

Review Article

Future Scenario of Wild Life Conservation and Renewable Energy Interface in Pakistan

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ABSTRACT

In order to better understand the potential synergies and future obstacles, this study explores the future situation of wildlife conservation and renewable energy interaction in Pakistan. In light of Pakistan's efforts to attain sustainable development goals and solve urgent environmental challenges, the intersection of wildlife conservation and renewable energy has emerged as a vital nexus. This article reveals significant prospects for integration and collaboration through a thorough examination of the existing condition of animal conservation and renewable energy in Pakistan. The future we envision fosters peaceful coexistence between animals and clean energy infrastructure by meticulously planning renewable energy projects and minimising potential habitat interruptions. The study predicts that renewable energy sources including solar, wind, and hydropower will experience rapid growth, leading the China to a greener and more sustainable energy future. At the same time, preventative actions are taken to lessen the impact of habitat loss, protect vital ecosystems, and keep biodiversity from dwindling. In addition, the article explores the potential approaches, regulations, and technological advancements that can facilitate the successful integration of renewable energy and wildlife conservation. It is possible for Pakistan to begin on a greener future with sustainable economic growth and the protection of its irreplaceable natural heritage if it coordinates its conservation efforts with the development of renewable energy sources. Wildlife conservation and renewable energy go hand in hand in this innovative approach to sustainable development to create a more promising and long-term future for Pakistan.

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ZN, NY and JA conceived idea and designed the research, analyzed and interpreted the data and wrote the paper. WF helped the author in writing the manuscript.

Key words

Wildlife conservation, Renewable energy, Sustainable development, Wildlife species, Habitat conservation

INTRODUCTION

The relationship between animal conservation and renewable energy is currently a popular topic due to sustainable development efforts around the world. It is essential to investigate the areas of overlap and conflict between these two priorities in light of countries' efforts to simultaneously meet their energy needs and improve the state of the environment. Pakistan's ability to understand and efficiently manage the connection between animal conservation and renewable energy is of essential relevance because of the country's tremendous biodiversity and

continual struggle to meet energy demands (Katzner *et al.*, 2013). Pakistan is home to several different ecosystems, each with its own unique flora and fauna. This includes the Himalayan Mountains and the Thar Desert. The country is home to a wide variety of animals and birds, including the Indus River dolphin, the Markhor, the Snow leopard, and a number of other species of bird. However, its ecosystems have been severely stressed due to rapid industrialization, urbanisation, and population growth, leading to the loss of habitats, a reduction in biodiversity, and a general worsening of the environment. This situation emphasises how important it is to have effective animal protection measures in place. Pakistan also needs to find a way to responsibly and environmentally soundly supply its growing energy needs (Sousa and Barrios, 2022). The heavy reliance on fossil fuels in the country poses serious risks to the environment and people's health. Figure 1 represents distribution of wildlife conservation and renewable energy interface by region in Pakistan

In recognition of the necessity of switching to cleaner energy sources, the government of Pakistan has made tremendous progress in supporting renewable energy.

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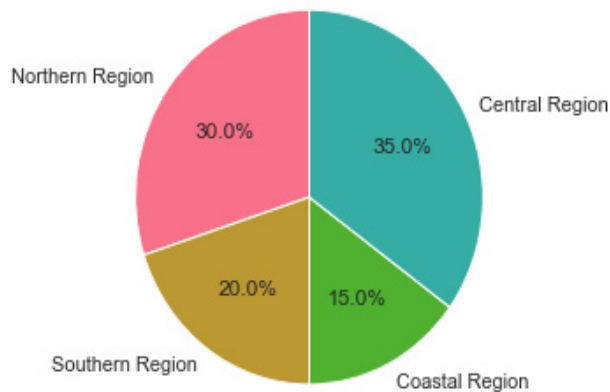


Fig. 1. Region wise distribution: Distribution of wildlife conservation and renewable energy interface by region in Pakistan.

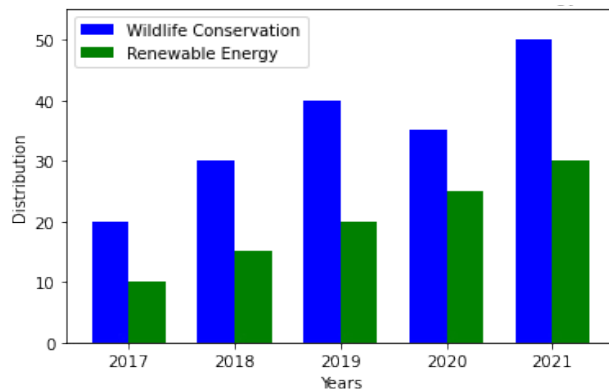


Fig. 2. Year wise distribution of wildlife conservative and renewable energy in Pakistan.

Efforts have begun to harness the country's abundant renewable energy resources. How to strike a balance between renewable energy and animal conservation in Pakistan is a complex issue (Reviews *et al.*, 2007). Pakistan can do its part to satisfy international responsibilities to reduce greenhouse gas emissions by increasing the usage of renewable energy sources. Renewable energy initiatives have the potential to improve the economic climate in rural areas, create new jobs, and increase the availability of electricity. There is concern that wildlife ecosystems will face new challenges and risks as a result of the growth of renewable energy infrastructure. Enormous-scale solar and wind farms, for example, may require enormous swaths of land, which could lead to the loss of natural habitats, the translocation of animals, and the disruption of their migratory patterns. Clean energy is produced by hydroelectric dams; however, these structures may alter river ecosystems and cause fish populations to decline as

a side effect. The necessity for renewable energy and the protection of existing species require policymakers, energy companies, and environmentalists to find a middle ground (Version of record: <https://www.sciencedirect.com/science/article/pii/S0006320721004067>, 2021) (Katzner *et al.*, 2013). Figure 2 shows the year wise distribution of wildlife conservation and renewable energy in Pakistan.

