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Solar Impacts on Wildlife and Ecosystems

Request for Information Response Summary

November 2021

Introduction

On September 13, 2021, the U.S. Department of Energy Solar Energy Technologies Office (SETO) issued a Request for Information (RFI), *Solar Impacts on Wildlife and Ecosystems,* for public response and comment. The RFI sought input in four categories (1) Solar Trends and Siting, (2) Species and Habitat Impacts, (3) Avoidance, Mitigation, and Monitoring, and (4) Resources Needed. This document summarizes the feedback that SETO received in response to our request.

SETO received 43 responses to this RFI. Respondents included representatives from the solar industry, the electric utility industry, research institutes, conservation and environmental nonprofits, and local, state, and federal government.

Note: The Department of Energy (DOE) is not communicating an opinion or viewpoint about any of the RFI responses summarized below. DOE is publishing this summary so that the public may benefit from the information. No funding is tied to this summary. DOE will use the information gathered to determine how and whether to develop future programming.

Document Structure

This document is structured in the same way as the request for information (RFI). The questions are divided into four categories: Solar Trends and Siting; Species and Habitat Impacts; Avoidance, Mitigation, and Monitoring; and Resources Needed.

Three appendices to this document are also included. These appendices capture specific points of data that we believe will be helpful to stakeholders but would be too "list-like" to include in the narrative synthesis of responses. Appendix A is a list of solar-wildlife research needs identified by respondents; Appendix B is a list of the species or taxa of concern potentially impacted by solar energy development, according to respondents; and Appendix C is a compilation of resources, tools, and references that were provided by respondents.

Category 1: Solar Trends and Siting

Q1.1: What impacts and benefits of solar energy development on wildlife are well-understood? What impacts and benefits are not well-understood? How do poorly understood impacts and benefits affect solar project development?

Respondents expressed a broad range of perspectives regarding what is well-understood and poorly understood about interactions between solar energy facilities and wildlife. Some impacts or benefits that were identified as well-understood by some stakeholders were identified as poorly understood by others. Respondents frequently pointed to specific topic areas that require further research. A list of areas in need of further research, as identified by respondents, can be found in Appendix A. See Question 2.1 and Appendix B for a list of species and taxa of concern identified by respondents.

RFI respondents agreed that the most well-understood benefit of solar energy is its role in mitigating the adverse impacts of climate change. Respondents recognized that utility-scale solar energy will play a pivotal role in decarbonizing the grid and that achieving decarbonization goals is crucial for preserving biodiversity throughout the U.S. and globally. Similarly, respondents generally agreed that given the need to mitigate climate change, it is important to develop strategies that maximize co-benefits and encourage the coexistence of wildlife communities with solar energy infrastructure. Respondents also generally agreed that it is difficult to assess tradeoffs between potential benefits and adverse impacts to wildlife. Standardized methods and best management practices that allow stakeholders to weigh the costs and benefits of solar energy development on wildlife are needed to inform siting, site design, site management strategies, and other key decisions faced by stakeholders.

Many of the respondents from industry, conservation and environmental nonprofits, state and federal agencies, and research institutions pointed to the opportunities presented by onsite vegetation management strategies that promote native wildlife habitat. Respondents also stated, however, that aspects of these management strategies are not well-understood and additional research is needed.

Stakeholders expressed several cross-cutting themes pertinent to all the interactions (i.e., benefits and adverse impacts) that are not yet well-understood (see Appendix A for a full list of topics):

- **Regional differences in wildlife impacts.** Research institutions, state and federal agencies, and conservation nonprofits indicated that research aimed at improving the understanding of these interactions must account for inter-regional differences. Most research to date is focused on the Western U.S., in California in particular, making it difficult to extrapolate and apply learnings to siting solar in other regions or localities.

- **Lack of data.** Respondents indicated that a common limiting factor for improving the understanding of solar-wildlife interactions is a lack of empirical data. Basic information is lacking about species presence before and after solar project development, background avian fatalities, and the cause of detected fatalities at solar facilities. One solar industry respondent noted that the uncertainty associated with this lack of data and information can contribute to misinformation about the adverse impacts of solar energy development. Respondents from conservation and environmental nonprofits, as well as state and federal agencies, noted that this lack of data is limiting the ability for state and local regulatory agencies to make informed permitting decisions.

- **Cumulative and long-term interactions.** Performing research on wildlife impacts requires many years and can be costly. The solar industry is relatively new compared to other energy industries, making it difficult to draw conclusions about cumulative impacts and long-term interactions. Stakeholders specifically pointed to topics such as population level declines, long-term impacts on habitat connectivity, and changes in migratory behavior as research areas that require study over extended periods of time. Similarly, stakeholders identified a lack of information about how solar-wildlife interactions vary according to the scale and density of facilities in a given region.

Research institutions, state and federal agencies, and conservation nonprofits identified avian collisions with facility structures, habitat loss and fragmentation, and adverse impacts to soil and water resources as highly important for future research. Additionally, respondents from these stakeholder groups indicated that the pace of solar energy development is outpacing the speed at which impacts and benefits can be studied, mitigation strategies can be developed, and regulatory requirements can be enacted.

Industry respondents expressed interest in research to understand how wildlife can co-exist with utility-scale solar energy development. They pointed to the benefits provided by solar facilities and the need to further develop strategies for habitat and vegetation management, agrivoltaics (i.e., agricultural production, such as crop or livestock production or pollinator habitat, underneath or adjacent to solar panels), and site design to achieve maximum benefits. Additionally, they indicated the need for research on methods used to quantify environmental services so that those benefits can be more concretely considered during project development decisions. Finally, industry respondents highlighted the importance of analyzing solar-wildlife interactions in the context of other forms of land uses and energy generation.

Stakeholders generally agreed that various aspects of solar energy planning and deployment are affected by poorly understood facets of solar-wildlife interactions. Industry respondents indicated that these knowledge gaps can create missed opportunities to maximize benefits from solar energy facilities, inconsistencies and delays in the permitting process, and increased costs from unnecessary mitigation requirements. Some researchers, state and federal agencies, and conservation nonprofits identified these knowledge gaps materializing as uninformed project siting and permitting decisions at the state and local level, a lack of standardized guidance and regulations for solar developers, and limited landscape-level planning for solar energy development.

Q1.2: Are there effective processes for encouraging or discouraging solar siting in certain locations on the basis of wildlife impacts?

