystems and birds. A potentially significant impact, particularly in arid regions, is changes to the local hydrology due to the high volume of water that is required for cooling and washing the mirrors. Technological improvements, such as dry-cleaning technologies, can help minimise this impact. There is evidence of bird mortality due to birds flying into the path of the concentrated light energy, although further research is needed to understand the scale of this impact on bird populations. If placed in degraded lands, there are often opportunities for habitat enhancement (UNEP 2016; Bennun et al. 2021).

Information gaps: severity of impacts on birds and insects due to risk of collision with infrastructure and singeing

Resources for further information: UNEP 2016; Bennun et al. 2021

WIND - ONSHORE

New wind turbine in Westmill. © Ashden / Ashden

Key biodiversity impacts: habitat loss, barrier effects, collisions with turbines and cumulative impacts on birds and bats

Biodiversity most at risk: birds - particularly birds of prey and migratory birds, bats

Potential to address project impacts: *medium* - avoidance through site selection, although often constrained to areas of high wind potential overlapping with ranges of sensitive species. Micro-siting of turbines. Measures to reduce turbine collision risk including acoustic deterrents, increasing the visibility of blades,[70] and curtailment (using radar data or digital video cameras to detect species at risk, and temporarily stopping or controlling the rotational speed of the wind turbine).[71] Areas with high natural carbon uptake and storage can be avoided through siting.

Potential for achieving nature-positive outcomes at project level: *medium*[72] - often opportunities to undertake on-site habitat enhancement if placed in degraded lands. Impacts to birds and bats are more difficult to address.

Summary: a key biodiversity risk associated with wind energy is mortality of birds and bats due to collisions with turbine blades, potentially leading to high fatality rates across a wide range of vulnerable species groups, including vultures, raptors, bustards and many migratory species. Such risks are difficult to avoid entirely, as turbine locations are tightly linked to wind energy potential. However, risks can be reduced through placement of turbines away from important bird areas and migratory routes. On-site mitigation strategies include increasing the visibility of turbine blades, acoustic deterrents and procedures to shut down specific turbines when vulnerable birds are in the area. For bats, stopping turbine blades from operating during low wind speeds can reduce collision risk at a minimal cost to energy generation (UNEP 2016; Bennun et al. 2021).

A large concentration of wind or solar farms in combination with other developments can create barriers for species movement and potentially cause significant cumulative impacts on species' populations. Such risks can only be addressed through rigorous spatial planning at scale, and development of strategic landscape-level planning that accounts for biodiversity. Ongoing monitoring and data sharing are key to developing a better understanding of the magnitude of impacts and effectiveness of mitigation measures. Opportunities for on-site habitat enhancement exists if placed on degraded lands (UNEP 2016; Bennun et al. 2021). It is important to direct development away from areas with high natural carbon uptake and storage.

Significant information gaps: magnitude of impacts and effectiveness of mitigation measures

Resources for further information: UNEP 2016; Bennun et al. 2021

WIND - OFFSHORE

A rotor blade is slowly lifted by an offshore crane for installation to t wind turbine of North America's first commercial offshore wind farm, the Block Island Wind Farm, off the coast of Rhode Island, USA. © Joan Sullivan / Climate Visuals

Key biodiversity impacts: habitat loss, increased physical infrastructure in the marine environment, increased ship traffic, marine noise from construction and maintenance, barrier effects, collisions with turbines, disturbance impacts on marine species during construction and maintenance, cumulative population impacts on birds and bats.

Biodiversity most at risk: sensitive benthic habitats and species and sensitive coastal ecosystem birds - particularly seabirds and migratory birds, bats and marine mammals

Potential to address project impacts: *medium* - avoidance through site selection, e.g., avoiding areas of high biodiversity value such as coral reefs and mudflats, protected areas, Key Biodiversity Areas, bird, sea turtle and marine mammal migration corridors, fish spawning and rearing areas, and areas with high natural carbon uptake and storage. Measures to reduce turbine collision risk including temporary shutdown during migration events, reducing lighting, acoustic deterrents and increasing visibility of blades. Measures to minimise the impact of acoustic disturbance include soft-start piling procedures, breaks in piling activity, acoustic deterrent devices and creation of noise barriers such as bubble curtains. Floating wind power creates less noise during the construction phase than bottom-fixed turbines. Floating structures increase risk of entanglement, and also lead to aggregations of fish populations.

Potential for achieving nature-positive outcomes at project level: *medium* - potential to create an artificial reef effect at the bottom elements, although influxes of invasive species must be avoided. Possibility to reduce the overall pressure on certain marine ecosystems as they can allow for certain species to recover or reproduce in areas of less physical disturbance, for example from restricted fishing.

Summary: similar to onshore wind impacts and mitigation. In addition, construction of offshore wind farms can impact species vulnerable to high noise, including marine mammals, sea turtles and some fish species, in particular during construction (e.g., pile driving for bottom-fixed wind power). Mammals and sea turtles also face risks of collision with construction vessels. The physical footprint of industrial-scale infrastructure will destroy benthic habitats. Operational impacts and impacts on seafloor habitats can be minimised through careful site selection and as a part of an ecosystem-based marine spatial planning process. Construction-related impacts can be minimised by implementing strict construction protocols to reduce noise and temporarily deter sensitive species. The additional risk for ship accidents and subsequent pollution can be mitigated by siting, surveillance and emergency tugs, speed restrictions and optimised shipping routes. Ongoing monitoring and data sharing are key to developing a better understanding of the magnitude of impacts and effectiveness of mitigation measures.

Significant information gaps: magnitude of impacts (in particular on migrating birds), effectiveness of mitigation measures, and risk of alien invasive species

Resources for further information: UNEP 2016; Bennun et al. 2021; WWF 2021

HYDROPOWER

Siltation threatens hydropower, an important source of electricity in Kenya. © Flore de Preneuf / World Bank

Key biodiversity impacts: aquatic, riparian and terrestrial habitat loss and degradation, changes to flow regimes including water, sediment and aquatic species, loss of connectivity, blocking movement of aquatic species up- and downstream, fish entrainment, impacts associated with linear infrastructure, and indirect impacts associated with in-migration of people into areas of natural habitat.

Biodiversity most at risk: freshwater habitats, fish and other aquatic species, particularly migratory and range-restricted species. Natural habitats flooded by the dam reservoir. Downstream habitats affected by changes in the flows of water and sediments, including coastal ecosystems, such as deltas, that are dependent on inflows of sediments.

Potential to address project impacts: *low* - location of infrastructure is tied to energy potential, limiting opportunities to avoid significant impacts. Avoidance of river corridors of high biodiversity importance and exploring non-hydropower alternative energy options is critical. Maintaining environmental flows and construction of fish passages can only attenuate some of the impacts in some cases.

Potential for achieving nature-positive outcomes at project level: *low* - limited restoration potential. Offsets are often not feasible due to the unique biodiversity impacted. Indirect impacts are difficult to control.

Summary: biodiversity values most at risk from hydropower include freshwater habitats and aquatic species, particularly migratory and range-restricted species. Key biodiversity impacts of hydropower are habitat loss due to flooding of the reservoir, and loss of connectivity and downstream ecosystems due to changes in the flow regime (also see Box 2). Altered sediment flow can have massive impacts on the riverbed all the way to deltas that shrink and sink. These impacts are difficult to mitigate, as the location of the hydropower dam is linked to the energy potential of the river. Maintaining environmental flows and construction of fish passages can mitigate some of the impacts. However, it must be acknowledged that these will not always maintain connectivity.[73] Ongoing monitoring is needed to better understand environmental and downstream flow regimes (e.g. concerning hydro peaking). Hydropower dams are often constructed in remote areas and new access roads can therefore increase human activities in the area, leading to indirect impacts such as habitat loss and species exploitation. There can also be a significant negative social dimension related to hydropower, including displacement of people and loss of critical services for dependent communities, including fresh water and fisheries. Despite these concerns, some stakeholders insist that tools/options are available to use hydropower in a nature-positive way.[74] Some internationally recognised hydropower sustainability tools are designed to provide guidance to industry on achieving good practice in hydropower development regarding biodiversity conservation.[75]

Significant information gaps: better understanding of managing environmental flow regimes. Impact of altered sediment flow on entire catchments

Resources for further information: TBC 2016; UNEP 2016; IFC 2018.

BIOENERGY

Biomass briquettes made from crop waste to be fed into a biomass stove. Nishant Bioenergy © Martin Wright (unpublished) / Ashden

Key biodiversity impacts: habitat loss, degradation, fragmentation, release of sequestered CO_2, due to land-use change, impacts on freshwater habitats associated with erosion and agricultural run-off, and indirect impacts associated with in-migration of people into areas of natural habitat.

Biodiversity most at risk: natural habitat and associated species

Potential to address project impacts: *very low* - Crops for bioenergy require large tracts of land. Measures to minimise impacts include preserving understory vegetation, conserving areas of natural habitat such as forest patches and riparian habitats within plantations, and maintaining or restoring wildlife corridors through plantations. Note that impacts associated with feedstocks for some newer types of bioenergy, including food waste and microalgae, remain uncertain. These bioenergy types make up a small proportion of current bioenergy yield.

Potential for achieving nature-positive outcomes at project level: *very low* - limited restoration potential for land used for bioenergy crops. Offsets are often not feasible due to the large amount of land impacted. Avoidance of potential damage to nature by using food waste for feedstock can be of benefit.

Summary: bioenergy sourced from crops requires a lot of land, which can lead to significant habitat loss, degradation and fragmentation (Immerzeel et al. 2014; Wu et al. 2018). Wherever possible, bioenergy crops should be planted on established agricultural land rather than on converted natural habitats. Measures to minimise impacts include preserving understory vegetation and conserving areas of natural habitat such as forest patches and riparian habitats within plantations, maintaining or restoring wildlife corridors through plantations, and holistic efforts to reduce and manage conflicts with wildlife. Erosion and agricultural run-off can lead to freshwater impacts and affect downstream coastal ecosystems. Mitigation should be focused on avoidance through land-use planning, including use of marginal, degraded or abandoned agricultural land, as well as policy and regulatory measures promoting a more sustainable bioenergy sector that accounts for biodiversity values. Offsets are often not feasible due to the large amount of land impacted. Biofuels can provide low-cost energy solutions at a local level, but the low energy density of biomass leads to an unavoidably large footprint when deployed at scale.[76] This means any climate mitigation benefits from bioenergy risk being outbalanced by the carbon released due to habitat conversion, and that it comes with extensive climate risks.[77]

However, there are experiences from bioenergy types that do not use crops as feedstocks that show it can be possible to manage the sustainability and biodiversity risks associated with bioenergy projects.[78] There are a number of tools available to countries already invested in bioenergy to help manage impacts and that can enable a more sustainable approach to biomass[79].

Significant information gaps: generally well understood for food and energy crops. Impacts less clear for advanced forms of bioenergy such as algal biofuels.

Resources for further information: Immerzeel et al. 2014; Wu et al. 2018; Jeswani et al. 2020.

GEOTHERMAL

Olkaria geothermal complex and power station, the first geothermal power plant in Africa. © IRENA

Key biodiversity impacts: habitat loss and degradation, changes to water regimes and water quality

Biodiversity most at risk: natural habitat and associated species

Potential to address project impacts: *medium* - Location of infrastructure is tied to energy potential. Geothermal resources are often located in areas of high biodiversity significance. Reinjecting geothermal wastewaters back into the reservoir can greatly reduce ecotoxicity impacts. Often opportunities for restoration.

Potential for achieving nature-positive outcomes at project level: *medium* – impacts on water regimes are more difficult to address

Summary: although geothermal energy has a relatively small footprint, this is tied to where there is potential, often in areas of high biodiversity conservation significance. If not carefully planned, geothermal can have significant impacts on local and downstream water regimes (Bayer et al. 2013; UNEP 2016; Gasparatos et al. 2017; Lammerant et al. 2020). Adopting geothermal technologies that have low ecological impacts, such as minimisation of openings, reinjection of thermal wastewater and directional drilling, are standard practices to minimise impacts. Redirecting emissions during well testing to avoid brine spray and defoliation proved helpful for projects in forests (Mutia 2010). The potential to reinject geothermal wastewaters back into the reservoir greatly reduces ecotoxicity impacts. However, impacts on water regimes are more difficult to address. There are often opportunities for restoration around geothermal energy developments. The hydrological impacts associated with geothermal energy are poorly understood.