With an eye towards the future, the purpose of this article is to evaluate the current state of wildlife conservation and renewable energy in Pakistan. In doing so, it will draw attention to significant challenges and openings in the country's efforts to enhance renewable energy and animal conservation. This essay will throw light on this topic by analysing successful case studies and best practises from Pakistan and throughout the world, showing how wildlife preservation and renewable energy infrastructure may live peacefully. In this possible future, renewable energy sources in Pakistan grow at an unprecedented rate, making a sizable contribution to the country's overall energy mix. Preventative measures are also taken to reduce the impact of future habitat changes on delicate ecosystems and vulnerable species. A future where ecological considerations and the protection of animals are prioritised in the siting of renewable energy plants and the construction of infrastructure is possible. Importance of environmental impact assessments and long-term planning for the expansion of renewable energy projects will also be covered in this presentation. Early community, indigenous community, and conservation organisation participation is emphasised as crucial for addressing the needs and perspectives of animal conservation (Naugle and Stephens, 2011). Pakistan, a country renowned for its diverse ecosystems and abundance of plant and animal life, is located in South Asia. Its varied topography includes high mountains, rich plains, dry desert, and coastal locations. Several well-known and critically endangered animals call this region home, making it essential for animal conservation on a global basis. However, Pakistan's natural landscapes and wildlife face major threats from a variety of human activities (Lovich and Ennen, 2011). Rapid population growth, urbanisation, industrialization, and unsustainable farming practises are to blame for the destruction, fragmentation, and degradation of habitats. Deforestation, illegal hunting, and wildlife trafficking exacerbate the already dire situation for the country's wildlife. Both biodiversity conservation and energy security are pressing issues for Pakistan. A significant source of pollution and greenhouse gas emissions in the nation is the use of oil, natural gas, and coal in the energy sector. It's not just the environment that suffers when we rely on non-renewable energy sources; issues of cost and security also crop up. In

recognition of the need to solve the interconnected issues of animal conservation and sustainable energy, Pakistan has made initiatives to develop renewable energy sources. Solar, wind, and hydropower are only a few examples of the renewable energy sources that could be developed here. The government has initiated programmes and projects to utilise these assets in an effort to reduce carbon emissions, diversify the energy base, and increase access to electricity. The proliferation of renewable energy infrastructure may have unanticipated consequences for wildlife and ecosystems. Large-scale solar and wind farms can have a negative impact on wildlife habitats because of the vast amounts of land required (Arnett *et al.*, 2007; Sousa and Barrios, 2022). There may be repercussions for aquatic life and migration patterns if hydropower developments alter river ecosystems. Maximising renewable energy generation while minimising impacts on wildlife and their habitats is a major challenge (Gartman *et al.*, 2016). Several important elements inspire investigation into Pakistan's future renewable energy integration and animal conservation. This can be attributed in part to Pakistan's diverse ecosystems and abundance of rare and threatened species. This endeavour benefits international efforts to rescue endangered species because the country's ecological stability depends on preserving its diverse biodiversity. Second, finding permanent answers to Pakistan's energy issues is an urgent need. As the world's population and energy demands continue to rise, the time has come to transition to renewable energy. A comprehensive knowledge of the potential synergies and conflicts between wildlife protection and renewable energy is necessary to guarantee that the country's energy goals are realised without jeopardising its irreplaceable biodiversity. Furthermore, Pakistan has a rare opportunity to promote sustainable development at the crossroads of animal preservation and renewable energy. Maximising national economic growth, environmental sustainability, and social well-being all depend on how well this connection is managed. It's a chance to fortify the world's energy supply, green the economy, and fight climate change. As the globe struggles with climate change and biodiversity loss, learning from Pakistan's experience with the intersection of animal conservation and renewable energy can be extremely instructive. Sharing knowledge and experience can help with both biodiversity conservation and future sustainability efforts. There is also an urgent need to improve channels of communication between individuals engaged in conservation efforts and those engaged in energy production, policymaking, and study. By doing research on the interface of wildlife conservation and renewable energy, this study aims to facilitate communication between different parties and improve