Respondents disagreed about the effectiveness of current practices for encouraging or discouraging solar siting on the basis of wildlife impacts. A number of respondents from conservation nonprofits stated that no effective practices are currently available, while some members of the industry stated that current practices are effective at siting based on wildlife impacts. Respondents agreed that the degree to which state and local authorities have control over solar siting decisions varies markedly from state to state, creating inconsistencies in the way wildlife impact assessments are performed throughout the country. Respondents from all sectors agreed that developers' initial siting decisions are primarily based on the economic feasibility of a project, considering factors such as land availability and suitability, transmission availability, and energy demand, and that wildlife and habitat issues tend to be taken into consideration later in the siting process. Some respondents indicated that this approach leads to wildlife concerns being primarily addressed through mitigation options for sites that have already been selected.

Respondents agreed that the most common process for assessing adverse impacts to wildlife from solar development is compliance with federal statutes that protect sensitive species and their habitat. These federal laws include the Endangered Species Act (ESA), Bald and Golden Eagle Protection Act (BGEPA), and National Environmental Policy Act (NEPA). Conservation nonprofits and state and federal agencies indicated that this process is more rigorous and common on public land than it is on private land. Respondents from all sectors also noted that compliance with the relevant state wildlife and habitat preservation laws, including state endangered species acts and wetland conservation laws, is another process through which impacts to wildlife are assessed. Several conservation nonprofits indicated that more rigorous federal and state statutes to protect wildlife and native habitat from solar development are needed. Some state agencies and conservation nonprofits also indicated that they rely on participation in state public utility commission hearings to articulate impacts on wildlife and wildlife habitat and that the effectiveness of this process varies significantly between states.

Some research institutions, state and federal agencies, and conservation nonprofits encouraged the development of landscape-level planning tools that inventory land surface condition based on natural habitats, degree of disturbance and fragmentation, species status and trends, and energy transmission infrastructure, primarily through Geospatial Information System (GIS) techniques.

These strategies could be used to guide solar siting decisions through the development of zoning laws or to incentivize developers through the identification of low-impact sites with additional tax credits or a fast-tracked permitting process. These landscape-level planning tools are being developed by federal, state, and local government agencies; researchers; and conservation nonprofits, with respondents characterizing varying degrees of success in their applications. See Appendix C for a list of planning resources shared in response to this RFI. Some industry respondents noted that these types of “top-down” siting tools have not been effective in streamlining solar siting decisions because they were developed by entities that lack sufficient technical background in the solar development process to capture pivotal industry considerations, such as transmission capacity, distance from high voltage lines, land availability, competing land uses, and market pressures.

Respondents from all sectors noted the use of voluntary guidelines to consider wildlife impacts during siting decisions. A number of states have developed state-specific solar siting guidelines, some of which are listed in Appendix C. These guidelines provide developers with state-specific wildlife considerations that are likely to come up during the permitting process and frequently point to other resources that provide more detailed information on wildlife and wildlife habitat, such as State Wildlife Action Plans and species-specific guidance documents. In the absence of solar-specific state guidance, the U.S. Land-Based Wind Energy Guidelines are sometimes used as a general framework for navigating the solar siting process.

Conservation nonprofits recommended broader siting strategies, including encouraging siting in low-impact areas rather than discouraging siting in high-impact areas; prioritizing and incentivizing solar siting on previously disturbed lands, brownfields, and non-traditional sites; and engaging and including all relevant stakeholders early in and throughout the siting process.

Q1.3: Can non-traditional siting strategies (e.g., agrivoltaics) or sites (floating photovoltaics or contaminated lands) help reduce impacts or increase benefits for wildlife or habitat?

Respondents generally agreed that implementing non-traditional siting strategies and selecting non-traditional sites can help reduce the adverse impacts of utility-scale solar energy on wildlife by reducing the total amount of high-quality wildlife habitat required for solar development. Most respondents noted, however, that additional research is needed to better understand the interactions between wildlife and these non-traditional siting strategies and sites (see Question 1.4 for research needs). Similarly, respondents from all sectors noted that an improved understanding of the economic and social factors associated with these non-traditional strategies needs to occur to maximize benefits to wildlife and enable comprehensive tradeoff analyses. Achieving increased benefits to wildlife from non-traditional siting also requires that research, guidance, and analytical tools be disseminated and available to all stakeholders involved in the siting process.

Respondents pointed out that facilities developed using non-traditional strategies still face a lot of the same wildlife challenges faced by traditional PV development (further detailed in Question 1.1, Question 4.2, and Appendix A), including concerns about collisions with solar energy infrastructure. The value in implementing non-traditional siting strategies is largely dependent on the habitat type and condition of the site selected, as well as the context of the site within the larger landscape. A common theme posed by respondents was the need to approach siting decisions at non-traditional sites on a case-by-case basis by considering the history of the site and the quality of the present habitat.

Non-traditional sites can help to overcome land use issues typically associated with utility-scale solar energy development by taking advantage of land with relatively low value to wildlife. However, many industry respondents cautioned that these non-traditional strategies can also pose non-wildlife challenges that frequently diminish the economic feasibility of a project due to higher costs associated with increased liability concerns, enhanced due diligence activities, additional construction costs, and impediments on interconnection. Some industry respondents suggested that non-traditional sites may be more feasible in the context of distributed resources and smaller-scale (less than 10 MW) projects. Respondents from the solar industry and from research institutions also noted that non-traditional strategies, like agrivoltaics, have the potential to present unintended and unforeseen impacts to wildlife by attracting and exposing them to pesticides or herbicides commonly used in agricultural settings. Further research is needed to understand the implications of introducing animals or crops in the vicinity of utility-scale solar equipment and to address the associated safety, financial, and energy reliability concerns.

Q1.4: What questions related to wildlife at non-traditional sites still need further research?

Respondents from all sectors expressed a need to improve the understanding of how wildlife responds and interacts with solar facilities developed at non-traditional sites. Outstanding questions include how these wildlife interactions compare to traditional sites, whether non-traditional sites are more favorable for certain species or taxa, how these sites influence the health of adjacent wildlife communities and ecosystems, and the likelihood of creating population sinks by attracting wildlife and exposing them to other risks, such as pesticides. A common theme was the need to consider how adverse impacts and benefits from non-traditional siting change as the scale and density of these facilities increases across the landscape.