Significant information gaps: hydrological impacts on freshwater and other dependent biodiversity

Resources for further information: Bayer et al. 2013; UNEP 2016; Gasparatos et al. 2017; Lammerant et al. 2020; Mutia. 2010.

NUCLEAR

Nuclear plant on the Rhône river, France © Michel Gunther / WWF

Key biodiversity impacts: habitat loss, degradation and fragmentation associated with uranium mining, and indirect impacts associated with in-migration of people into areas of natural habitat.

Biodiversity most at risk: natural habitat and associated species.

Potential to address project impacts: *medium* – avoidance through site selection (for power plant). Mitigation for uranium mining focused around restoration after decommissioning. Indirect impacts around the mine site can be difficult to control.

Potential for achieving nature-positive outcomes at project level: *medium* – opportunities to undertake on-site restoration and offsets to address mine site impacts.

Summary: the key biodiversity impacts of nuclear energy are associated with uranium mining. These include habitat loss, degradation and fragmentation, as well as impacts on associated species (OECD 1999; Environmental Law Alliance Worldwide 2010; CSBI & TBC 2015). Elevated sea-surface temperatures from water cooling effluent can impact coastal environments. Avoiding sensitive areas when mining for uranium is a key mitigation measure, although this may be difficult to implement in practice. Mitigation measures will likely be focused on restoration after decommissioning of uranium mines. Measures to reduce emissions, pollution and tailings management are also important. Indirect impacts around the mine site can be difficult to control and mitigation options are poorly understood.

Further impacts of nuclear power may include the release of hot wastewater from cooling systems into surrounding aquatic habitats. There can be opportunities for on-site habitat enhancement around nuclear power plants if placed on degraded lands. Nuclear energy also carries risks associated with the transport, waste management and storage of nuclear waste, which could in turn lead to significant environmental impacts.

Significant information gaps: significance and mitigation of indirect impacts

Resources for further information: OECD 1999; Environmental Law Alliance Worldwide 2010; CSBI & TBC 2015; Sovacool 2012.

FOSSIL FUELS

Penguin rescued after oil spill being cleaned at the Southern African National Foundation for Conservation of Coastal Birds. Republic of South Africa.. © Martin Harvey / WWF

Key biodiversity impacts: habitat loss, degradation and fragmentation associated with extraction, often from areas of intact natural habitat. Indirect impacts associated with in-migration of people into the areas affected, leading to over-exploitation. Climate-change induced impacts on species and ecosystems. Local pollution. High water usage – implications for arid regions.

Biodiversity most at risk: natural habitat and associated species vulnerable to climate change

Potential to address project impacts: *low* – Location of infrastructure is tied to resources. Fossil fuel resources are often located in areas of high biodiversity significance. Often opportunities for limited on-site restoration.

Potential for achieving nature-positive outcomes at project level: *low* – opportunities to undertake on-site restoration and offsets to address site impacts. Indirect impacts difficult to address.

Summary: extraction of fossil fuels often occurs in areas of high biodiversity intactness and conservation significance, resulting in significant loss and degradation of natural habitat and impacts on associated species. Site-level mitigation is focused on minimising impacts and restoring habitat post extraction. Offsets are needed to address residual impacts. Offsets are inherently uncertain and difficult to implement. Indirect impacts as a result of in-migration of people into the affected areas can become drivers of significant further habitat loss through conversion of forests and other natural habitats for agriculture and unsustainable use of natural resources. Burning of fossil fuels is a major driver of climate change, in turn negatively impacting many of the world's threatened species and ecosystems.

Resources for further information: CSBI & TBC 2015; IPIECA 2020

3.2 ASSOCIATED INFRASTRUCTURE

POWER LINES

High voltage tower in forest. © B-roll Shots / Shutterstock.com

Key biodiversity impacts: habitat fragmentation, collisions with power lines, electrocution on distribution lines, restricting wildlife movement and cumulative population-level impacts on birds

Biodiversity most at risk: birds and bats; forests and other habitats highly impacted by fragmentation

Potential to address project impacts: *high* – Burying of power lines, installation of bird flight diverters on power lines, bird-safe design of distribution line, restoration of natural habitat after construction (to avoid permanent habitat conversion)

Potential for achieving nature-positive outcomes at project level: m*edium* – effective management of the space underneath overhead power lines can deliver important ecosystem services to local biodiversity.[80] Offsets that address collision and electrocution risk of unmitigated power lines elsewhere in the landscape can be considered.

Summary: electrocution due to poorly designed power lines continues to pose a significant risk to many birds (UNEP 2016; Bennun et al. 2021). Construction of safe distribution lines that include insulation and appropriate spacing of conductors can address such risks when integrated into early design. Collisions with transmission lines can be reduced through installation of bird flight diverters, bird-safe designs and by burying power lines or routing them to avoid sensitive areas such as wetlands (Bennun et al. 2021). Attention is required to the habitat conversion caused by a new powerline or access road, since the natural processes are usually permanently altered

Significant information gaps: effectiveness of mitigation measures to lesser studied species at high collision risk

Resources for further information: UNEP. 2016; Bennun et al. 2021.

HYDROGEN

Hydrogen production plant in Iceland. © Glenmore / Shutterstock.com

Key biodiversity impacts:

Grey and blue hydrogen: habitat loss, degradation and fragmentation associated with extraction, often from areas of intact natural habitat. Indirect impacts associated with in-migration of people into areas of natural habitat. Climate-change induced impacts on species and ecosystems.

Green hydrogen: habitat loss, impacts on species vulnerable to wind and solar development (see preceding boxes). Impacts on species in freshwater ecosystems in particular, as green hydrogen production is water intensive and has the potential to negatively impact freshwater ecosystems if proper safeguards are not in place.

Biodiversity most at risk:

Grey and blue hydrogen: natural habitat and associated species vulnerable to climate change

Green hydrogen: natural habitat and associated species

Potential to address project impacts:

Grey and blue hydrogen: *low* - location of infrastructure is tied to resources. Fossil fuel resources are often located in areas of high biodiversity significance. Often opportunities for limited on-site restoration.

Green hydrogen: *medium* - avoidance through site selection. As green hydrogen will require a source of renewable energy, the ability to address project impacts is linked to the underlying wind/solar that will power the hydrogen production. Thus, the above commentary on best practices for wind/solar will apply to green hydrogen as well. Additional impacts from green hydrogen include the water usage required, so avoiding areas of water scarcity for site selection will be critical.

Potential for achieving nature-positive outcomes at project level:

Grey and blue hydrogen: *low* - opportunities to undertake on-site restoration and offsets to address site impacts. Indirect impacts difficult to address.

Green hydrogen: *medium* – as above, will be tied to the underlying renewable resources and water usage, often opportunities to undertake on-site habitat enhancement if placed in previously modified/degraded land. Opportunities to select sites with plentiful water.

Summary: the key biodiversity impacts of hydrogen depend on its production method. Because grey and blue hydrogen rely on the extraction of fossil fuels, which often occurs in areas of high biodiversity intactness and conservation significance, they are prone to resulting in significant loss and degradation of natural habitat and impacts on associated species. Green hydrogen, produced with renewable energy, has the potential for a lower impact on biodiversity with proper site selection of wind and solar.

Resources for further information: IEA, The Future of Hydrogen (2019) and Global Hydrogen Review (2021), Ptx. Sustainability Dimensions and Concerns, Atmospheric Implications of increased Hydrogen use (2022)

ENERGY STORAGE (BATTERIES)

Inside a battery storage container © Ashden

Key biodiversity impacts: habitat loss, degradation, fragmentation and impacts on associated species; impacts associated with linear infrastructure and indirect impacts associated with in-migration of people into the areas affected, leading to over-exploitation.

Biodiversity most at risk: natural habitat and associated species.

Potential to address project impacts: varies depending on type of resource – potential to reduce need for resource extraction and associated impacts through recycling and reuse of components.

Potential for achieving nature-positive outcomes at project level: varies

Summary: with the increase in variable renewable energy technologies comes an increase in the need for batteries to store the energy. This will lead to an increase in mining of metals and minerals used to produce batteries, such as cobalt, nickel, rare earths and lithium. Mining impacts can vary, but usually include habitat loss and degradation. Lithium mining is water intensive, especially in brine deposits. Key biodiversity impacts associated with lithium mining are water contamination and hydrological changes due to water abstraction. Many of these minerals can also be found in the deep ocean. However, little is known about the biodiversity and ecosystems of the deep sea and, likewise, the potential impacts associated with deep seabed mining.

Significant information gaps: impacts associated with deep seabed mining, understanding of future demand reduction and innovation - policymakers lagging behind in understanding what the future holds and using outdated information as a basis for decision-making.

Resources for further information: Dominish et al. 2019; Sonter et al. 2020a.; SINTEF, 2022

A laborer is seen working at diesel-powered crusher in front of a wind turbine. This is a 17.5 MW wind project, consisting of eighteen wind farm sites in the Indian states of Tamil Nadu, Maharashtra, Rajasthan and Karnataka. © Land Rover Our Planet

4. The importance of placement

STRATEGIC PLANNING TO INFORM RENEWABLE ENERGY EXPANSION

The space required for renewable energy technologies to enable the transition to net-zero points to the need for careful siting. Unfortunately, poorly located energy developments continue to fragment and destroy natural habitats. Over 17 per cent of large-scale (greater than 10 MW) wind, solar and hydropower projects globally currently operate within important conservation areas.[81] These impacts are projected to increase - nine per cent of wind and seven per cent of solar projects are currently planned for development within Key Biodiversity Areas (KBAs), areas of global importance to biodiversity. Many, if not all, of these developments could have been sited elsewhere through better early planning and consideration of their impacts on nature.[82]

Integration of natural and societal values into energy planning is key to developing effective national emission reduction plans that do not compromise social and environmental goals. Through synthesis of available biodiversity datasets and spatial planning exercises (Box 5 on page 32), appropriate sites for renewable energy expansion can be identified, away from areas of high biodiversity sensitivity, such as along bird and marine mammal migration routes.[83] Such plans also need to account for the risk of cumulative impacts from multiple developments. Ideally, renewable energy would be developed on brownfield sites, on other degraded land, or on land already used for other purposes such as urban development, but plans should always also consider how to avoid displacing other economic activities to areas of intact natural habitat.[84] Governments must work with stakeholders to take a holistic approach to terrestrial, freshwater and marine development, both as part of their national energy spatial planning processes and through regional and global collaboration.

However, in many places, proper biodiversity data for good strategic planning is lacking. This is often the case with, for example, offshore bird migration routes, and the data collection to trace such migration routes can take many years. Investment in nature sensitivity mapping is urgently needed, and should be part of the strategic spatial planning that governments develop at national and regional levels. Furthermore, governments should provide detailed on-site data for project developers to enable site selection with the best avoidance and mitigation potential. Developers winning auctions to develop projects could pay for this data when a licence is granted.

Siting also needs to consider proximity to energy users. Local energy solutions, such as distributed energy generation applications and microgrids, can provide affordable and clean energy while avoiding biodiversity impacts such as bird and bat collisions with power lines. Renewable energy industrial precincts that co-locate heavy industry with renewable energy on previously modified land can maximise energy efficiency and minimise the need for additional grid infrastructure.[85] By planning such developments away from natural habitats, significant risks can be avoided, while offering opportunities to undertake on-site restoration and habitat enhancement, such as reintroducing wildflower meadows for pollinators.