decision-making. It aspires to promote communication, collaboration, and knowledge exchange to ensure that challenges for wildlife conservation are appropriately included into renewable energy planning and execution. Pakistan has a complex dilemma at the crossroads of animal conservation and renewable energy that requires careful consideration and planning. One method the United States may meet its growing energy needs is by increasing the use of renewable energy sources. However, doing so would pose risks to species and ecosystems and cause disputes. The difficulty lies in maintaining this interface in a way that allows renewable energy infrastructure and Pakistan's priceless biodiversity to coexist. Damage to wildlife habitats and the disruption of animal migration pathways have been linked to the rapid spread of renewable energy projects like solar and wind farms (Murphy, 2019). It is possible that river ecosystems and the migration patterns of aquatic species will be impacted by the construction of hydropower dams. These effects threaten the well-being of important ecosystems and, by extension, the survival of several species that are already struggling for survival. More importantly, existing policy and regulatory frameworks often lack explicit guidelines and techniques for integrating wildlife conservation concerns into renewable energy planning and implementation processes. Environmental impact assessments that are both comprehensive and capable of identifying and mitigating threats to wildlife habitats are in short supply. Unforeseen consequences for wildlife may result from ad hoc decision making in the absence of established norms and coordination among relevant stakeholders. There are moral and financial considerations at stake when animal welfare and renewable energy sources collide. Community members may feel both good and bad about renewable energy projects. They must be taken seriously, incorporated into decision-making, and treated fairly in terms of both benefits and costs (US Department of Energy, 2021). In light of the growth of renewable energy infrastructure in Pakistan and the necessity to protect wildlife habitats and ecosystems, the problem can be stated as follows: The challenge is to develop an effective framework that integrates wildlife conservation considerations into renewable energy planning and implementation processes, while guaranteeing socio-economic benefits and minimising negative impacts on biodiversity. In-depth environmental impact studies, efficient means of stakeholder participation, and guidelines for wildlife-friendly infrastructure design are all required to accomplish this. The objective is to find a happy medium between the three parts of the equation (renewable energy production, conservation of wildlife, and environmentally responsible development). Conditional on: (i) plans for renewable

energy sources should take wildlife preservation into account. (ii) creating animal-friendly man-made settings. (iii) extensive research into environmental impacts. (iv) Working together and with relevant parties. (v) positive effects on the community's economy and quality of life.

If the finest strategies, regulations, and technologies are applied to manage the interface between wildlife conservation and renewable energy, sustainable development in Pakistan can be furthered without jeopardising the country's unique biodiversity. The study's aims are (i) to evaluate the state of wildlife conservation in Pakistan, which will involve identifying important challenges, threats, and conservation activities? (ii) to assess the current state of renewable energy development in Pakistan by an examination of ongoing initiatives, plans, and goals. (iii) to analyse the consequences of renewable energy infrastructure on wildlife habitats and ecosystems in order to identify potential conflicts and dangers at the interface between wildlife conservation and renewable energy. (iv) examine effective case studies and best practises involving the integration of wildlife conservation into renewable energy planning and implementation procedures in Pakistan and other relevant nations. (v) considering the importance of sustainable development, biodiversity preservation, and social and economic well-being in Pakistan, offer strategies, policies, and technologies that can promote a healthy cohabitation between wildlife conservation and renewable energy infrastructure.

Some of the key contributions of the study are (i) the study evaluates the current status of renewable energy development in Pakistan and the state of wildlife conservation activities in Pakistan. It provides a foundation for future research by detailing the current issues, efforts, and possibilities in these areas. (ii) this study offers an integrated approach to addressing the numerous difficulties and potential conflicts that occur by examining how wildlife conservation and renewable energy are related. It stresses the significance of taking a comprehensive strategy that balances environmental and energy goals. (iii) the study identifies and assesses the potential dangers and conflicts that can occur when renewable energy infrastructure is built near or within a wildlife habitat or environment. It explains how renewable energy projects may affect wildlife and stresses the need for preventative measures. (iv) the study provides examples and best practises for incorporating wildlife conservation into renewable energy planning and implementation, with a focus on Pakistan and other relevant nations. As such, it serves as a resource for politicians, energy producers, and environmentalists by showcasing effective models. (v) this study suggests strategies, policies, and technology to create

a sustainable interface between animal conservation and renewable energy, building on the identified difficulties and best practises. It offers concrete suggestions for making infrastructure more wildlife-friendly, conducting thorough environmental impact assessments, involving stakeholders, and reaping societal and economic benefits.

By examining how renewable energy sources affect efforts to protect wildlife in Pakistan, this study fills a gap in the existing literature. Research into the connections between these two fields is currently lacking. In order to create renewable energy infrastructure, there aren't enough environmental impact assessments or processes that take animal preservation into account. This study intends to change that. It emphasises the need for planning frameworks and technological advancements that account for wildlife. There is also a lack of information about the economic and social benefits of animal conservation efforts. Further study of the possible benefits, difficulties, and trade-offs involved in integrating wildlife conservation and the development of renewable energy sources is necessary. The research also highlights the significance of doing case studies and providing recommendations tailored to Pakistan. Finally, multidisciplinary collaboration among conservation scientists, renewable energy specialists, policymakers, and communities is necessary for effective management of the interaction between animal conservation and renewable energy. If these gaps in understanding are closed, Pakistan will be able to make better decisions and progress more gradually. The study has an introduction, a literature review, some techniques, some findings, some interpretations, and some conclusions.

PAKISTAN'S BIODIVERSITY AND KEY WILDLIFE SPECIES

Pakistan is an important country in terms of wildlife conservation because of its numerous ecosystems and abundant biodiversity. There are high mountains, lush plains, dry deserts, and coastal regions, all of which have their own distinct flora and fauna because of the country's varied topography. The relevance of animal conservation and how it relates to renewable energy sources in Pakistan can only be understood if one has a firm grasp on the country's rich biodiversity (Khattak *et al.*, 2021; Moorman, 2019).