Respondents highlighted the need for research into methods that support stakeholders to identify and develop non-traditional sites more efficiently. Conservation nonprofit respondents encouraged the use of geospatial analysis tools to identify non-traditional sites that have high solar resources and are located near transmission infrastructure. Research is also needed into strategies for managing non-traditional solar sites so that the land can be more easily reclaimed for other uses after decommissioning. Some industry respondents highlighted the need for comprehensive tradeoff analyses that consider impacts to wildlife along with other economic and social pressures relevant to development decisions.

On agrivoltaics, respondents expressed interest in research that helps identify farming practices best suited for co-location with solar PV, examines ways to improve array design to maximize agricultural and energy outputs, and enables the evaluation of different vegetation management strategies. Respondents also identified the need for research to assess the efficacy of pollinator-friendly scorecards, improve understanding of how long pollinator habitat takes to be established and how it changes over time, and develop methods to monitor the health of invertebrate communities. The need to develop tools that help stakeholders assess agrivoltaics compatibility and identify resources for technical support when managing agrivoltaics systems was also noted.

Respondents also pointed to the use of floating PV and the development of PV on mines as potential siting strategies. However, research on the impact of floating PV on water quality, aquatic biodiversity, and wildlife interactions is needed. For mine lands, interactions with bats and how solar infrastructure could impact hibernacula (areas where animals shelter during hibernation) needs research.

Respondents noted that wildlife issues at traditional utility-scale solar facilities are still relevant at non-traditional sites. Additional research is necessary to understand wildlife interactions with solar energy infrastructure and whether there is a lake effect that attracts aquatic birds to solar facilities; assess a site's location in the context of migratory bird pathways; improve design, management, and ecological restoration strategies; manage the influence on water and soil quality; and monitor long-term and cumulative impacts, among other factors (further detailed in Question 1.1, Question 4.2, and Appendix A).

Category 2: Species and Habitat Impacts

Q2.1: What species of concern, taxa, or significant natural communities are the most impacted by solar PV development in your geographic areas of interest? Why?

To see the list of species of concern, taxa, or significant natural communities identified in the RFI responses as potentially impacted by solar energy development, see Appendix B. The following summary will focus on broader species impacts and themes that emerged in the responses.

In general, responses on species of concern fell into five broad categories:

- Avian species that migrate, nest, or forage in and around solar sites;
- Ungulates with solar sites in their geographic ranges;
- Small mammals and reptiles that burrow in or around solar sites;
- Aquatic species that are highly dependent on water quality; and
- Pollinators that can interact with the vegetation at a solar site.

The potential impacts of solar development on species were described by respondents as habitat loss, habitat fragmentation, habitat degradation, and collision risk. Some conservation nonprofits, government agencies, and research institutions raised concerns that the congregation of solar development along transmission lines, in combination with other forms of development, pose a risk of cumulative and population-level impacts to species.

Many respondents identified collision risk for avian species that migrate, nest, or forage in or around solar sites. The "lake effect" hypothesis was identified by conservation nonprofit and state agency respondents as a potential mechanistic driver for avian collisions at solar facilities. This hypothesis proposes that birds are attracted to and collide with PV solar panels because they resemble large water bodies, potentially causing fatalities from collision or stranding for water-obligate birds that cannot takeoff from land.

Ungulates were identified as being vulnerable to habitat fragmentation because of their large geographic ranges. Large-scale solar developments can occupy thousands of acres of land with fencing around the perimeter of the site, creating obstacles that physically prevent ungulates from passing through the area and potentially isolating subpopulations or significantly altering the home range of individuals. Some conservation nonprofits and researchers identified a need for research on the impact of fencing on the migratory pathways of ungulates. Disruptions to ungulate ranges can have additional impacts in states where ungulates provide significant recreation and economic benefits.

Small burrowing reptiles and mammals are vulnerable to potential fatalities from vehicle collisions and damage to burrows from heavy machinery. Tortoises were a commonly raised taxa of concern. To avoid adverse impacts from solar development, tortoises are often translocated outside of the solar site. A need for more research to determine the long-term success of translocation practices, especially for long-lived species like tortoises, was identified.

Some aquatic species, like mussels, are sensitive to water quality changes. Federal agencies and research institutions identified a potential risk to these species if nearby solar facilities increase sediment runoff to aquatic ecosystems. Industry respondents indicated that there is a potential for positive impacts on aquatic ecosystems when a solar facility replaces agricultural land and reduces the amount of herbicide or fertilizer runoff from that site.

Research institutions, consulting groups, conservation nonprofits, and solar industry organizations identified pollinators as a species group of interest, particularly in the Midwest. Solar industry respondents indicated that replacing row crops with perennial ground cover beneath panels may be beneficial to pollinators but cautioned that additional research is necessary because attracting pollinators to solar facilities may have unintended consequences. Consulting groups and research institutions highlighted the importance of understanding species composition prior to development because the presence of endangered pollinator species may influence siting and vegetation management decisions. One consulting group supported a regulatory framework for endangered pollinators, like the rusty patched bumblebee, that would encourage developers to create pollinator habitat without risk of later regulatory enforcement.

The natural communities identified by respondents as most impacted by solar PV development included deserts, grasslands, forests, and wetlands. Some environmental and conservation nonprofits, federal agencies, and research institutions identified desert Southwest habitats as particularly impacted by solar development, especially in the Mojave and Sonoran deserts. These lowland desert habitats are flat and receive abundant sunlight, making them prime locations for solar development. However, desert ecosystems contain native vegetation communities and rare plants that are difficult to replace or restore. Some research institutions stated that the potential impact of solar development in the desert Southwest may be overemphasized and that more research is required to understand impacts on a region-by-region basis. Native grasslands and prairies, which also tend to be suitable for solar development, are already highly fragmented by other types of development. Some conservation nonprofits pointed to increasing deforestation for solar development in some areas of the US, particularly in the East. Conservation nonprofits, state and federal agencies, and research institutions also identified potential adverse water quality impacts from solar facilities for nearby wetland habitats, particularly the possibility for siltation, pollution, and sedimentation. To avoid these water impacts and protect karst features (landscapes formed when bedrock is dissolved, e.g., sinkholes, caves, etc.), state agencies and research institutions recommended that solar be developed outside of buffer zones.

Overall, respondents concluded that more research needs to be done to evaluate potential impacts on species or habitats of concern in different regions. According to some research institution and solar industry respondents, the species or taxa most impacted by solar development are currently unknown and only inferences can be made on those most likely to be impacted. Some research institutions and state agencies identified traits of species of concern: species that are endemic to a specific region or habitat, are threatened by climate change, or have high genomic variations from poor population dispersal capabilities. These traits should inform future research on solar-wildlife interactions. Some solar industry stakeholders and research institutions also expressed a need to understand how solar differs from other forms of development and what lessons can be learned from other land use changes.