Many countries currently lack the resources to develop effective energy expansion plans that adequately account for nature. Renewable energy financiers can play an important role in supporting governments in implementing comprehensive spatially explicit planning exercises, with involvement from civil society, as well as by withholding finance from renewables projects with likely adverse biodiversity impacts and promoting investment in nature-positive projects. In turn, the pre-identification of suitable areas for renewable energy development can help remove uncertainty, fast-track permitting and provide a clear regulatory framework for companies to operate within. At the regional scale, power-sharing agreements and cross-border trading can help drive large-scale energy development to areas of maximum yield and low impacts on nature.[86] Examples include the European Commission's Energy Roadmap, which set an interconnection target of 15 per cent by 2030,[87] and efforts to promote renewable energy sharing in west Africa through the West Africa Power Pool.

TOOLS TO INFORM SPATIAL PLANNING

There are a number of conservation and energy planning tools available to help inform development decisions. For example, BirdLife International has developed AVISTEP: the Avian Sensitivity Tool for Energy Planning. This free-to-access online mapping tool provides a detailed spatial assessment of avian sensitivity in relation to different types of energy infrastructure — wind farms (both on- and offshore), photovoltaic (PV) solar facilities, and overhead power lines. It can be used across the development process, both in support of national and subnational strategic planning and for site-level screening and evaluation. The current iteration covers India, Nepal, Thailand and Viet Nam, but the tool is currently being expanded globally. In addition, BirdLife's Soaring Bird Sensitivity Map provides information on the distribution of soaring bird species across the Mediterranean, Middle East and North Africa to inform wind energy siting decisions.

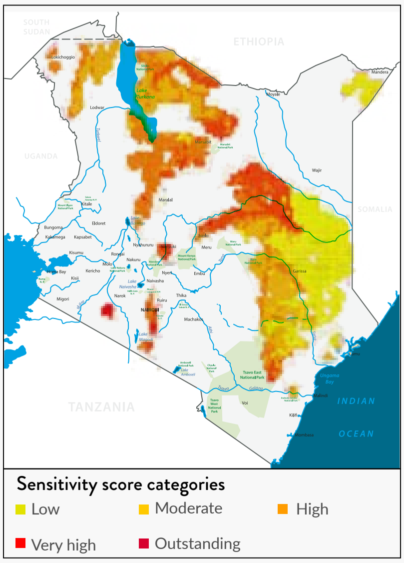
WWF hosts a suite of conservation and planning tools and datasets. These include databases for marine, freshwater and terrestrial ecosystems globally as well as tools that map species distributions against terrestrial ecoregions. WWF has also developed a Risk Filter Suite, which includes the Water Risk Filter and the Biodiversity Risk Filter. These are portfolio-level screening tools designed to help companies and investors prioritize actions that enhance business resilience and contribute to a sustainable future. The Nature Conservancy (TNC) has created planning tools to support a sustainable energy transition, such as its Paris to Practice tool, and the Energy Sprawl tool, which visualises the trade-offs between energy, carbon emissions and land use based on the world's projected energy needs. TNC's SiteRight tool for the USA and India helps to identify suitable areas for wind and solar development in areas of lower biodiversity sensitivity. The World Bank has created the Energy Sector Management Assistance Program rezoning tool, which helps explore and identify suitable areas for solar, onshore and offshore wind energy development based on both environmental and socio-economic considerations. For large-scale hydropower spatial planning, TMP Systems and International Rivers' Riverscope Tool is a comprehensive assessment tool examining the impacts and viability of dams. Other tools for hydropower include the Future Dams programme, TNC's Hydropower by Design tool, and the Rapid Basin-wide Hydropower Sustainability Assessment Tool (RSAT).

Effective planning tools need to be underpinned by good data. The Integrated Biodiversity Assessment Tool (IBAT) hosts the world's most authoritative biodiversity data to inform project decisions. IBAT provides subscribers with global data from the World Database on Protected Areas, World Database of Key Biodiversity Areas and the IUCN Red List of Threatened Species. IBAT provides detailed reports on these databases as well as a rapid visual screening for critical biodiversity. IBAT doesn't currently include areas of importance for species and ecosystem connectivity (other than aggregation zones), which are particularly important to avoid for both solar and wind, but UNEP-WCMC is planning a new database on 'connectivity areas' which would address this gap. For offshore energy planning, the Ocean Data Viewer hosts a suite of global marine biodiversity and ecosystem service datasets, made available by international scientific institutions and other organisations to inform decision making. The Marine Mammal Protected Areas Task Force has created and hosts the Important Marine Mammal Areas e-Atlas and database to highlight priority areas for marine mammal conservation.

BOX 5: STRATEGIC EIA TO SUPPORT THE ENERGY TRANSITION IN KENYA

Strategic environmental assessments (SEA) are a valuable tool to account for environmental sensitivities within renewable energy planning, helping assess the potential environmental and social impacts of policies, plans and programmes. An SEA was recently undertaken by Kenya's Ministry of Energy, involving a wide range of stakeholders, including conservation NGOs, and with funding from the United States Agency for International Development (USAID) Power Africa Transactions and Reform Program.


A giraffe in front of the city of Nairobi © Pfotenpaparazzi



Engagement with species specialists allowed identification and mapping of biodiversity sensitivities against potential zones for wind development. Findings were used to identify areas suitable for wind energy development away from sensitive biodiversity features such as vulture colonies and bird migration routes. The map shows how biodiversity sensitivity for species varies across areas with economic wind resources. Categories reflect the presence of sensitive species, based on range maps, observations and (for vultures) movement of tagged birds.

OPPORTUNITIES FOR PLACEMENT ON LOW-IMPACT LAND

Placing renewable energy in previously degraded areas will help avoid further habitat loss and associated release of carbon stocks.[88] Studies by The Nature Conservancy and WWF show that the world can source up to 17 times the amount of energy required by current global targets from converted land alone (see map below).[89]

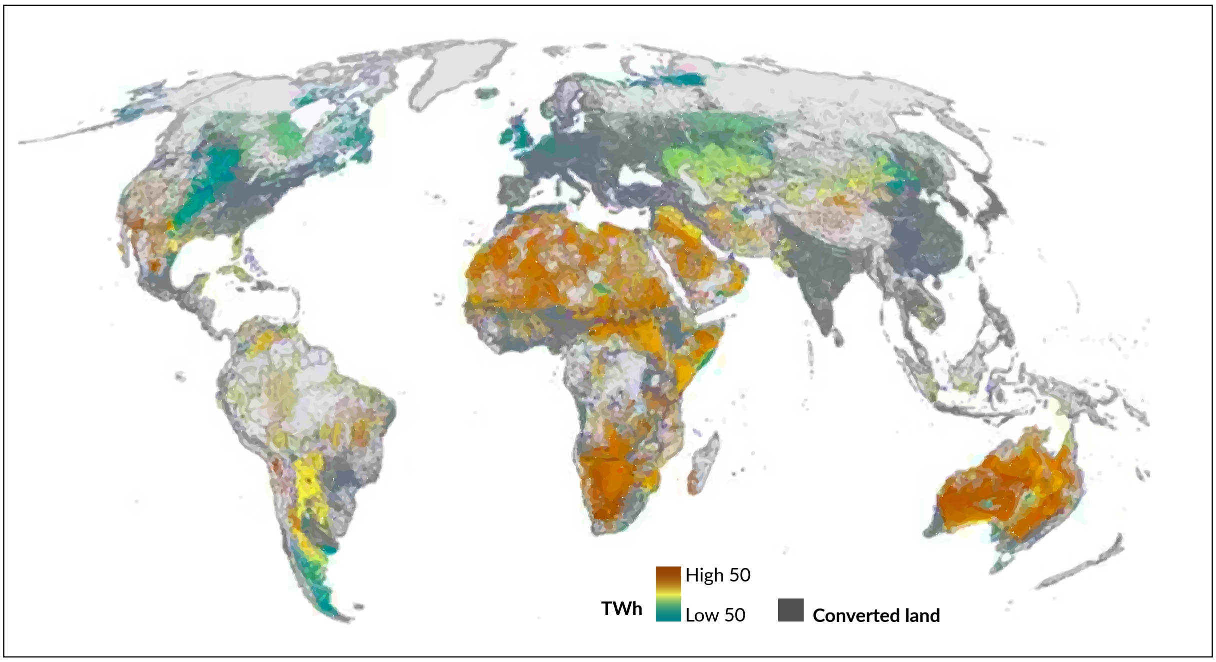


Figure 3: Map of converted land overlaid with maximal wind and solar technical potential Source: from Baruch-Mordo et al. 2019.

Most countries, including the top-ten emitters of greenhouse gases, can meet the Paris Agreement goals by placing renewable energy infrastructure on previously cultivated or mined lands, industrialised areas and within urbanised areas such as on rooftops. For example, for the UK to meet its net-zero targets, it would need to expand solar farms into 0.3 per cent of its total land area. This is equivalent to just under half a percent of the land currently used for farming, and roughly half of the space currently taken up by golf courses.[90] These studies show that, through proper strategic planning, countries can achieve power systems that are low carbon, low cost and low impact on social and environmental resources.

COMPARATIVE LAND-USE AND EMISSIONS INTENSITY

Compared to fossil fuels, renewable energy can sometimes appear to have larger land-use intensity (km²/unit of energy). This depends whether related measurements include provision for the space between systems. For example, in Figure 4 below, the space between solar panels, or that between wind turbines, has been included in the land-use intensity estimation, which gives them a much larger footprint. However, whether or not this space is actually impacted will depend upon its use after installation. As explained previously (page 14), to ensure the smallest land-use intensity footprint from solar and wind, these systems should be sited on land that is already converted. For CO_2 emissions, the numbers show clearly the dramatically higher impact of fossil fuels such as gas and coal compared with renewables

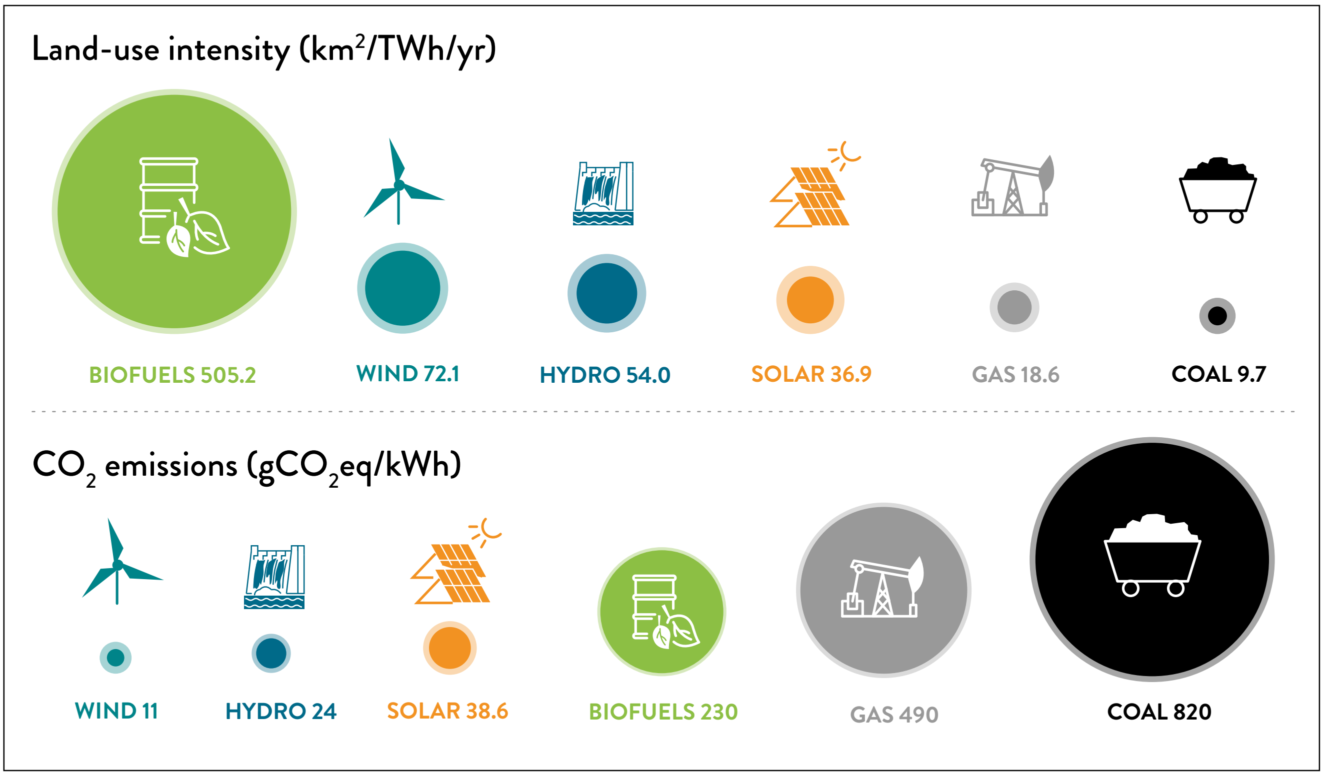


Figure 4: Land-use footprints for fossil fuels and renewable energy sources, adapted from Kiesecker and Naugle (2017)[91]

SITING ON LAND OPERATED BY INDIGENOUS PEOPLE

It is sanctioned in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) that indigenous peoples have the right to be heard and participate in decision-making, planning and implementation of projects that may affect their rights to self-determination, to participation, their human rights, and/or legal, customary or traditional use of land and natural resources and/or their culture. Free, Prior and Informed Consent, (FPIC), by the rights holders, (or the organization they might nominate to represent them), is an UN-principle that should be followed in all cases where indigenous peoples are affected. An important requirement of FPIC is that consent/approval from rights holders should be required in order for a license to be granted. Inputs from stakeholders must be implemented and used through a meaningful governance structure, which should include systems that reflect their views, help facilitate negotiations, and modify planning as needed.