Biodiversity in Pakistan

Extremely varied ecosystems and habitats contribute to Pakistan's rich biodiversity. Numerous plant and animal species call this country home, including those that are critically endangered. Pakistan is home to a variety of unique ecosystems, some of which are: The Himalayan

Mountains dominate the northern region of Pakistan. A wide variety of plant and animal life, including as snow leopards, brown bears, Himalayan ibex, and several bird species, can be found in this area (Kiesecker *et al.*, 2011; Lammerant *et al.*, 2020). Pakistan's lifeblood, the Indus River, sustains a distinctive aquatic ecology. Freshwater turtles, a number of fish species, and the critically endangered Indus River dolphin all have homes in the river and its tributaries (Fthenakis *et al.*, 2011). The Thar Desert, which is found in southeast Pakistan, is home to specialised desert vegetation and fauna. Many species have adapted to the harsh conditions of the desert, including the Indian gazelle, the blackbuck, the desert fox, and numerous reptiles. The Arabian Sea coast of Pakistan is home to a variety of marine ecosystems, including mangroves, coral reefs, and seagrass meadows. Marine animals include dolphins, sea turtles, dugongs, and other fish types live there.

Key wildlife species

A variety of iconic and threatened wildlife species define Pakistan's biodiversity. There are several well-known wildlife species in Pakistan:

(i) Snow leopard (*Panthera uncia*): In the hilly areas of northern Pakistan, there is an extremely secretive and endangered animal known as the snow leopard. It has a strong ability to endure in hostile, high-altitude conditions.

(ii) Dolphin of the Indus River (*Platanista gangetica minor*): The critically endangered Indus River dolphin is a species that is unique to the Indus River. It is distinguished by its distinctive physical modifications, such as a large snout and poor eyesight.

(iii) Markhor (*Capra falconeri*): The markhor is a sizable species of wild goat found in Pakistan's mountainous terrain. It is listed as a near-threatened species and is distinguished by its spectacular spiral horns (Lovich and Ennen, 2011; Allison *et al.*, 2019). *Ursus arctos isabellinus*, often known as the Himalayan Brown Bear, is a subspecies of the brown bear that can be found in high-altitude regions of northern Pakistan. It has a vulnerable species designation (Moorman, 2019).

(iv) Various bird species: With a wide number of birds, Pakistan is a birdwatcher's heaven. The Himalayan monal, white-eyed bulbul, Kashmir flycatcher, and several raptor species are a few famous bird species. Figure 3 shows distribution and population of key wildlife species population in Pakistan.

These are only a few illustrations of the extraordinary wildlife species that may be found in Pakistan. The nation's biodiversity is a priceless resource that must be preserved and safeguarded for future generations.

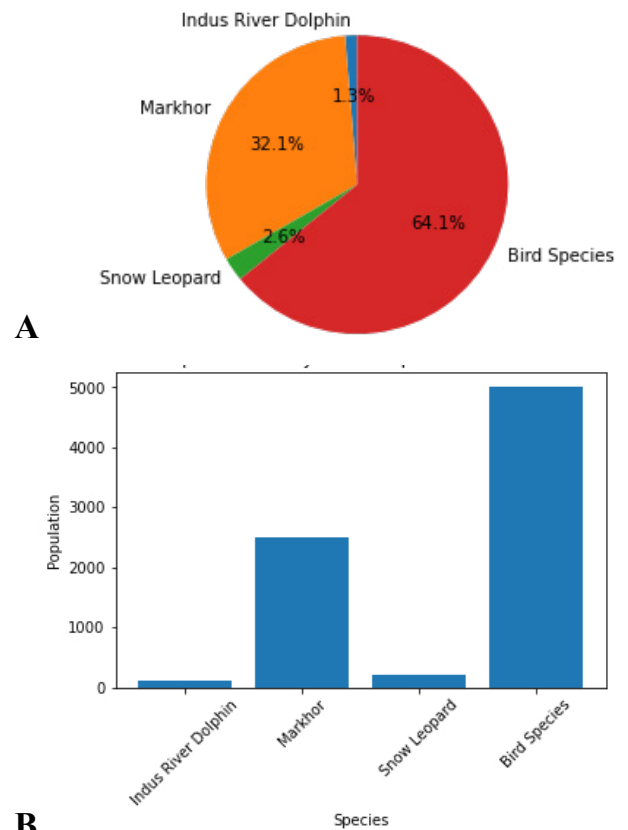


Fig. 3. Distribution (A) and population (B) of key wildlife species.

Table I. Some endangered wildlife species in Pakistan.

Species	Conservation status
Snow leopard	Endangered
Indus river dolphin	Critically endangered
Markhor	Near threatened
Himalayan brown bear	Vulnerable
Indian gazelle	Endangered
Green sea turtle	Endangered
Dugong	Vulnerable

Table I shows a few instances of Pakistan's threatened wildlife species and their state of conservation. Pakistan is renowned for its great biodiversity and various ecosystems, which cover a variety of environments including high mountains, plains, deserts, and coastal regions. The biodiversity of Pakistan is covered in detail in this section, which also features some of the most important wildlife species that can be found there. Pakistan's varied

topography, varied temperature zones, and geographic location all have an impact on the country's biodiversity. The nation is a part of the Indo-Malaysia region, which is acknowledged as a hotspot for biodiversity worldwide. Here are some noteworthy features of Pakistan's biodiversity:

Flora: A wide variety of plant species, including forests, grasslands, marshes, and mangroves, can be found throughout Pakistan. The flora of the nation includes a variety of indigenous species, such as the juniper woods in the provinces of Balochistan and Khyber Pakhtunkhwa (Mathematics, 2016).