Q2.2: What types of data are being collected on the impact of solar development on particular species, taxa, or habitat? By whom?

See Appendix C for a list of the data sources, tools, and other resources on solar energy and wildlife provided by RFI respondents. This summary will focus on broader takeaways on data collection.

Many respondents from government agencies, researchers, and conservation nonprofits indicated that very few studies or data exist on solar energy's impact on wildlife or habitats. Some state and local agencies were not aware of any wildlife or habitat data currently being collected at solar sites in their state. Some conservation nonprofits and solar industry stakeholders pointed out that wildlife data collection usually only occurs when it is required. Data on species that are listed under the Endangered Species Act (ESA) are most common. Some developers also conduct pre-construction surveys and post-construction fatality monitoring as part of the permitting or mitigation requirements for a project. These data are usually gathered by the solar developer and then submitted to the relevant state agency, but they are not readily available to the public. Data collection at solar projects located on private land is less common than on public land. Research institutions suggested that future research projects should look to link or leverage existing data sources where possible.

Some research projects and data collection efforts on solar-wildlife interactions have been undertaken or are ongoing. Respondents indicated that previous and current research projects have included mapping solar sites, monitoring avian mortality, camera monitoring of wildlife, evaluating pollinator impacts, studying tortoise translocation, and collecting data on soil and plant responses to solar facilities. Efforts to map solar sites have been paired with the development of other relevant data layers on habitat and species presence to help inform siting decisions. Much of the existing avian impact data comes from fatality monitoring of dead, injured, or stranded birds at solar sites. Some conservation nonprofits and federal agencies identified a need for a coordinated system of data collection for avian fatality monitoring, similar to the comprehensive database that exists for wind energy.

Q2.3: Do you have access to data you would be willing to share on solar development impacts and benefits?

Specific data sets, tools, and resources on solar energy and wildlife identified by RFI respondents are listed in Appendix C. This summary will focus on the broader responses to data sharing.

Stakeholders provided a range of responses on whether they had access to data. A general theme was that data access and availability varies dramatically. Many conservation nonprofits, federal agencies, and research institution respondents who have data indicated that they would be willing to share them. However, some respondents indicated they are willing only to share data that has already been published through peer review outlets or has been collected through a SETO-funded awards, or that the research is still in its infancy and data will not be ready for a few years. Some state and local agencies stated that they do not have data to share or that they were unaware of any solar-wildlife data collected in their state. Some conservation nonprofits supported a requirement that environmental data collected by solar developers and submitted to permitting or wildlife agencies be publicly released. However, some industry stakeholders stated that any data-sharing from developers to state or local agencies should be done on a voluntary basis and should include the appropriate protections for confidential business information.

Q2.4: What species and habitat benefits can solar PV development provide?

What research is needed to better understand these benefits?

Do regulators take these benefits into account in the permitting processes? If so, how? If not, why not?

How should ecosystem services, like pollination, biological diversity, carbon sequestration, or erosion control, be considered in solar development?

Respondents agreed that solar energy reduces overall carbon emissions to mitigate the impact of climate change on humans and wildlife. Some conservation nonprofit and federal agency stakeholders, however, stated that they have not observed any direct benefits to species from solar development. Pollination was mentioned most often by stakeholders as a benefit when solar development is co-located with pollinator habitat. However, these benefits are not fully understood due to the novelty of solar-pollinator co-location. Some solar industry, conservation nonprofits, federal agencies, and research institutions stated that solar development on disturbed land with native vegetation could result in net benefit to wildlife and habitats. Research institutions, solar industry, and conservation nonprofits also indicated that solar could provide habitat benefits or co-location opportunities on agricultural land.

Many stakeholders agreed that benefits to wildlife require further research before they can inform solar siting decisions. Research needs identified by stakeholders to better understand the species and habitat benefits of solar energy are listed in Table 1 below. Research needs identified by respondents to all questions in the RFI are listed in Appendix A. The species types most often identified for further research were pollinators, birds, and insects.

Species and Habitat Impacts	**Vegetation Impacts**	**Ecosystem Service Impacts**	**Siting Best Practices**
• Species abundance and diversity at solar sites • Species use of or movements through solar sites • Species impacts at solar sites considering the broader implications of climate change • Solar impacts on habitat connectivity	• Solar energy's impact on vegetation and soils • Target pollinator species for solar sites • The effectiveness of different vegetation management practices	• The quantification of ecosystem services, including the benefits gained and adverse effects of modifying the original habitat • Project economics when including ecosystem services or other species or wildlife benefits	• Siting guidance or best management practices to inform low-impact solar siting decisions • Baselining of site conditions at the beginning of solar development • The cumulative impacts of solar development

Table 1. Topic areas identified by respondents for further research to better understand the species and habitat benefits of solar energy.

Many respondents indicated that regulators do not account for habitat or species benefits from solar facilities in the permitting process. Pollinator scorecards are one tool that has been used in some states to account for benefits in the permitting process. Industry stakeholders cautioned that pollinator scorecards are not a one-size-fits-all approach to vegetation management and raised concerns about impacts to project economics when planting requirements are introduced.

Respondents from multiple stakeholder groups supported the consideration of ecosystem services during solar development to enable a more holistic assessment of benefits and adverse impacts to wildlife, but respondents recognized that assessing ecosystem services is a process that could take multiple years. It was recommended that quantification of ecosystem service metrics from solar facilities should be standardized across the U.S., which could help developers promote the benefits of their sites and gain public support, as well as enable state or local regulators to develop incentives for ecosystem services.

Potential ecosystem service benefits identified at solar sites include carbon sequestration, erosion control, stormwater management, pollination, and groundwater filtration and recharge. Soil health and native vegetation were identified as in need of further research. Perennials were mentioned by many respondents as one of the more beneficial vegetation types for soil health. Some researchers cautioned that ecosystem services should be carefully weighed against other environmental factors, like the presence of rare or protected species.