Igarapé at the Juruena River, Amazonia, Brazil. The National Park of Juruena is a protected area supported by Arpa © Zig Koch / WWF

5. Considering nature in the transition to net-zero

The renewable energy transition offers a unique opportunity to radically transform the way we source and use energy and realise both carbon-neutral and nature-positive outcomes (Figure 5). To achieve this, we must consider not only our energy system's carbon costs, but also its impacts on nature at all levels, from site- to systems-level planning and implementation. The mitigation hierarchy to avoid, reduce, restore, and compensate can help frame actions that contribute to nature-positive change along a net-zero pathway.

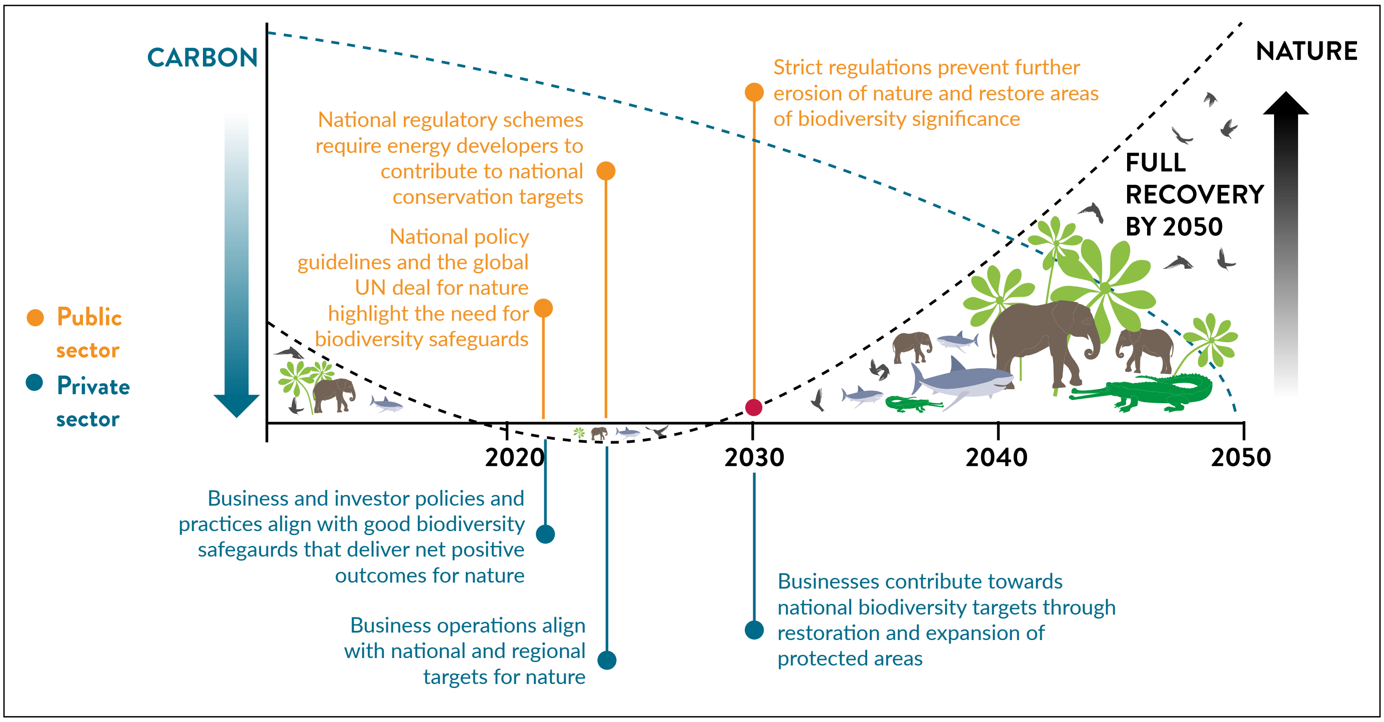


*Figure 5: Milestones along a nature positive transition to net-zero **Source**:* Nature Positive, 2022.[92]

Although traditionally applied at the site level, it can guide national and regional policy change and drive meaningful systems changes to the way we derive and use energy, and the minerals needed for the energy transition (Figure 6).[93] There are mitigation opportunities for each of these elements, based on key categories of actions:[94]

- Transform underlying systems, at multiple levels, to address the drivers of nature loss;
- Avoid and reduce future pressures causing nature loss; and
- Restore and regenerate past losses so that nature can recover in extent and integrity.

To effectively achieve a nature-positive energy transition, there are key factors that must be integrated into the elements of the transition at different levels, including system change, policy and regulation, and practical implementation, as set out in Figure 6.

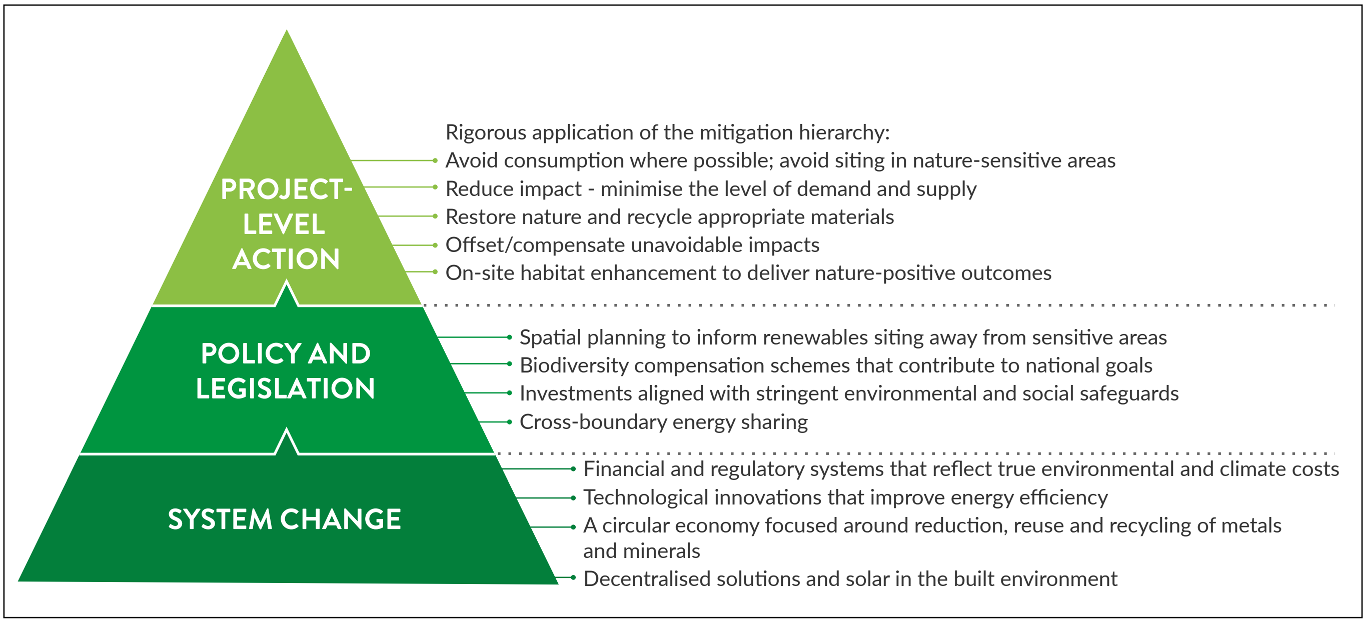


Figure 6: Key enabling factors for a nature-positive energy transition

SYSTEMS CHANGE

Systems change will be fundamental to reversing the loss and degradation of nature. This includes reforming economic and regulatory systems and commitment from the public and private sectors to reflect the cost of their environmental, climate and social impacts. Systemic changes are also needed to how we finance the energy sector. Investors need to fully consider the true environmental, social and health costs of energy options. Transformational change to address perverse market structures and distortions that favour fossil fuels over clean energy, including the rapid phase-out of fossil fuel subsidies, is needed to enable an equitable energy transition. Fiscal policies that incentivise sustainable energy solutions, such as adequate carbon pricing covering emissions across sectors, can facilitate such a transition. At a local scale, land holders can be incentivised to support energy development through compensation schemes. In the United States, for example, farmers can receive up to US$8,000 annually per turbine when leasing cropland for wind energy development.[95]

Redirecting fossil fuel subsidies towards innovative solutions can help address issues around renewable energy reliability and deployment at scale. These include:

- Retrofitting and modernising existing hydropower projects if environmentally sound, adding turbines to non-powered dams (e.g., navigation structures), and re-operating existing hydropower dams to 'firm up' wind and solar generation.
- Technological advances in storage capacity, including battery storage and gravity-based storage[96] to absorb energy when it is plentiful and deliver it during periods when generation is lower.
- Artificial intelligence and smarter digital electricity networks to predict capacity and help forecast demand, helping to stabilise the power supply.

In some cases, combining renewable energy technologies, for example pairing hydropower with floating solar, can both stabilise power supply and maximise yield while minimising the need for further conversion of land. Agrivoltaic systems that combine semi-transparent PV panels with crop production can help meet food and energy needs while minimising land competition and risk of displacement.[97] For example, it has been estimated that current global energy demand could be met by solar production if less than 1 per cent of current cropland were converted to an agrivoltaic system.[98]

Major changes are also needed to implement a circular energy production chain that maximises the reuse and recycling of minerals needed to produce and store renewable energy, minimising the need for extracting new resources. Renewable energy infrastructure needs to be designed to disassemble and to refurbish or recycle, while all parts should be repairable, replaceable and completely reusable in one way or another. Full traceability of raw materials across energy value chains can help identify environmental risks associated with resourcing and minimise supply chain impacts. Critically, a shift to a circular economy must also be coupled with more efficient use of energy and behavioural changes that reduce energy needs in the developed world while providing universal energy access. Repowering should also be used to reduce the environmental impact of renewable energy deployment. Full life-cycle analysis of projects should be conducted before they are considered eligible for any public funding support, and investments in (research) projects and start-ups are needed to support this transition.

In many cases, changing systems to work with nature provides opportunities to realise both climate and nature goals. Nature-based solutions offer promising options to protect, manage and restore ecosystems whilst providing important climate mitigation benefits. Examples of nature-based solutions include: restoring upland forests to sequester carbon while regulating water flows and managing flood risk; restoring watersheds to regulate water supply; and rehabilitating coastal habitats to attenuate wave action and reduce flood risk.[99] When implemented correctly, they provide win-win solutions to address society's challenges and promote human well-being.[100]

Large-scale system changes need to account for their impacts on people's livelihoods, consider the inclusion of vulnerable groups and contribute to the reduction of energy poverty. Poor implementation could lead to unintended consequences and issues around energy injustice. For example, while a rapid transition away from fuelwood towards clean cooking technologies, as forecast by the IEA,[101] may reduce forest and woodland degradation, it could also reduce the value of these habitats to local people and lead to a situation where they are forced to pay for energy. Likewise, the energy transition and substitution of energy technologies may cause unemployment among fossil fuel industry workers if they are not reskilled and directed to the renewable energy sector. Such trade-offs need to be considered in a fair and just transition.