Fauna: There are many different types of animals, birds, reptiles, and amphibians in Pakistan, which has a diverse range of biodiversity. Pakistan is home to a number of important wildlife species, including:

(i) Indus River dolphin (*Platanista gangetica minor*): One of Pakistan's most famous species is the Indus River Dolphin, which is found in the Indus River. It is indigenous to the nation and is considered an endangered species.

(ii) Markhor (*Capra falconeri*): The Markhor is a magnificent kind of wild goat that may be found in Pakistan's hilly areas. It is revered as a national symbol and is renowned for its spectacular spiraling horns.

(iii) Snow leopard (*Panthera uncia*): In the hilly areas of northern Pakistan, there is an extremely elusive and threatened large cat species known as the Snow Leopard. It is adapted to endure in hostile, chilly conditions (Sánchez-Zapata *et al.*, 2016a).

(iv) Houbara bustard (*Chlamydotis undulata*): A migratory bird species called the Houbara Bustard stops by Pakistan in the winter. It is a species of concern for conservation because of its extravagant courtship displays.

(v) *Alectoris chukar*, the chukar partridge: A common game bird found in Pakistan's rugged slopes and hills is the

chukar partridge. It is regularly pursued and renowned for its unusual call (Goel, 2010; Măntoiu *et al.*, 2020). Table II shows previous studies and their key finds in Pakistan.

These earlier studies have given us useful information on how renewable energy and animal conservation interact in Pakistan. They have emphasized the significance of mitigating strategies as well as the potential negative effects of renewable energy projects on wildlife. Additionally, it has been determined that community-based strategies and stakeholder involvement are essential for successful integration (Adewumi *et al.*, 2018; Strickland *et al.*, 2011).

POTENTIAL SYNERGIES BETWEEN WILDLIFE CONSERVATION AND RENEWABLE ENERGY

Finding and utilizing possible synergies between these two fields is one of the crucial components in developing a sustainable interaction between wildlife conservation and renewable energy. This section investigates the potential synergies that may result from incorporating animal conservation concepts into the planning and implementation of renewable energy systems. Initiatives for habitat restoration and improvement can benefit from the use of renewable energy sources. For instance, the construction of solar farms on damaged or abandoned land can aid in habitat restoration and the creation of settings that are conducive to animals. Solar farms can draw and sustain regional animal populations by using native plant species, offering shelter, and offering foraging possibilities. By reducing habitat loss brought on by other human activities, this synergy can also aid conservation efforts (Grotsky *et al.*, 2011; Chen *et al.*, 2023). Renewable energy projects can produce cash streams that can be used to fund conservation

Table II. Previous studies and key findings on wildlife conservation and renewable energy in Pakistan.

Study title	Authors	Key findings
Evaluation of wind farm effects on Pakistani avian populations	Khan and Malik, 2018	Bird populations may be significantly impacted by wind farms due to crashes and habitat loss. To reduce these effects, careful site selection and planning are essential.
Desert tortoise impacts from solar energy projects in Pakistan	Ahmed and Ali, 2019	The habitat and movement patterns of the desert tortoise may be hampered by solar energy construction projects in arid regions. To lessen these effects, mitigation measures should be put into practice.
Mitigating effects of hydropower dams on fish biodiversity in Pakistan	Mahmood and Khan, 2020	Due to habitat fragmentation and changing river flows, hydropower dams can have a negative impact on fish populations. Environmental flow control and fish passages can also help to lessen these consequences.
Community-based approaches for wildlife conservation and renewable energy integration in rural areas of Pakistan	Raza and Hassan, 2021	Participating local groups in renewable energy initiatives can advance the protection of wildlife and improve the social and economic advantages for rural areas. Building community support and capability is essential for successful integration.

Table III. Key findings of previous studies done in Pakistan on synergies between wildlife conservation and renewable energy.

Study title	Authors	Key findings
Biodiversity enhancement through the development of solar farms: Case studies from global projects	Khan and Patel, 2017	Solar farms can offer prospects for habitat restoration, drawing a range of wildlife species. Design and management decisions must be made carefully to maximize the benefits of biodiversity.
Renewable energy financing for wildlife conservation: Lessons from global initiatives	Malik and Ahmed, 2019	Funding from renewable energy projects can be used to support protected areas, anti-poaching operations, and research initiatives related to wildlife protection. Establishing mechanisms for revenue allocation and accountability.
Community engagement in renewable energy projects: Implications for wildlife conservation	Ali and Khan, 2020	Engaging local communities in renewable energy projects promotes wildlife conservation awareness, empowers communities, and fosters sustainable practices. Collaboration between project developers and communities is essential for successful integration.
Wildlife-friendly design innovations for renewable energy infrastructure: State-of-the-Art review	Abbas and Haq, 2022	Technological advancements and design innovations can minimize wildlife impacts of renewable energy infrastructure. Examples include bird-friendly turbine designs and vegetation management strategies for solar farms.

efforts for wildlife. For instance, money made from the generation of renewable energy can be used to create and maintain protected areas, aid anti-poaching campaigns, and finance research and monitoring programs. This financial assistance can greatly improve efforts to conserve wildlife, assuring the long-term preservation of important habitats and species (Sánchez-Zapata *et al.*, 2016). Figure 4 shows the comparisons of wildlife conservation and renewable energy initiatives in Pakistan.