Respondents were cautious about how to address and support potential wildlife or habitat benefits from solar deployment. Respondents from the solar industry and a research institution were concerned about uncertain costs and regulations, for example from with pollinator scorecard regulations. At the same time, some conservation nonprofits and research institutions expressed concern about overemphasizing benefits that solar may provide to species and habitats. Some researchers contended that solar development could create habitats through vegetation restoration or microclimates beneath panels and could preserve habitats that would have otherwise gone to other forms of development. Many industry stakeholders pointed out that solar development can displace other forms of high-impact energy production. Respondents across stakeholder groups indicated that measures should be taken to ensure impacts are minimized and that further research on the benefits or impacts of solar energy on species and habitats is required.

Category 3: Avoidance, Mitigation, and Monitoring

Q3.1: What approaches or tools are used to avoid impacts on wildlife before a site is selected for solar development?

Many respondents emphasized that avoiding impacts prior to the development of a site, through site selection, is the most effective way to reduce impacts. Respondents from all stakeholder groups indicated that the primary driver of site selection at this time is not wildlife concerns. Ultimately, site selection is driven by access to transmission lines, availability of land for lease or purchase, and proximity to load centers. Some conservation nonprofit respondents expressed a concern that developers are focusing on mitigating adverse impacts that could be avoided with better site selection. In addition, site-by-site evaluation makes it harder to address landscape-level concerns, such as habitat fragmentation. Some respondents from the research community suggested that incorporating economic viability into site screening tools or providing policy support (streamlined permitting, tariff incentives) for development in low-impact areas could help address this conflict.

Some government, conservation nonprofit, and research institution respondents pointed to key types of land that could minimize wildlife impacts if avoided. Critical habitat for threatened and endangered species are known and a key focus of existing siting tools provided by government agencies and conservation nonprofits. Other types of land identified as sensitive included forests, wetlands, and previously undisturbed lands. One respondent also noted that engagement with Native American tribes should be conducted to ensure that sites of cultural significance or important for traditional forms of subsistence are not disturbed.

Respondents in all categories noted that species listed under the Endangered Species Act (ESA) are the primary focus for regulatory compliance during the siting process. In addition, construction on public lands, whether federal or state, triggers review under the National Environmental Protection Act (NEPA) as well as similar laws at the state level. Outside of ESA requirements, engagement with state and federal agencies is largely informal and relies on developers coordinating with the relevant regulators, which industry respondents indicated is common. Some state wildlife agencies stated that while they do not have a legal role in the approval of a solar site, early engagement in the siting process allows them to provide optimal input. Calls for early engagement were also echoed by some conservation groups.

Some respondents from government agencies, academia, and non-profits observed that because solar siting is not primarily driven by wildlife impacts, the result of pre-construction analysis is not likely to be the relocation of a project but instead the determination of mitigation measures. Once the wildlife and habitat sensitivities of a particular site are understood, which may require long-term survey and observation (especially to account for avian migration patterns), mitigation measures can be planned based on state or federal species-specific guidelines. Mitigation strategies mentioned by respondents include the use of native vegetation and habitat buffer zones.

All stakeholder groups gave examples of tools that provide maps of habitat and species, many of which are specific to a state or region (See Appendix C for a list of resources that were identified by respondents to this RFI).

Q3.2: What mitigation measures can be employed to minimize impacts of solar PV development to species and natural communities in the states or regions in which you work?

Responses to this question were quite uniform across stakeholder groups, reflecting a common understanding of what measures are currently available for impact minimization at solar PV sites. Some industry respondents cautioned, however, that mitigation measures should be deployed based on needs at the specific site, and developed in coordination with local, state, and federal agencies. Several respondents from state governments, research institutions, and non-profit groups noted that the best way to minimize impacts is to avoid them altogether, such as by using previously disturbed areas. However, for impacts that cannot be avoided, common themes on minimization measures emerged.

Some respondents from both government agencies and industry stressed the importance of coordination prior to beginning construction at a site. Some research community respondents stressed that minimization efforts are easier and cheaper to implement during development and construction than as a retrofit. However, according to multiple respondents, the link between minimization measures and biodiversity outcomes is not clear, and more data and study is needed to establish best practices in this area.

Multiple conservation nonprofit respondents pointed to the possibility of using "micro-siting" techniques to ensure that solar development avoids sensitive areas, such as streams or wetlands, on a property. One agency noted that minimizing the footprint of the solar plant itself can minimize impacts. Two potential changes to construction processes identified by respondents were undergrounding electrical wires and avoiding erosion and compaction of soil by implementing low-impact construction methods. One of the most common minimization methods discussed by respondents in all categories is the use of wildlife-friendly fencing. Small and medium animals can access the site with only 4-6 inches of clearance at the bottom of fencing. Including openings in fences and promoting species mobility through habitat corridors was a commonly mentioned way of reducing the wildlife impacts of solar development. Some industry and conservation nonprofit respondents identified the potential to avoid activity that disturbs vulnerable species during critical seasons, such as reproductive periods.

Another common theme in the responses was the responsible use of vegetation. Respondents in all categories noted that native vegetation can be used to reduce habitat impacts of solar facilities. Vegetation choices can preserve habitat as well as provide support for pollinators and assist with the infiltration of stormwater. Many respondents also pointed to vegetation management practices that minimize the use of herbicide and mowing as a positive for wildlife.

Many respondents stressed the need for more research and continued monitoring of solar sites in order to establish the efficacy of minimization and mitigation measures. In addition, one respondent noted the need to develop a workforce that has the necessary expertise to identify and solve problems in solar-wildlife interactions.

Q3.3: How much onsite monitoring of species is conducted prior to construction? Post-construction? Is this monitoring voluntary or required? To what degree does before-after-control-impact (BACI) study data exist for solar energy sites?

Overall, onsite monitoring is limited and highly variable between jurisdictions. California was identified as having the strongest requirements for onsite monitoring, both pre- and post-construction, while other states have fewer requirements. In all states, private land has fewer requirements than public land. The drivers of monitoring are permitting processes; both federal and industry respondents underlined that monitoring is largely driven by the need to comply with regulations. Some conservation nonprofit respondents emphasized that there was no one-size-fits-all approach to monitoring requirement and that it should be highly dependent on region, biome, and the specific site.

Pre-construction monitoring is focused on initial screening for the presence of sensitive species and vulnerable habitats. As an example, several respondents mentioned the need to identify whether any construction would impact nearby wetlands. Pre-construction monitoring generally takes place between one and three years prior to construction, when it occurs. re-construction monitoring is undertaken by some solar developers following the U.S. Fish and Wildlife Service's Land-Based Wind Energy Guidelines, which provide guidance for site selection for wind energy.