POLICY AND LEGISLATION

Desired system changes need to be advanced via national and regional policies that will underpin a sustainable transition to net-zero. Governments play a critical role in facilitating a renewable energy expansion that is 'LowCx3':

1. **Low carbon:** electricity systems that have a low carbon footprint and are efficient;

2. **Low cost:** electricity systems that are reliable and affordable;

3. **Low conflict:** avoiding areas of biodiversity sensitivity and areas of high importance to people's wellbeing.[102]

Decisions around the appropriate mixes of energy types and centralised or decentralised energy systems are highly context specific. They have important social and environmental implications that require careful consideration through early strategic assessment and planning. For example, poorly planned biofuel (ethanol) expansion in Brazil risks the release of 45 million tonnes of CO_2 equivalent.[103] On the other hand, biofuel expansion that accounts for nature could reduce these emissions by nearly 90 per cent, avoid impacts on habitat for 113 species, and deliver a similar energy yield.[104] Accounting for environmental and social impacts can also make economic sense. For example, the proactive siting of renewable energy on converted lands and near demand centres has been shown to significantly reduce transmission costs due to economies of scale while providing energy access to rural populations in Africa.[105]

Such system changes associated with renewable energy expansion need to be considered throughout the timeframe of any new infrastructure project's development and implementation. The lifecycle for such installations (see Figure 7) encompasses all stages of infrastructure development. Environmental, social, and economic costs and benefits analyses, as well as resilience and disaster and emergency response strategies, should be considered and prepared for all phases of the infrastructure lifecycle. Only from this process can the project's full impact be determined and managed in advance.

In the marine environment, the identification of suitable areas for offshore wind deployment needs to be based on an ecosystem-based approach to marine spatial planning (MSP) at national and regional scale, placing infrastructure in a way that minimises its negative impacts on marine ecosystems and integrates eco-friendly designs. MSP can help identify suitable areas, including areas previously used for oil and gas development, or through co-location with other developments, such as aquaculture.

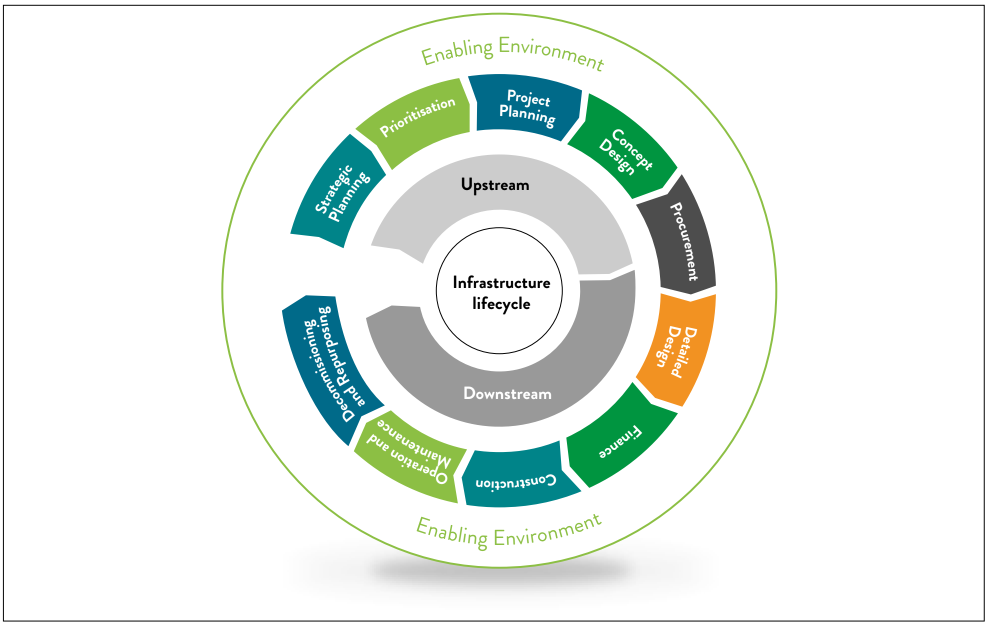


Figure 7: An infrastructure project lifecycle. Source: GIZ and UNEP: Sustainable Infrastructure Tool Navigator

Environmental and social impact assessment (ESIA) processes are the main regulatory instrument for approving projects and enforcing good mitigation practice and are a fundamental tool to avoid and limit potential impacts at the project level. ESIA standards and implementation need to be effective in addressing the potential impacts of renewables. Project approvals should be contingent on demonstration of robust implementation of the mitigation hierarchy to reduce impacts to non-significant levels, and (if unavoidable) compensate for any residual impacts, with sound monitoring, evaluation and adaptive management plans in place.

Going beyond promotion of good mitigation practice, regulations can require developers to contribute to the protection and restoration of biodiversity, in alignment with national targets. To foster innovative solutions and advance best practice, regulatory schemes should also weigh the impact on nature as a major criterion in public competitions and auctions for granting licences.

Policy reform by governments needs to be reflected in industry and finance. Developers can establish industry commitments to avoid developing in areas of high biodiversity significance and set clear and ambitious corporate nature-positive goals that contribute to conservation targets (see Box 6). Financiers can establish investment policies that align with good practice environmental safeguards and deliver net-positive outcomes for biodiversity.[106] The International Finance Corporation (IFC) Performance Standards are widely recognised as the most influential in driving positive social and environmental change, including requirements to deliver 'no net loss' or, preferably, net-positive impacts on nature.[107,108] Adaptation and strict enforcement of similar or better standards by all institutions financing the energy transition would help ensure developers contribute to rather than jeopardise sustainable development goals.[109]

PROJECT-LEVEL ACTION

Clean energy financiers, developers and legislators all have a role to play towards avoiding and limiting potential negative impacts at the project level. As a basis, the implementation of strict environmental safeguards is needed to mitigate project-level impacts which cannot be avoided through early planning and site selection. The mitigation hierarchy provides an effective framework that prioritises early avoidance and on-site minimisation over less certain and costly measures to restore and offset impacts on nature.[110] Early planning is key; developers can identify and address issues early through screening of risks and consideration of site and design alternatives, such as rerouting linear infrastructure to avoid impacts. Impacts can be further reduced through on-site, evidence-based mitigation practices, as well as implementing measures to control indirect impacts such as induced in-migration and associated degradation of biodiversity within the wider landscape.[111] Progressive rehabilitation of temporary construction facilities and full restoration of biodiversity after decommissioning are further strategies for fully mitigating impacts. In all cases, robust and standardised monitoring protocols and indicators must be implemented to fully assess impacts and the efficacy of mitigation measures. A precautionary approach to assume a degree of impact up front can help implement additional mitigation during operations, such as curtailment of turbines if unanticipated impacts occur.

Unlike other forms of energy generation, wind and solar offer opportunities to generate energy alongside food production and/or the maintenance and improvement of biodiversity. In some cases, solar arrays can have a positive effect on agricultural yields through shading, maintaining soil fertility and reuse of water for panel cleaning.[112] Doing so may also contribute to climate mitigation. For example, studies in Asia demonstrate that land seeded with herbs and managed as pastures within solar farms can reduce per kWh carbon emissions associated with land-use change by three-to-five times compared with permanently cleared land, and even become carbon sinks through sequestration over the long term.[113] Where planned for early in the project cycle, wind and solar projects can also be sites for nature-based regeneration.[114]

To meet societal expectations and drive profitable yet sustainable change, both renewable energy investors and purchasers need to integrate biodiversity-specific criteria fully into their environmental, social and governance (ESG) standards. Although there is currently no formal environmental certification for renewable energy suppliers, screening investments for explicit biodiversity criteria can help avoid the most serious risks. Basic criteria include confirming the developer can meet good international industry practice standards for nature (such as the International Finance Corporation Performance Standards) and has adopted appropriate verification practices along its supply chain to ensure that the sourcing and purchasing of materials will not lead to significant impacts elsewhere.

Building biodiversity into a sustainability strategy will help ensure that clean energy projects do not undermine commitments on nature, while they contribute to tackling the climate crisis.

BOX 6: A NATURE-POSITIVE ROADMAP FOR RENEWABLE ENERGY DEVELOPERS

Companies increasingly recognise that good biodiversity practice makes good business sense.[115] Similar to corporate carbon neutrality targets, Science-based targets for nature (SBTN) provide forward-thinking renewable energy developers with an opportunity to get ahead of regulation and policy changes by going beyond traditional impact reduction towards a nature-positive business model.[116] In being nature positive, a company strives, through its processes and activities, to deliver overall positive outcomes for nature and its contribution to human wellbeing.

Establishing a SBTN, such as a nature-positive commitment (which is usually open for any business to sign up to voluntarily), will help companies align with societal environmental sustainability goals and can significantly enhance brand and reputation. Nature-positive targets typically encompass multiple actions across a company's value chain, aimed at delivering an overall positive biodiversity outcome. To be credible, nature-positive targets must be measurable, actionable and based on scientifically robust methodologies. To align with developing biodiversity goals,[117] companies should set clear, time-bound targets, for example 'no net loss' of biodiversity by 2025 and becoming 'net positive' by 2030. To meet these targets, several interim goals, such as arresting deforestation along a mineral supply chain, can be specified. These goals can help measure and maintain progress towards the end target.

The nature-positive process typically begins with a lifecycle assessment to understand where the biggest impacts and dependencies on biodiversity lie. This assessment allows a company to focus on its most important impacts and dependencies. In turn, this information can help prioritise actions and develop a monitoring and evaluation plan. On the ground, nature-positive actions include effective implementation of the mitigation hierarchy, which prioritises avoiding and minimising impacts rather than compensating for them after the fact.

Initial steps a renewable energy developer can take to make its operations nature positive.

MAKE A COMMITMENT Develop simple and clear commitment to nature and align with new global standards for doing business and goals for sustainable development

BUILD INTERNAL CAPACITY AND AMBITION To be successful, awareness of the issues may need to be raised and resources committed to achieving a bold transformation

BE A LEADER Add your voice to global initiatives advocating positive change - Help engage and influence policymakers on the need to adopt ambitious policies on nature

UNDERSTAND INTERACTION WITH THE NATURAL WORLD Understand biodiversity risks, dependencies, and opportunities associated with developments and the impacts related to material sourcing.