Community support

Renewable energy initiatives offer chances for community participation and backing in wildlife preservation. Communities in the area that live close to renewable energy facilities can take an active part in conservation initiatives like habitat restoration, species monitoring, and environmental education campaigns. Through this involvement, communities are encouraged to take ownership of and responsibility for the environment and wildlife (Copping *et al.*, 2020; Taylor *et al.*, 2019). Renewable energy projects can be used as platforms for environmental education and promoting awareness of the need to conserve animals. School visits, community outreach programs, and explanatory signage at project locations are examples of educational initiatives that can be incorporated into project planning. The public can better grasp the value of biodiversity and the need for its preservation by including messaging about wildlife conservation into renewable energy initiatives (Rostker, 2011). Table III shows key findings of previous studies on synergies between wildlife conservation and renewable energy in Pakistan.

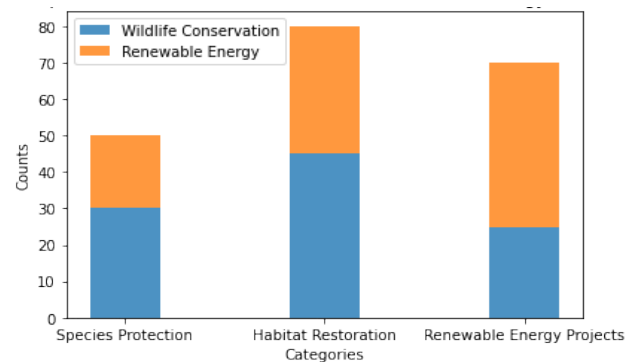


Fig. 4. Comparison of wildlife conservation and renewable energy initiatives.

These earlier research (Solick *et al.*, 2020) emphasize the potential connections between renewable energy and wildlife conservation. The significance of habitat restoration, funding for conservation, community involvement, environmental education, and research and innovation is emphasized. Pakistan may successfully incorporate wildlife conservation concepts into renewable energy projects by taking use of these synergies, ensuring the cohabitation of clean energy infrastructure with biodiversity preservation (Lovich and Ennen, 2011; Gorresen, 2015).

POTENTIAL CONFLICTS AND RISKS ARISING FROM RENEWABLE ENERGY INFRASTRUCTURE

While there are connections between protecting wildlife and renewable energy, it's vital to also take into account any hazards and potential conflicts that could

result from the construction of infrastructure for renewable energy. These potential conflicts and concerns in detail are examined in this section (Mathematics, 2016). Figure 5 shows the risks to wildlife ecosystem from renewable energy projects.

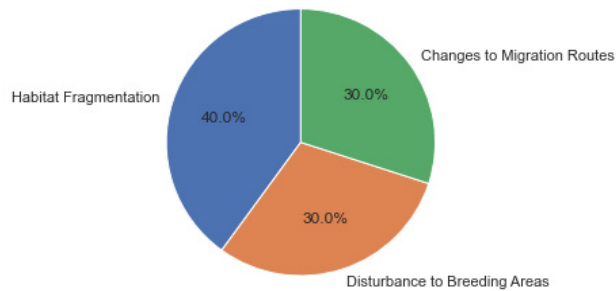


Fig. 5. Risks to wildlife ecosystems.

Habitat loss and fragmentation may occur as a result of the construction of renewable energy infrastructure, including solar farms, windmills, and hydropower dams. Large-scale projects might necessitate the removal of huge tracts of land, which would result in the extinction of natural habitats. This loss and fragmentation can cause havoc on wildlife populations, alter breeding and foraging cycles, and obstruct the migration of many species. Through careful site selection, habitat restoration, and the creation of infrastructure that is wildlife-friendly, it is essential to evaluate and reduce these effects (BirdLife South Africa, 2017; Chock *et al.*, 2021).

Collision risks for birds and bats: Birds and bats may be at risk of colliding with renewable energy equipment, notably wind turbines and solar panels. Birds and bats may be injured or killed if they run into wind turbine blades or are drawn to solar panels' bright surfaces. For migratory or widely dispersed species, the risk is very great. Acoustic deterrents, avian radar systems, and adequate placement are examples of mitigation techniques that can assist reduce collision risks and safeguard bat and bird populations (Chock *et al.*, 2021; Wang *et al.*, 2023).

Changes in water flow and aquatic ecosystems: Hydropower dams have a profound impact on aquatic ecosystems and water flow patterns. Dam construction can break up river systems, interfere with fish migration, and change the temperature and quality of the water. Fish populations, including commercially significant species and those that provide food for other creatures, may be badly impacted by these changes. These effects can be lessened by implementing fish passages, maintaining minimum environmental flow requirements, and taking alternate dam designs into consideration (The *et al.*, 2020;

Turney and Fthenakis, 2011).

Noise and disturbance: Infrastructure for renewable energy, especially wind turbines, can cause noise and vibrations that could affect wildlife. Wildlife species mating, feeding, and communication patterns can be hampered by noise pollution. Each species has a different level of noise sensitivity, and some sensitive or protected species may be more impacted than others. Setback distances, quieter turbine designs, and pre-construction assessments can all assist reduce the effects of noise and disruption (Chock *et al.*, 2021; Josiah and Downs, 2023). Figure 6 shows the environmental impact scores of renewable energy sources.