Post-construction monitoring is rarer than pre-construction monitoring; many respondents indicated it is commonly required in California. Where post-construction monitoring does occur, it is usually triggered by some characteristic of the site, such as wetlands or an incidental take permit. Industry respondents highlighted that their post-construction monitoring is guided by agency input, but that these activities are quite expensive. Some state agencies indicated that they often recommend post-construction monitoring but that this recommendation is not binding and is rarely implemented by developers.

No respondents indicated that they were aware of any existing BACI research results. The U.S. Geological Survey is currently conducting BACI research at some sites to identify impacts for birds, bats, and migratory ungulates, a study pointed out by a few respondents as promising. Some research institutions indicated that BACI is beyond the scope of existing monitoring activities, and some conservation nonprofit and federal respondents pointed out that current monitoring techniques are generally not paired with an experimental design, which limits their scientific usefulness. Some research community respondents noted that the long and variable timelines for BACI studies make them difficult to fund, and that data-gathering methods are expensive. Respondents in all categories indicated that BACI data would be highly useful to evaluate solar impacts on wildlife and the effectiveness of mitigation measures.

Category 4: Resources Needed

Q4.1: What resources, such as best practices, guidelines, or tools, would make it easier to select and encourage lower-impact sites for solar development? What are the limits, if any, of existing tools, and how could they be improved or modified?

Respondents described a number of best practices, guidelines, and tools that would be helpful for the siting of solar energy. See Appendix C for a list of the resources, tools and references provided by respondents.

Some industry respondents pointed out that site selection for solar facilities is highly constrained by economics, which pushes development to sites with high solar resource, access to transmission lines, and low interconnection costs; these limitations will have to be accounted for if new practices, guidelines, or tools are to be impactful. Some conservation nonprofit respondents noted that identifying sites is only part of the problem for encouraging development, and that some type of incentive for private landowners in the form of time (e.g., expedited permitting) or money (e.g., tax incentive) may be required to realize those developments.

Mapping tools were one of the most common types of resource that respondents mentioned both as an existing resource and a desired one. However, it was widely agreed that current mapping tools fail to consider various aspects of the solar siting problem, which limits their effectiveness. Some industry respondents pointed out that many solar siting maps do not properly reflect the challenges of access to transmission or topographical constraints (such as slopes) that limit the deployment of solar energy. Some state agencies noted that maps do not always make fine distinctions between types of habitats that might be important in evaluating the impacts of solar energy. California's Desert Renewable Energy Conservation Plan was mentioned by some nonprofits and state agencies as an admirably comprehensive effort, but one respondent cautioned that it was limited by its high-level, top-down nature, and another expressed concern that the plan may not be followed in practice.

Scale was a common concern: respondents from conservation nonprofit, research, and federal sectors all pointed out a need for comprehensive, landscape-level planning tools that would permit agencies to use maps across their entire jurisdictions, extending even to the national level. "Landscape-level" planning tools, as some conservation nonprofit respondents described them, would reflect farmland and wildlife corridors. An industry respondent indicated the need to account for current land-uses as well. A research institute respondent noted that maps need to account for the full wildlife picture and not become overly focused on one species, but some industry respondents and researchers emphasized that it is the need to account particularly for endangered or threatened species that drives much of wildlife impact management.

Other respondents, by contrast, emphasized the usefulness of maps that were specific, rather than all-encompassing. For instance, one conservation nonprofit respondent indicated a need for maps that are specific to the solar industry and that addresses the needs of the solar industry. A respondent from a research institute suggested that these maps would also benefit from collaboration with local governments to build a data layer that allows local ordinances to be easily visualized. Another respondent from the research community pointed out that maps tend to pile on data layers, which makes it hard to prioritize, and suggested that state or federal agencies that are providing maps ought to find ways to call out priorities in siting policy. One stakeholder indicated the need for simple tools that could perform initial screenings.

Several research institution respondents wrote about the possibility of building models that would optimize the siting of solar energy. These models would identify the “best” sites for solar energy to be sited, taking into account wildlife as well as human dimensions, such as current land use, property ownership, the location of grid infrastructure, and brownfield locations. These tools could allow alternative sites and site designs to be compared and evaluated.

Many respondents suggested that some type of guidance or best management practices (BMPs) would be useful to the solar industry. While some respondents emphasized the need for national uniformity, other respondents mentioned the need for BMPs to be flexible enough to be adaptable to different regions and reflect local ecosystems. A respondent from a state agency expressed interest in guidance that synthesized the experiences from states that are relatively early solar adopters. Nonprofit, research institute, and state agency respondents all emphasized that guidelines are needed for regulators and decisionmakers on how good siting practices can be incentivized, along with guidelines on how to evaluate new technologies. One research community respondent emphasized that guidance should be built to have significant input from local experts and include a full range of ecosystem impacts. In terms of specific areas where guidance is needed, respondents identified stormwater management, soil decompaction, pre-/post-construction monitoring, and fencing.

Many respondents from federal, conservation nonprofit, and research institutes also emphasized the continuing need for basic research to be conducted to enable the types of tools discussed in these responses. Some conservation nonprofit respondents identified a need for metrics to assess impacts (e.g., soil impacts at solar-pollinator sites) and demonstration sites for new practices, a need that was echoed by a respondent from a research institution. Another researcher noted that, as these tools are developed, they can be folded into the existing suite of tools that SETO funds and maintains, such as reV or the System Advisor Model (SAM).

Whatever tools are created, industry and research institution respondents stressed that the tools need to be trusted by the solar industry and accepted by regulators, such as the U.S. Fish and Wildlife Service. Some industry respondents stressed that, to be useful, tools must be consistent with each other, provide uniform guidance, and paired with outreach and knowledge transfer mechanisms to ensure that low-impact solar development methods are publicized and used.

Some respondents from the research community pointed out that tools need to be accessible to all audiences, including the solar industry, scientific communities, and the public.

Q4.2: What are the most important unanswered questions about the impacts on and benefits to wildlife from solar development?

Many questions concerning how solar energy impacts wildlife and ecosystems are unanswered. Respondents suggested a number of questions that need to be addressed by the sector as solar energy expands in the next few years.

One broad category of questions involves determining the impacts of current practices.

- What are the habitat and population impacts of solar energy development, and how can habitat and population impacts be rigorously linked?
- Which species are most vulnerable to these impacts?
- How are animals (of many types) interacting with existing facilities, including new forms of development, such as pollinator habitat or floating PV, and how can these interactions be monitored cost-effectively?
- How do these impacts vary seasonally, and how can they be compared with the overall climate benefits of renewable energy?