A man driving a solar-charged rickshaw with a huge solar panel on the roof © Avijit Ghosh / Climate Visuals Countdown

6. Key messages and recommendations

KEY MESSAGES

1. **To meet net-zero emissions by 2050, the IEA indicates that 93 per cent of electrical generation will need to come from renewable energy - predominantly wind and solar.**

   A renewables-based global energy system compatible with limiting the average global temperature rise to 1.5°C will reduce damage to biodiversity by around 70 per cent, saving up to 700,000 species from potential extinction (comparing the IEA Stated Energy Policy Scenario with the IEA's Net Zero Emissions Scenario).[118]

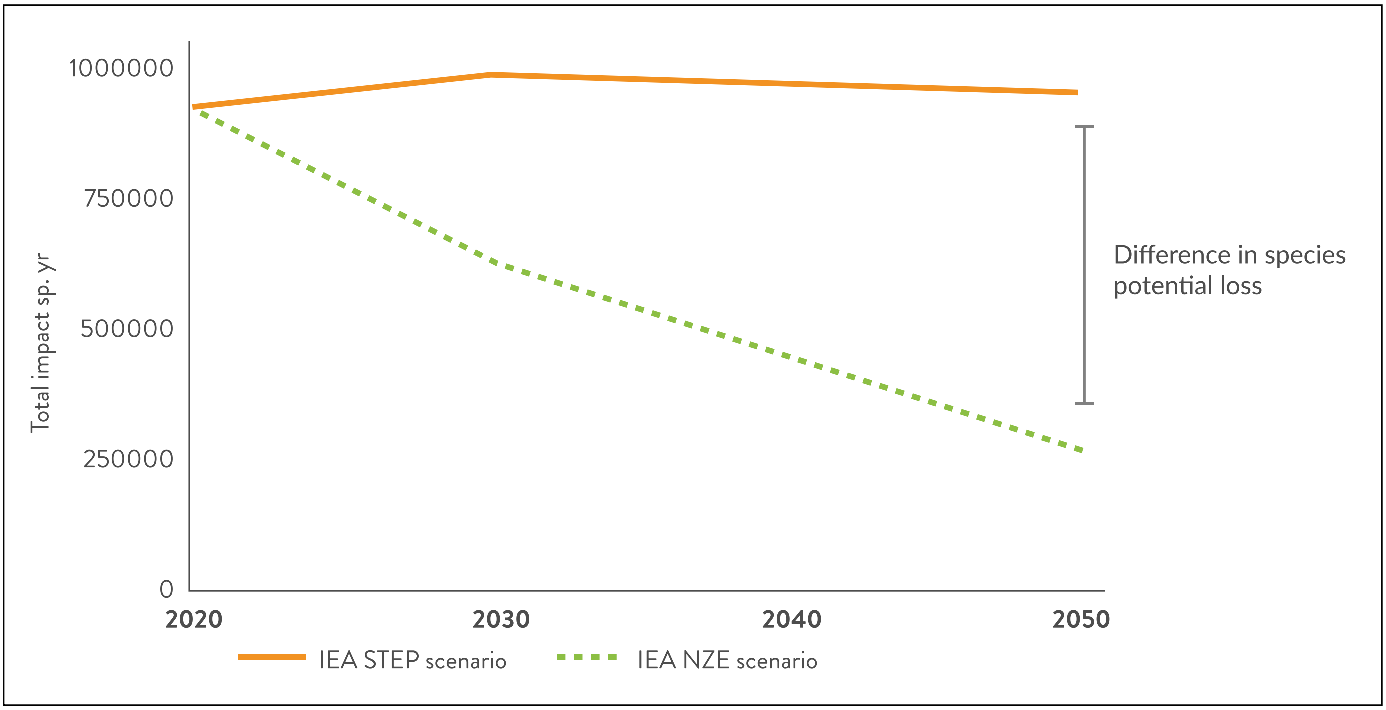
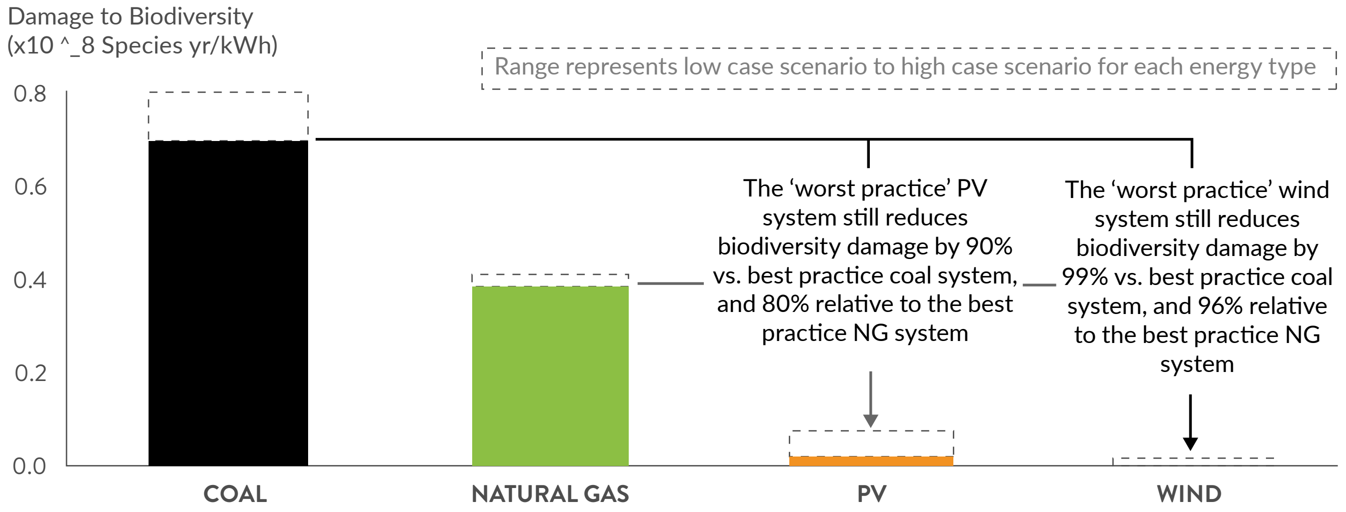


***Figure 8:** Lifecycle assessment of Stated Energy Policy scenario and Net Zero Energy scenario impacts on biodiversity **Source:** see endnote* [119]

2. **When considering the entire lifecycle and the full range of environmental impacts, deriving and storing energy from renewables is far less environmentally damaging overall than using fossil fuels.** [119]

   Every form of energy technology, from solar panels to coal mines, has some impact on nature. However, to help address the biodiversity crisis while ensuring social safeguards, the evidence is unequivocal that we must shift from the more polluting fossil fuels (coal, oil and gas) to renewable energy technologies (such as wind and solar PV).



Notes:

i. *Assuming all 2020 coal and natural gas electricity capacity shifts to wind and solar PV at a 50/50 mix.*

ii. *The unit for damage to ecosystem quality is species.yr, derived from the potentially disappearing fraction (PDF) approach. PDF is a measure quantifying the fraction of today's present species that will potentially become extinct in a specific geographical location due to an emission or anthropogenic intervention. In that, it is a measure for loss of species richness, i.e. potential species extinction. PDF includes losses that happen right after the intervention, and also time-integrated damages. For example, a pulse of CO_2 emissions, still leads to species loss after 100 years*

***Figure 9**: Lifecycle assessment of energy technology impacts on biodiversity **Source:** see endnote* [119]

3. As we transition to a net-zero carbon world, we must recognise that not all low-carbon energy sources are created equal. **Supporting those renewable technologies with the lowest impact on nature can have major benefits for biodiversity and also be low-cost.**

   Wind and solar tend to have lower overall impacts on nature than other renewable energy types, though other such renewables can be the most appropriate solution, depending upon local circumstances.

   The use of hydropower or bioenergy must be carefully assessed to determine the full impact under local conditions. Experience suggests that badly-planned hydropower dams can have a severe impact on biodiversity.[120] Some long-term research shows that hydropower has a severe negative impact on biodiversity, ecosystem health and, in many cases, even on human well-being.[121] The impact on rivers by hydropower generation is very high in some parts of the world, with many plants even failing to reach minimum ecological requirements.[122] However, in some cases, the conversion of existing hydropower plants, or strategically designed new projects, can provide sustainable energy alternatives including ancillary services (such as storage capabilities that contribute to grid stability), at a lower cost to nature and people than other local options.

   Bioenergy will often have a significantly greater negative impact on nature than wind and solar PV, with much of the global production potential of bioenergy linked to protected areas for biodiversity. There are a wide range of biofuel options, some of which can provide low-cost energy solutions at a local level. These therefore need to be assessed on a case-by-case basis. However, the low energy density of bioenergy risks any climate mitigation benefits being outbalanced by carbon released due to habitat conversion.

Even for wind and solar, it is essential to recognise that there will be a range of options for implementation. Using best practice solutions for solar PV and wind, evaluated under local conditions, can help reduce damage to biodiversity, potentially saving up to 90,000 species.[123]

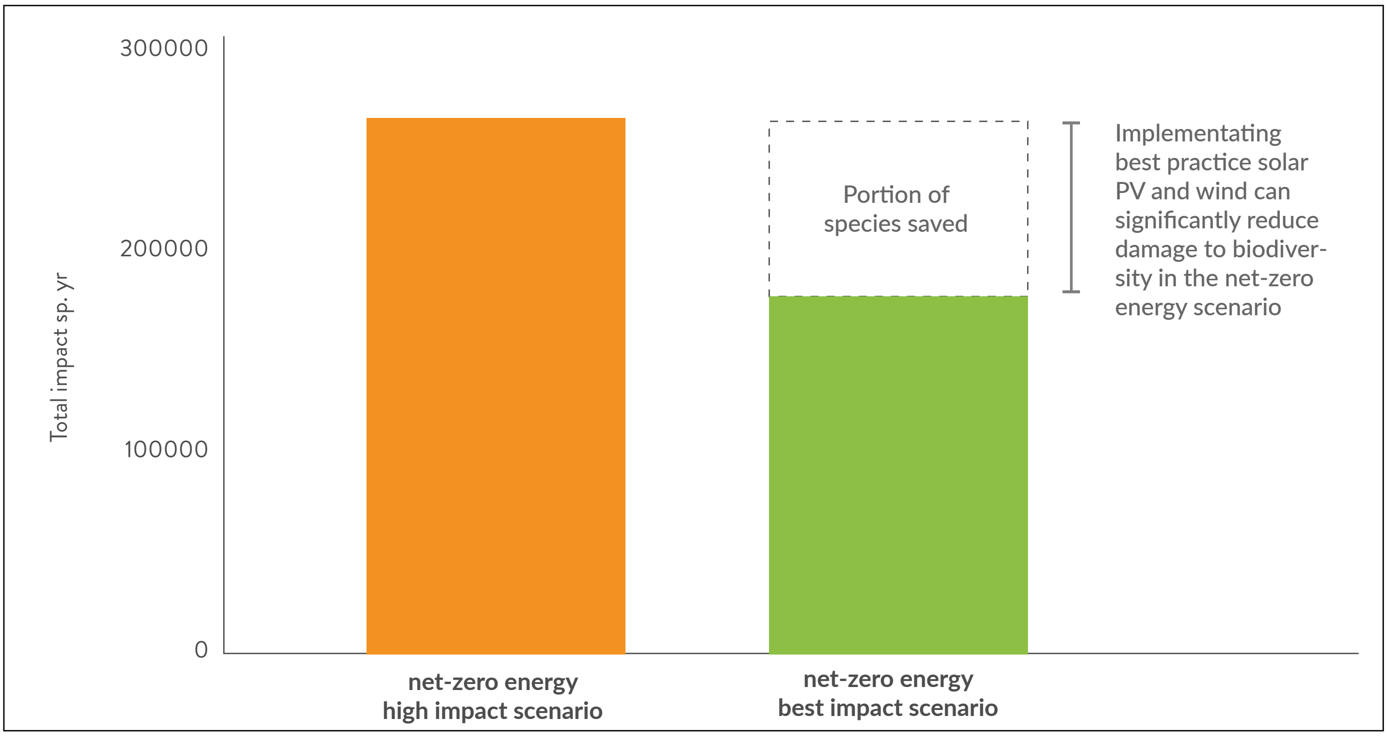


***Figure 10**: Total biodiversity damage between high end and low end impact net-zero energy scenarios **Source:** see endnote [124]*

4. **Existing global-scale mapping of sites for wind and solar indicates that there is enough energy available on low-conflict sites to achieve the IEA's projections for a power system consistent with the 1.5°C climate target.**[125]

   The global technical potential of utility-scale, low-impact wind and solar is several times the renewable energy targets that countries have committed to under the Paris Agreement. This should allow almost all countries to achieve power systems that are low carbon, low cost and low impact on social and environmental resources. In addition, this low-impact renewable potential exceeds projected 2050 power demand under a scenario where all sectors (industry, transportation, etc.) become electrified.[126]

   Spatial planning that considers the full range of technical, environmental and social risks and constraints can provide a crucial tool for identifying the right sites for energy development, and proper mitigation measures at these sites will lessen the biodiversity impact even further.

KEY RECOMMENDATIONS

This report has stressed the urgent need for a global transition from energy generation based on fossil fuels to a world that is fully powered by renewable energy. It recognises, however, that the required scale-up of renewables raises concerns regarding its impact on nature. Without proactive management, there is potential for continued loss of biodiversity at a rate that risks undermining our current lifestyles and ultimately our very existence.