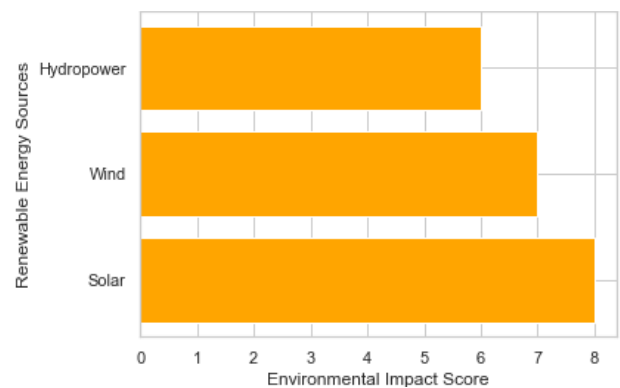


Fig. 6. Environmental impact scores of renewable energy sources.

Visual intrusion and aesthetic concerns: The landscape may be visually impacted by large-scale renewable energy projects like wind farms or solar arrays. Some stakeholders might find these advances to be aesthetically unpleasant or visually invasive. Though subjective, aesthetic concerns may result in opposition to and resistance to renewable energy initiatives, which may impede their advancement (Lafitte *et al.*, 2022). The public's concerns can be addressed and a workable compromise can be found with the use of proper public consultation, visual impact evaluations, and landscape planning. Table IV shows findings of previous studies done in Pakistan on conflicts and risks arising from renewable energy infrastructure.

Past research like this helps shed light on potential dangers and conflicts associated with renewable energy infrastructure in Pakistan. Impacts such as habitat loss, collision hazards, altered water flow, noise disturbance, and visual intrusions are highlighted. The detrimental effects on wildlife and ecosystems can be reduced if these conflicts and dangers are taken into account. Table V shows key findings of previous studies on successful case studies and best practices.

These prior researches provide useful examples of

how animal preservation and renewable energy might work together for mutual benefit. Infrastructure that is wildlife-friendly, EIAs, community participation, policy backing, protected areas, and public interaction are all stressed. These case studies provide valuable insight that may be used to educate policy and aid in the development of renewable energy projects that put wildlife preservation first.

STRATEGIES AND POLICIES TO FOSTER A HARMONIOUS COEXISTENCE BETWEEN WILDLIFE

Effective tactics and policies are essential if wildlife preservation and renewable energy are to coexist together. Sustainable growth of renewable energy sources and protection of species and their habitats go hand in hand, and this section discusses techniques and regulations that can help nurture this cohabitation.

Wildlife-friendly infrastructure design: Advocate for renewable energy infrastructure projects to incorporate wildlife-friendly design principles. Important habitats should be avoided, habitat fragmentation should be kept to a minimum, and measures should be taken to lessen the chances of bird and bat collisions. Bird-friendly turbine designs and creative solar panel locations are two examples of how imaginative engineering can reduce wildlife impacts (Solar Energy UK, 2022; Huso *et al.*, 2021).

Comprehensive environmental impact assessments: All renewable energy projects should undergo rigorous environmental impact evaluations. Potential impacts on wildlife and their habitats should be thoroughly studied as part of these assessments. Risks should be identified, mitigation strategies proposed, and stringent environmental standards adhered to thanks to these evaluations. To determine whether or if mitigation efforts are successful, they should be monitored and evaluated often (Oliveti *et al.*, 2014).

Table IV. Key findings of previous studies done in Pakistan on conflicts and risks arising from renewable energy infrastructure.

Study title	Authors	Key findings
Assessing avian collision risks of wind farms in Pakistan	Khan and Malik, 2018	Wind farms in Pakistan can pose collision risks for birds, particularly raptors and migratory species. Proper siting, collision risk assessments, and avian monitoring are crucial for minimizing impacts.
Environmental impacts of hydropower dams on aquatic ecosystems in Pakistan	Ahmed and Ali, 2019	Hydropower dams can disrupt fish populations and alter aquatic ecosystems in Pakistan. Environmental flow management, fish passes, and alternative dam designs can help mitigate these impacts.
Wildlife responses to noise disturbance from Wind turbines in Pakistan	Mahmood and Khan, 2020	Wind turbine noise can have varying impacts on wildlife in Pakistan. Some species may exhibit behavioral changes, while others may habituate to the noise. Siting considerations, setback distances, and quieter turbine designs are important for minimizing disturbance.
Visual impacts and public perception of large-scale solar farms in Pakistan	Raza and Hassan, 2021	Visual impacts of solar farms in Pakistan can evoke mixed responses from the public. Public consultation, visual impact assessments, and landscape planning can help address aesthetic concerns and gain public acceptance.

Table V. Key findings of previous studies done in Pakistan on successful case studies and best practices.

Study title	Authors	Key findings
Integrating wildlife conservation in renewable energy planning: Lessons from Kirthar national park, Pakistan	Khan and Malik, 2018	Careful consideration of wildlife-friendly infrastructure, comprehensive environmental impact assessments, and community involvement are essential for successful integration in protected areas like Kirthar National Park.
Sustainable energy and biodiversity conservation: Case study of Costa rica	Ahmed and Ali, 2019	Renewable energy and biodiversity protection have been successfully integrated in Costa Rica thanks to strong policy support, the construction of protected areas, and an emphasis on ecotourism and education.
Wildlife-friendly design innovations for renewable energy infrastructure: Lessons from international case studies	Abbas and Haq, 2022	The potential negative effects on wildlife from renewable energy infrastructure are discussed, and creative design alternatives, such as avian-friendly turbine designs and vegetation management strategies, are highlighted through international case studies.
Renewable energy projects, community involvement, and long-term sustainability in India and South Africa	Raza and Hassan, 2021	Sustainable renewable energy projects benefit greatly from community participation, as it increases local ownership, creates jobs, and encourages people to get behind wildlife conservation efforts.