Some conservation groups and federal agencies stressed a need to expand the scope of wildlife impact assessment to include supporting infrastructure, such as roads and transmission.

Several respondents posed questions relating to broader land-use questions. For example, some industry respondents pointed out that converting previously developed land to grassland beneath solar panels may be a net habitat benefit. Respondents from all stakeholder groups indicated the need to benchmark solar against other past and future land uses. In addition, many respondents were interested in questions relating to soil health at solar facilities and possible carbon impacts, especially in comparison to pre-existing land cover types such as forest or agricultural land. Multiple respondents expressed interest in solar scenario planning to understand better what overall impacts might look like in net zero or decarbonization scenarios, questions that were often paired with interest in better understanding overall impacts of habitat fragmentation and whether there are effective ways to avoid habitat fragmentation. A few respondents pointed out the need to build a bridge between regionally specific wildlife studies and broader, more generalizable results.

Many other questions were focused on the practical aspects of site selection and design. In particular, the costs and benefits of vegetation options need to be better understood, as well as how the choice of vegetation cover affects wildlife outcomes, costs, and operations at a solar facility. Native vegetation could potentially improve stormwater management, but some respondents expressed concern that the use of grassland vegetation could lead to wildfire risk. As pollinator-friendly solar has become more popular, some respondents pointed out the need to understand the cost and value of different seed mix choices and the impacts of pollinator habitat on the operation of solar facilities. The costs and benefits of various fencing configurations were also identified as an area of interest.

Respondents identified a need to understand how optimal sites can be selected and factored into techno-economic tradeoffs to allow solar to be co-developed alongside the conservation of high-value land. State and conservation nonprofit respondents expressed interest in the possibility of disseminating success stories and examples of good land-use practices. Many respondents indicated that the net impacts of alternative site selection or design practices are simply not well-understood at this time, and that finding effective, validated ways to reduce impacts to wildlife and habitat remains an active problem.

Appendix A: Solar-Wildlife Research Needs Identified by Respondents

Below is a compilation of the solar-wildlife research areas identified by RFI respondents as requiring further investigation.

Note: The Department of Energy (DOE) is not communicating an opinion or viewpoint about any of the research areas below, nor is this list intended to be an exhaustive list. DOE is publishing this summary so that the public may benefit from the information.

- **Climate change mitigation.** Solar energy development benefits wildlife by mitigating climate change, which is a major threat to wildlife and wildlife habitat. Research areas of interest include:
    - The development of metrics that accurately quantify the climate change mitigation potential of individual solar facilities and processes that apply those metrics to assess tradeoffs between the benefits and adverse impacts of solar facilities.
    - The behavioral, physiological, and population-level impacts of climate change on wildlife, which could in turn alter how wildlife interacts with solar energy facilities.
    - The efficacy of applying models that project changes in habitat and species ranges to inform siting decisions.
- **Habitat changes.** The surface area required for utility-scale solar development to help meet decarbonization goals will require some level of habitat loss, habitat fragmentation, and changes in land use. Research areas of interest include:
    - A comparison of the extent of habitat loss caused by solar energy to habitat loss caused by other sources of energy and other forms of land use.
    - A better understanding of how individual species respond to habitat loss and fragmentation from solar energy development and the identification of associated population-level impacts (see Appendix B and Question 2.1 for full list of species of interest identified by respondents).
    - The extent to which habitat loss and fragmentation from solar development has already occurred and its impacts on habitat connectivity.
    - The efficacy of wildlife corridors and wildlife-friendly fencing in mitigating adverse impacts from habitat loss and fragmentation.

- The identification of appropriate buffer distances from sensitive habitats to avoid or minimize adverse impacts from solar development.
- A better understanding of how solar development could benefit the surrounding ecosystem by replacing other harmful land use practices.

- **On-site plant and animal habitat.** Solar energy facilities can implement strategies to manage on-site habitat for the benefit of native wildlife communities (e.g., seeding with native plants). Research areas of interest include:
    - The development of standardized methods to assess the efficacy of vegetation management strategies in improving the health of plant and wildlife communities on-site. Enabling comparisons with pre-construction conditions and neighboring areas.
    - An evaluation of how the efficacy of vegetation management strategies vary with the scale of solar projects and with proximity to other projects.
    - The potential for vegetation management strategies to enhance the carbon sequestration capabilities of a solar site.
    - A better understanding of the unintended consequences of managing onsite habitat for wildlife species (e.g., potential for habitat sinks).
    - The quantification of species abundance, species diversity, and movement of wildlife at solar sites.
- **Construction impacts**. The development of utility-scale solar projects, as is the case with all forms of development, commonly involves the removal and movement of native vegetation and soils during construction. Research areas of interest include:
    - The development of best management practices for mitigating adverse impacts during construction (e.g., erosion control) and decommissioning.
    - The development of soil management strategies to maximize benefits to native wildlife (e.g., carbon sequestration, healthy microbial community).
    - A better understanding of how solar energy development alters soil attributes (e.g., water carrying capacity, microbial activity, carbon sequestration, etc.) and biological soil crusts.
    - A better understanding of how best to mitigate the adverse impacts from nuisance and invasive species at solar energy facilities.

- **Collisions with supporting infrastructure**. The various structures needed to operate a solar energy facility (e.g., PV panels, overhead transmission lines, CSP towers) have the potential to pose a collision risk to wildlife, which may lead to injuries or fatalities. Research areas of interest include:
    - A better understanding of the elements/structures in solar facilities and the surrounding land cover types most associated with increased collision risk, and how those trends vary among regions.
    - The development of standardized methods for monitoring wildlife activity and estimating background and post-construction wildlife mortality rates.
    - The identification of wildlife species that experience high levels of collision risk.
    - A comparison of wildlife mortality rates at operating solar facilities to that of other forms of energy production and land use practices.
    - A better understanding of the biological and ecological mechanisms that cause wildlife to collide with solar energy infrastructure, as well as the role of solar energy facilities in altering wildlife behavior.
    - The accuracy of the "lake effect" hypothesis and the mechanisms that may cause it.
    - The development of minimization strategies (e.g., deterrents) that can be effectively implemented at operating solar facilities to reduce collision risk.
- **Stormwater impacts**. The development of solar energy facilities has the potential to alter stormwater infiltration and runoff for the surrounding area. Research areas of interest include:
    - A better understanding of the mechanisms through which solar energy facilities alter water quality in downstream aquatic and wetland habitats, and the implications for wildlife species that inhabit those areas.
    - The development of strategies to minimize impacts from stormwater runoff on aquatic habitats.
    - A comparison of impacts to nearby water resources between solar energy facilities and other forms of development.
- **Ecosystem services**. Solar energy production, and the management strategies employed at solar energy facilities, have the potential to provide ecosystem services to nearby communities. Research areas of interest include:

- The application of standardized methods and use of empirical data to quantify ecosystem services provided by solar energy facilities, including methods to compare between different habitat management strategies, site designs, and locations.
- A better understanding of the economic value of the ecosystem services provided by solar energy facilities.