This review is intended to provide a foundation for the work of CLEANaction. The report raises a range of issues related to the potential levers that will enable an energy transition that delivers on climate and biodiversity, but does not attempt to find lasting solutions in any detail. This process will be the aim of the partners in the CLEANaction coalition – to recognise the need for urgent action, define the steps that must be taken, and facilitate their urgent implementation. The recommendations from this review are grouped below and are intended to help show the way to a sustainable future. With this platform, CLEANaction will endeavour to bring together partners who can formulate an agreed work programme and set a timeframe for its implementation.

SYSTEM CHANGE

Policy-makers, business leaders, and investors should:

1. Prioritise investments in energy efficiency
2. Reform financial, economic and regulatory systems to reflect the cost of their environmental and climate impacts
3. Promote a just energy transition with full account of its social impact and with minimal disruption to nature
4. End or redirect energy subsidies, incentives or investments that harm nature and jeopardise climate targets into renewable energy and energy efficiency measures
5. Strengthen corporate disclosure and reporting on biodiversity impacts and mitigation outcomes
6. Ensure there is traceability of raw materials and account for supply chain impacts within corporate commitments
7. Align investments with national and global biodiversity targets and, wherever possible, set nature-positive goals
8. Adopt a circular economy approach to optimise energy efficiency, maximise reuse of energy materials and minimise demand for natural resources
9. Establish cross-border energy-sharing agreements to drive energy development to areas of maximum yield while reducing its footprint
10. Scale up nature-based solutions that contribute towards climate and biodiversity goals

POLICY AND LEGISLATION

Policy-makers, business leaders, and investors should:

1. Develop national regulatory schemes that require energy developers to contribute to national conservation targets[127]
2. Establish corporate and finance nature-positive commitments, and clear and ambitious conservation targets, aligned with national biodiversity commitments
3. Undertake strategic-level planning at national or regional scale to identify potential energy savings, suitable renewable energy sources and sites for energy expansion in areas of low biodiversity sensitivity
4. Implement power-sharing agreements and regional coordination to facilitate energy expansion at scale, into areas of maximum yield and minimum impact
5. Invest in early nature-sensitivity mapping to help direct technology siting through proper data, and require industry to avoid protected areas, Key Biodiversity Areas and other areas of particular sensitivity and value[128]
6. Apply stringent environmental impact assessment (EIA) processes and require standards to all new developments according to best practice
7. Make project approvals contingent upon the robust application of the mitigation hierarchy to reduce impacts to insignificant levels, and only approve licences to projects that implement best practices in managing impacts on nature
8. Ensure sufficient funding is allocated to cleaning up and restoring areas degraded from inappropriate energy use
9. Provide environmental authorities with the mandate and sufficient capacity to effectively manage the nature consequences of action proposed in applications for new energy generation
10. Foster innovative solutions and advance best practice through regulations that weigh impact on nature higher than other criteria in competitions and auctions for licences (for example, for offshore wind)

SITE-LEVEL MITIGATION

Policy-makers, business leaders, and investors should:

1. Aim for all new developments to be nature positive by placing biodiversity front and centre in development decisions
2. Prioritise use of already-converted lands such as urban areas, industrialised spaces, existing infrastructure, or use land in conjunction with other productive uses (e.g., agrivoltaics)
3. Implement strict protocols to minimise species impacts, such as the risk of collision with birds and bats, noise pollution etc.
4. Establish clear closure and end-of-life plans
5. Include cumulative impacts of all activities present in the wider project area in the environmental impact assessment (EIA)
6. Promote local employment and new job creation through consistent on-site impact monitoring and management

7. Apply a circular approach to ensure the highest possible rates of reuse and recycling and put in place mechanisms to ensure ethical sourcing of materials and minerals
8. Incentivise and subsidise co-use and co-existence solutions such as agrivoltaics
9. Undertake on-site habitat enhancement, such as reintroducing wildflower meadows for pollinators around wind turbines and solar panels
10. Promote citizen engagement to motivate the integration of biodiversity considerations into early energy planning

CROSS-CUTTING THEMES

The production of this report has highlighted common themes that need to be integrated into all of the measures recommended above. These include the need for all actors to:

- Emphasise the importance of decarbonisation through science-based targets and implementation
- Encourage the development of new technologies and low-carbon solutions in hard-to-abate sectors
- Include a lifecycle assessment, which applies a standardised method to account for the full range of potential impacts across a project's lifecycle
- Promote studies, knowledge sharing and best practices for better understanding of the interaction between renewable energies and biodiversity
- Promote accelerated decarbonisation through early switching to proven, nature-safe, low-carbon options and ensure low barriers to widespread deployment

GPS Renewables is a waste-to-energy technology company that is pioneering the development of clean and low-cost technology for waste management solutions in India and abroad.
© Ashden / Ashden

Ramping up production at Balcombe's new power plant © *Oliver Rudkin / 10:10*

8. Additional measures

In addition to the priorities highlighted in section 4.1, there is a wide range of other measures related to energy and nature interventions that can be considered by stakeholders to further facilitate the process of expanding renewable energy with minimum damaging impacts on biodiversity. The table below presents a summary of various recommendations drawn from the perspectives of different stakeholders. These must be involved in any attempts to ensure that future energy interventions take full account of the likely impact on nature, and that appropriate action is taken to minimise any negative consequences of new energy applications.

The table below presents possible actions to:

- **TRANSFORM** to allow the maximum use of renewable energy technologies without excessive disruption to nature
- **AVOID** unnecessary harm to nature from renewable energy
- **REDUCE** the impact on biodiversity from clean energy measures
- **RESTORE AND REGENERATE** biodiversity with energy-related action

FOCUS/SCALE OF MITIGATION	TRANSFORM	AVOID	REDUCE	RESTORE AND REGENERATE
SYSTEMS CHANGE	• Plan for and promote decentralised energy generation systems with distributed renewable energy systems that allow for power line sharing and which direct required power stations to areas with low environmental sensitivity • Withhold finance from renewable projects with high biodiversity impacts	• Foster innovation and new technologies that avoid and reduce impacts • Incentivise and subsidise co-use and co-existence solutions such as agrivoltaics • Promote the prioritisation of repowering and hybridisation solutions against the conversion of natural land	• Establish cross-border energy-sharing agreements to drive energy development to areas of maximum yield while reducing its footprint • Optimise energy yield in modified habitats, such as installation of floating PV over artificial features such as dam reservoirs • Produce bioenergy from animal and food waste	• Remove relevant dams to restore environmental flows • Promote nature-positive investments such as green bonds that help secure and restore nature • Use ecosystem-based spatial planning where space for both nature and renewables is designated, and implement holistic marine spatial planning, involving all relevant stakeholders

POLICY AND LEGISLATION	• Make project approvals contingent on demonstration of robust implementation of the mitigation hierarchy to reduce impacts to non-significant levels • Compensate for any residual impacts, with sound monitoring and evaluation, and adaptive management plans in place. • Provide enough capacity and mandate to environmental authorities to manage nature consequences well in applications	• Develop and implement holistic marine spatial planning, involving all relevant stakeholders and using an ecosystem-based approach • Implement power-sharing agreements and regional coordination to facilitate energy expansion at scale into areas of maximum yield and minimum impact • Require industry to avoid protected areas, Key Biodiversity Areas, and other areas of particular sensitivity and value such as ecological corridors and migration routes • Require that areas with high natural carbon uptake and storage are avoided	• Apply effective safeguards to reduce and compensate for harm to biodiversity • Identify optimised energy solutions that minimise harm to nature, such as replacing dams and bioenergy monocultures with solar expansion • Establish and enforce clear requirements for wildlife-friendly energy transmission and distribution networks, and retrofitting of existing unsafe power lines • Legally restrict underwater noise to protect marine ecosystems (as for example Germany, Belgium, the Netherlands and Denmark have done)[129]	• Identify priority areas for restoration and implement policies for energy sector contributions towards restoration goals • Require environmental bonds as a compulsory deposit for any activities that impact the environment • Imposing a nature fee on the area used for new infrastructure, corresponding to the cost of restoring the same type of nature elsewhere • Subsidise farmers to encourage wind and solar development on private land
SITE-LEVEL MITIGATION	• Offset residual impacts through investments into projects that restore habitats and avert future losses elsewhere	• Route linear infrastructure and power lines away from sensitive areas including protected areas, KBAs, ecological corridors, wetlands, vulnerable coastal habitats and forests • Bury power lines wherever feasible	• Control influx of people into the operational area of the project, and manage associated impacts on biodiversity • Minimise mineral extraction and supply chain impacts by optimising site-based infrastructure	• Undertake rehabilitation of temporary facilities and post decommissioning • Use nature-inclusive design for infrastructure to provide opportunities for natural regeneration (e.g., on offshore wind turbine foundations)

Bar-headed Geese (Anser indicus), B.R.B. canal, Lahore, Punjab. One of the world's highest flying migratory birds © WWF-Pakistan

9. Annexures

ACRONYMS

Acronym	Description
AVISTEP	Avian Sensitivity Tool for Energy Planning
CO_2	Carbon dioxide
CBD	Convention on Biological Diversity
CSP	Concentrated solar power
CLEANaction	Coalition Linking Energy and Nature for Action
DRC	Democratic Republic of Congo
EIA	Environmental impact assessment
ESIA	Environmental and social impact assessment
GDP	Gross domestic product
GHG	Greenhouse gas
IEA	International Energy Agency
IFC	International Finance Corporation
KBA	Key Biodiversity Area
LCA	Life-cycle assessment
MSP	Marine spatial planning
NDCs	Nationally Determined Contributions
NGO	Non-governmental organisation
NZE	Net-zero emissions

PV	Photovoltaics
RETs	Renewable Energy Technologies
SBTN	Science-based targets for nature
SDG	Sustainable Development Goals
SEA	Strategic environmental assessment
STP	Solar thermal power
TNC	The Nature Conservancy
UNEP	UN Environment Programme
UNEP FI	UN Environment Programme Finance Initiative
USAID	United States Agency for International Development
WWF	World Wide Fund for Nature

GLOSSARY

Term	Description
Arid ecosystems	Where annual precipitation averages less than 10 inches (25cms) per year.
Agrivoltaics	Projects that use land for both agriculture and solar photovoltaic systems
Barrier effects	The phenomenon by which man-made structures impede the natural movement patterns of wildlife.
Biodiversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.
Blue carbon areas	Highly productive coastal ecosystems that are particularly important for their capacity to store carbon within the plants and in the sediments below, for example, mangroves, tidal and salt marshes, and seagrasses.
Blue hydrogen[130]	Produced by splitting methane to create CO_2 as a by-product, which is stored and not emitted (though the long-term effect of CO_2 storage is uncertain).
Cumulative impacts	Impacts that result when the effects of an action are added to or interact with other effects in a particular place and within a particular time.
Ecotoxicity	The subject of study of the field of ecotoxicology (a portmanteau of ecology and toxicology), referring to the potential for biological, chemical or physical stressors to affect ecosystems.
Green hydrogen [130]	Hydrogen made via the electrolysis of water powered solely by renewables.
Grey hydrogen [130]	Hydrogen produced from reforming natural gas.
Low conflict sites	Sites that avoid areas of biodiversity sensitivity and areas of high importance to people's wellbeing.
LowCx3	Low carbon, low cost, and low conflict.
Mitigation hierarchy	An approach which aims to help manage biodiversity risk, and which is commonly applied in environmental impact assessments (EIAs). It presents a hierarchy of steps: avoidance, minimisation, rehabilitation, restoration and offset.
Natural habitat	A complex of natural, primarily native or indigenous vegetation, not subject to significant conversion or degradation, the primary purpose of which is to provide habitat for wildlife.
Nature-based solutions	Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal or marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits.