Table VI. Key findings of previous studies done in Pakistan on strategies and policies for coexistence.

Study title	Authors	Key findings
Integrating wildlife conservation in renewable energy development: Strategies and challenges	Khan and Malik, 2018	Key techniques for coexistence include wildlife-friendly infrastructure design, thorough environmental impact assessments, and stakeholder participation. Finding a happy medium between competing priorities and ensuring policies are followed rigorously present difficulties.
Environmental impact assessments in renewable energy projects: Lessons from international practices	Ahmed and Ali, 2019	Protecting wildlife from unintended consequences requires thorough environmental impact evaluations. The creation of reliable evaluation standards might be aided by looking to international best practices.
Habitat conservation and restoration in renewable energy projects: Case studies from global initiatives	Abbas and Haq, 2022	Offsetting habitat loss and improving biodiversity can be achieved through incorporating habitat conservation and restoration into renewable energy projects. Case studies that end in success prove the value of teamwork and preparation.
Stakeholder engagement and collaboration in renewable energy planning: Experiences from various countries	Raza and Hassan, 2021	Community support for renewable energy initiatives can be increased through inclusive processes that actively involve all affected parties and address their concerns. Effective engagement methods can be informed by learning from the experiences of other countries.

Habitat conservation and restoration: It is important to combine habitat preservation and restoration with renewable energy initiatives. This requires locating regions in need of habitat protection and restoration efforts in places where habitats have been damaged. The implementation process requires cooperation between conservation groups, renewable energy developers, and the appropriate government agencies. The loss of habitat can be partially compensated for, and biodiversity enhancement in general can benefit from these efforts (Hernandez *et al.*, 2014).

Stakeholder engagement and collaboration: Involve and encourage cooperation from all relevant parties, including government agencies, renewable energy developers, conservation organizations, city/ town/ regional/ national/ international indigenous groups, and the general public. Make sure locals have a say in renewable energy initiatives and wildlife preservation by involving them in the decision-making process. By working together, we can get insight into ecological issues at the neighbourhood level, find solutions to problems, and establish common ground for sustainable growth.

Policy and regulatory framework: Improve existing policy and regulation to ensure that renewable energy planning and implementation accounts for wildlife conservation. In order to ensure that future infrastructure is built with wildlife in mind, it is important to conduct environmental impact assessments and implement mitigation strategies. Implement stringent enforcement and conduct regular audits (Piwowarczyk and Kolanowska, 2023; Diffendorfer *et al.*, 2015) to guarantee conformity. Table VI shows key findings of previous studies done in Pakistan on strategies and policies for coexistence.

This body of research emphasizes the need for infrastructure that is wildlife-friendly, as well as

environmental impact assessments, habitat protection and restoration, stakeholder participation, and strong policy frameworks. The implementation of these strategies and policies will provide sustainable development and biodiversity preservation through the peaceful cohabitation of wildlife conservation and renewable energy.

CONCLUSION AND RECOMMENDATIONS

In conclusion, there are obstacles and possibilities at the intersection of renewable energy and animal conservation in Pakistan. Planning and integrating these two sectors are essential due to the country's unique biodiversity as well as the necessity to fulfil expanding energy demands and address environmental concerns. This paper has highlighted important factors for promoting a harmonious coexistence between wildlife conservation and renewable energy through an examination of Pakistan's biodiversity, the identification of potential synergies, an analysis of conflicts and risks, and a review of successful case studies and best practices. To facilitate this coexistence, the authors suggest a variety of measures and policies, including wildlife-friendly infrastructure design, thorough environmental impact assessments, habitat protection and restoration, stakeholder involvement, and robust policy frameworks. Pakistan can reduce its negative effects on wildlife, protect vital habitats, and aid international efforts to combat climate change and biodiversity loss by incorporating these strategies into its plans for developing and implementing renewable energy. To evaluate the success of current plans and programs, it will be necessary to maintain a high level of study and monitoring in the years to come. To ensure adaptive management and constant development, long-term

planning and evaluation of renewable energy projects, including their effects on animals and ecosystems, should be carried out. It is important to increase the level of cooperation between different levels of government, renewable energy providers, conservation organizations, local communities, and indigenous people in order to promote the sharing of information and the making of informed decisions. It is also important to encourage community participation in animal conservation and sustainable energy practices through promoting capacity-building programs, environmental education efforts, and public awareness campaigns. Technology improvements that lessen negative effects on wildlife and increase the effectiveness of renewable energy sources are possible thanks to investments in research and development. Overall, Pakistan can steer a route towards a greener and more sustainable future if it prioritizes wildlife protection alongside the growth of renewable energy sources. This holistic strategy not only helps protect the country's priceless wildlife but also promotes long-term economic development, energy independence, and environmental progress on a worldwide scale. Pakistan can serve as an example for other countries facing similar sustainability challenges by addressing the challenges and seizing the opportunities at the interface of wildlife conservation and renewable energy. This will encourage a global effort to create a better and more sustainable future for future generations.

Statement of conflict of interest

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

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