Nature positive	The description of a world where nature (species and ecosystems) is being restored and is regenerating rather than declining”
Biodiversity offsets	Measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development after appropriate prevention and mitigation measures have been taken. The goal of biodiversity offsets is to achieve no net loss and preferably a net gain of biodiversity on the ground with respect to species composition, habitat structure and ecosystem function and people’s use and cultural values associated with biodiversity.
Protected area	Locations which receive protection because of their recognised natural, ecological values.
Population-level impacts	Impacts which effect the long-term viability of a species’ population.
Riparian	Related to, living on, or located at the banks of a watercourse, usually a river or stream.
Run-of-river	Hydropower projects that channel flowing water from a river through a canal to spin a turbine. Typically, a run-of-river project will have little or no storage capacity.

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ENDNOTES

1 Nature Risk Rising, World Economic Forum, Jan 2020

2 Most of the climate and energy models in developed regions of the world show that reduction of energy consumption is a precondition to managing future renewable energy-oriented systems (see e.g. Mühlenhoff & Bonadio 2020)

3 IEA. 2021.

4 Baruch-Mordo et al. 2019, IEA. 2021, Thieme et al. 2021. See more at www.brighterfuture.panda.org

5 Some new technologies offer huge potential but the harm to nature differs substantially between different applications and needs to be fully assessed.

6 See UN's International Good Practice Principles for Sustainable Infrastructure, 2021

7 See www.brighterfuture.panda.org

8 Such areas include ecological corridors, migration routes, fish spawning and rearing areas, and areas with high natural carbon uptake and storage

9 See the 2021 WWF report, Feeling the Heat: The Fate of Nature Beyond 1.5°C of Global Warming.

10 WWF. 2022.

11 By 2030: Protect 30% of Earth's lands, oceans, coastal areas, inland waters; Reduce by $500 billion annual harmful government subsidies; Cut food waste in half. See the Official CBD Press Release - 19 December 2022, Montreal

12 See WWF's 2021 The transition away from oil & gas policy position on the urgent need to transition away from fossil fuels

13 IEA. 2021a.

14 The share of hydropower needed to meet climate targets by 2050 compared with the share of hydropower today varies from one continent to another.

15 IEA. 2019a.

16 Including those produced by the IPCC, IEA and the International Renewable Energy Association.

17 Under this net-zero by 2050 scenario, solar PV capacity will need to increase 20-fold and wind power 11-fold between now and 2050. See IEA. 2021b.

18 As recognised in the 2021 Glasgow Climate Pact, preamble, page 1: "Noting the importance of ensuring the integrity of all ecosystems, including in forests, the ocean and the cryosphere, and the protection of biodiversity,[...]" and Article 38: "Emphasises the importance of protecting, conserving and restoring nature and ecosystems to achieve the Paris Agreement temperature goal, including through forests and other terrestrial and marine ecosystems acting as sinks and reservoirs of greenhouse gases and by protecting biodiversity, while ensuring social and environmental safeguards."

19 Kiesecker et al. 2019.

20 Kiesecker et al. 2019 - https://iopscience.iop.org/article/10.1088/1748-9326/aaf6e0/meta; The Nature Conservancy.

21 See Opperman et al. 2019.

22 For example, see UNEP. 2016; Luderer et al. 2019.

23 UNEP 2016; Gibon et al. 2017; Luderer et al. 2019.

24 WWF. 2019a

25 Thieme et al. 2021.

26 Experience has also demonstrated the problems that can be associated with hydropower, including reduced water flow and access to floodplains. Hydropower can cause geopolitical issues due to transboundary impacts. Other concerns include impacts on climate change adaptation, effects on mangroves, altering of nutrient flows and potential food security disruption, since a third of global food production depends on rivers.

27 Gibon et al. 2017; Luderer et al. 2019; van de Ven et al. 2021.

28 I.e., the top-ranked 30 per cent of land of highest priority for biodiversity protection. See Santangeli et al. 2016.

29 McManamay et al. 2021.

30 Luderer et al. 2019.

31 IEA 2021b.

32 Thieme et al. 2021; Moran et al. 2018.

33 Hydropower currently supplies around 65 per cent of Brazil's electricity. Many dams occupy land that provides spiritual and cultural services to indigenous people, which can cause conflict. It is therefore important to assess such ecosystem services,

including the impact on affected communities, early in the planning process.

34 G. Grill et al. 2019.

35 Opperman et al. 2019.

36 See World Bank Group. 2018. and tools developed by the .

37 See 'A Brighter Future', WWF and The Nature Conservancy, https://brighterfuture.panda.org

38 IHA. 2022.; WWF. 2019b.; WWF. 2019c.

39 Jacobson et al. 2019.

40 Carbon Tracker Initiative. 2021; van de Ven et al. 2021.

41 Jacobson et al. 2019.

42 Hertwich et al. 2015; UNEP. 2016; Gibon et al. 2017; Luderer et al. 2019.

43 Baruch-Mordo et al. 2019.

44 126,000 km2, or 1.3 per cent of land, vs. 0.1 per cent needed for the renewable energy footprint and a further 0.7 per cent for wind turbine spacing; from www.thesolutionsproject.org.

45 https://thebreakthrough.org/blog/whats-the-land-use-intensity-of-different-energy-sources

46 Sovacool. 2012; Hertwich et al. 2015.

47 See, for example, European Commission, 'Climate change and biodiversity loss should be tackled together', EC Horizon Magazine, October 2021.

48 Bennun et al. 2021.

49 These include painting turbine blades to increase visibility for birds and acoustic deterrents for bats. For a comprehensive review, see Bennun et al. 2021: Mitigating biodiversity impacts associated with solar and wind energy development : guidelines for project developers, IUCN.

50 See Bennun et al. 2021 for further information.

51 Gibon et al. 2017; Luderer et al. 2019; IEA 2021c, 2021c; Pell et al. 2021.

52 Sonter et al. 2020a.

53 SINTEF. 2022.

54 Sonter et al. 2020a.

55 Pell et al. 2021.

56 CSBI & TBC. 2015.

57 IEA. 2021c.

58 Copper Recycling - Copper Alliance

59 NS Energy Staff. 2021.

60 See CSBI & TBC. 2015.

61 Sonter et al. 2020a.

62 Sonter et al. 2020b.

63 Teske et al. 2016.

64 Stratmann et al. 2021.

65 Weaver & Billett. 2019.

66 Koschinsky et al. 2018.

67 Weaver & Billett. 2019.

68 See www.savethehighseas.org/momentum-for-a-moratorium.

69 UNEP FI. 2022.

70 For example, studies by NINA in Norway showed 70 per cent reduced mortality rate when rotor blades were painted black.

71 For further explanation of curtailment, see this PowerPoint presentation from SINTEF Energy Research.

72 The restoration/enhancement potential for solar and wind is similar, although it is probably higher for wind farms as there is often more restorable land between turbines. However, unlike solar farms, wind farms raise the issue of collision impacts on vulnerable birds and bats. These impacts are very difficult to fully address or offset. The overall medium rating considers both

these factors (restoration/enhancement potential and species impacts).

73 Fish passage has had limited success, particularly in the tropics where the diversity of fish needing passage is very high, and multiple life-history traits need to be accommodated by the passage facility. Similarly, e-flows can help mitigate effects on changes in the flow regime but won't allow, for example, the passage of sediments at the levels that would have occurred without a dam and reservoir being there. See also: Noonan et al. 2012 and Radinger et al. 2021 (Conservation Biology).

74 E.g. IHA: https://www.hydropower.org/blog/how-sustainable-hydropower-can-promote-biodiversity).

75 E.g. https://www.hydrosustainability.org/hydropower-sustainability-tools

76 McManamay et al. 2021.

77 Luderer et al. 2019.

78 In Nordic countries, for example, large parts of the fossil energy economy have been transformed to native forest-based bioenergy, e.g. https://energsustainsoc.biomedcentral.com/articles/10.1186/s13705-021-00290-9

79 See for example Examples of Positive Bioenergy and Water Relationships | Bioenergy (ieabioenergy.com)

80 https://renewables-grid.eu/publications/green-electricity-corridors-briefing-paper.html

81 Rehbein et al. 2020.

82 The terms "Energy Master Plan" and "Integrated Resource Plan" are used to describe effective tools for planning

83 Bennun et al. 2021.

84 See van de Ven et al. 2021 for more on risk of displacement from poorly planned solar expansion.

85 See the 2020 briefing paper from WWF, Renewable Energy Industrial Precincts.

86 Santangeli et al. 2016.

87 European Commission. 2017. The Commission defines interconnection as a member state's import capacity as a percentage of its total generation capacity.

88 Hernandez et al. 2019.

89 Baruch-Mordo et al. 2019.

90 Carbon Brief. 2022.

91 See Kiesecker et al. 2020.

92 see www.naturepositive.org

93 See Arlidge et al. 2018.

94 Based on the Science-based Targets Network's 'ART3 Framework'. See Science-based Targets for Nature – Initial guidance for business

95 Burt et al. 2017.

96 Including storage towers that can store energy in a similar method to pumped hydropower stations

97 Emmott et al. 2015.

98 Adeh et al. 2019.

99 See WWF's work on nature-based solutions.

100 See WWF's Powering nature: Creating the conditions to enable nature-based solutions report.

101 IEA. 2021.

102 See Opperman et al. 2019.

103 de Andrade Junior et al. 2021.

104 de Andrade Junior et al. 2021.

105 Baruch-Mordo et al. 2019; Drechsler et al. 2017.

106 WWF & TBC. 2021.

107 de Silva et al. 2019.

108 For more information, see IFC Performance Standard 6. The IFC has also developed Environmental, Health and Safety Guidelines for Wind Energy.

109 A large number of other development banks and financial institutions have broadly aligned their own environmental standards with those of the IFC, although these are often not effectively implemented in practice. See WWF & TBC. 2021.

110 CSBI & TBC. 2015.

111 Bennun et al. 2021.

112 Hernandez et al. 2019.

113 van de Ven et al. 2021.

114 See Hernandez et al. 2019 for examples.

115 See TBC insight's paper, What does Nature Positive mean for business?

116 See the Science Based Targets Network website and its Initial Guidance for Business

117 Particularly the Convention on Biological Diversity's Kunming-Montreal Global Biodiversity Framework

118 From "Net Zero by 2050", IEA, Paris https://www.iea.org/reports/net-zero-by-2050, License: CC BY 4.0, and Gibon, T., Hertwich, E.G., Arvesen, A., Singh, B. & Verones, F. (2017) Health benefits, ecological threats of low-carbon electricity. Environmental Research Letters 12: 034023

119 Gibon, T., Hertwich, E.G., Arvesen, A., Singh, B. & Verones, F. (2017) Health benefits, ecological threats of low-carbon electricity. Environmental Research Letters 12: 034023, IEA WEO 2021; Luderer et al. 2019.

120 Construction of dams can lead to flooding, disruption of river flow and fragmentation of freshwater ecosystems, often with severe consequences for migratory and other species. See Box 1 for details.

121 See Schmutz & Sendzimir. 2018. Riverine Ecosystem Management.

122 Schwarz. 2019.

123 High-end system impact versus low-end (best practice) system impact for IEA NZE scenario - Gibon, T., Hertwich, E.G., Arvesen, A., Singh, B. & Verones, F. (2017) Health benefits, ecological threats of low-carbon electricity. Environmental Research Letters 12: 034023, IEA WEO 2021)

124 High-end system impact versus low-end (best practice) system impact for IEA NZE scenario - Gibon, T., Hertwich, E.G., Arvesen, A., Singh, B. & Verones, F. (2017) Health benefits, ecological threats of low-carbon electricity. Environmental Research Letters 12: 034023, IEA WEO 2021)

125 Baruch-Mordo et al. 2019, IEA 2021, Thieme et al. 2021. See also https://brighterfuture.panda.org/#solutions

126 Baruch-Mordo et al. 2019. See also pages 23 and 63 in Opperman et al. 2019.

127 For example imposing a nature fee on the area used for new infrastructure, corresponding to the cost of restoring the same type of nature elsewhere.

128 Such areas include ecological corridors, migration routes, fish spawning and rearing areas, and areas with high natural carbon uptake and storage

129 Koschinski S., Lüdemann K. 2020.

130 There are many different colours of hydrogen currently being considered for more extensive use, but this report considers the three that are generally most prominent: blue, grey, and green

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