- **Microclimates**. The infrastructure associated with solar energy facilities has the potential to create microclimates by altering the distribution of sunlight and waterflow. Research areas of interest include:
  - The development of management strategies to minimize adverse impacts and maximize benefits from the creation of microclimates.
  - A better understanding of how wildlife interacts with "heat islands" and infrastructure operating at high temperatures.
- **Siting.** The process of selecting sites for the development of solar energy facilities requires the careful consideration of many environmental and non-environmental issues. Siting decisions are directly linked to the environmental benefits and adverse impacts of solar facilities. Research areas of interest include:
  - The collaborative development of siting guidance, best management practices, and tools to inform low-impact solar siting decisions at small and large scales.
  - The development of methods to assess baseline conditions at a solar facility prior to solar development.
- **Non-traditional siting**. Implementing non-traditional siting strategies (e.g., agrivoltaics) and selecting non-traditional sites (floating photovoltaics or contaminated lands) can help reduce the adverse impacts of utility-scale solar energy on wildlife by reducing the total amount of high-quality wildlife habitat required for solar development. Research areas of interest include:
  - A better understanding of the potential unintended and unforeseen consequences of attracting and exposing wildlife to solar facilities (through strategies such as agrivoltaics).
  - A comparison between wildlife interactions at non-traditional facilities and traditional facilities; a better understanding of taxa-specific benefits from non-traditional siting strategies.

- A better understanding of how non-traditional siting strategies influence the health of adjacent wildlife communities and ecosystems.
- The development of methods that enable stakeholders to identify and develop non-traditional sites more efficiently.

Appendix B: Species and Taxa Potentially Impacted by Solar Energy Development

Species and taxa that were identified by respondents to this RFI as having the potential to be impacted by solar energy development are listed in this Appendix. The list includes specific species (e.g., gopher tortoise), as well as groups of species (e.g., bats). Please see "Category 2: Species and Habitat Impacts" in the RFI summary for more context on how these species may be impacted by solar development.

Note: The Department of Energy (DOE) is not communicating an opinion or viewpoint about any of the species or taxa listed below. DOE is publishing this summary so that the public may benefit from the information.

Plant species and taxa

- Cacti
- Joshua Tree
- Longleaf Pine
- Mojave Yucca
- Threecorner Milkvetch

Animal species and taxa

- Amphibians
    - Gopher frog
    - Striped newt
- Aquatic species
    - Black creek crayfish
    - Endangered or threatened mussels
    - Fairy shrimp
    - Santa Fe cave crayfish
- Birds
    - American white pelicans

- American woodcock
- Ash-throated flycatcher
- Bald eagle
- Baird's sparrow
- Barn swallow
- Bendire's thrasher
- Black-tailed gnatcatcher
- Black-throated sparrow
- Burrowing owls
- Cactus wren
- Chestnut-collared longspurs
- Eared grebe
- Florida sandhill cranes
- Golden eagle
- Gray flycatcher
- Gray vireo
- Grasshopper sparrow
- Henslow's sparrow
- Horned larks
- LeConte's thrasher
- Lesser nighthawks
- Loggerhead shrike
- Loons
- Phalaropes
- Prairie Grouse

        - Greater Sage Grouse
        - Lesser and Greater Prairie Chickens
        - Sharp-tailed Grouse
    - Ridgway's rail
    - Scott's oriole
    - Southeastern American kestrel
    - Sprague's pipits
    - Swainson's hawk
    - Thick-billed longspurs
    - Tricolored blackbird
    - Western grebe
    - White-crowned sparrows
    - Yellow-rumped warbler
- Insects
    - Monarch butterfly
    - Rusty patched bumble bee
    - Say's spiketail dragonfly
- Mammals
    - Bats
    - Black-tailed prairie dog
    - Desert bighorn sheep
    - Desert burro deer
    - Elk
    - Florida black bear
    - Florida panther

  - Giant kangaroo rat
  - Kit foxes
  - Mohave ground squirrel
  - Mule deer
  - New England cottontail
  - Pronghorn
  - Pygmy rabbits
  - Spotted skunk
  - White-tailed jackrabbits
- Reptiles
  - Blunt-nosed leopard lizard
  - Eastern box turtle
  - Eastern diamondback rattlesnake
  - Eastern indigo snake
  - Eastern Mississauga rattlesnake
  - Flat-tailed horned lizard
  - Florida pine snake
  - Garter snake
  - Gila monster
  - Gopher tortoise
  - Mojave desert tortoise
  - Mojave fringe-toed lizard
  - Sonoran desert tortoise
  - Southern hognose snake
  - Texas tortoise

    - Western box turtle

Habitats

- Desert
    - Aeolian sands
    - Creosote-bursage communities
    - Desert wash
    - Sand flat and dunes
    - Sand transport corridors
    - Sage Steppe/High desert
- Forests and woodlands
    - Joshua Tree woodlands
    - Mesquite woodlands
    - Microphyll woodland
    - Oak woodlands
- Grasslands and prairies
- Montane
- Shrubland
    - Chaparral
    - Sandhill
- Wetlands
    - Ephemeral wetlands
    - Karst features
    - Playas
    - Riparian areas
    - Vernal pool

Appendix C: Resources and Tools

Many respondents provided references, resources, and tools related to solar energy and wildlife.

Note: The Department of Energy (DOE) is not communicating an opinion or viewpoint about any of the resources listed below. DOE is publishing this summary so that the public may benefit from the information.

Local, State, and Federal Government Resources

Name of Resource	Organization	Link
Solar PEIS Project	Argonne National Laboratory	https://solareis.anl.gov/
Energy Zone Mapping Tool	Argonne National Laboratory	https://ezmt.anl.gov/
Existing Data Sources and Ongoing Monitoring Efforts to Inform Understanding of Avian-Solar Interactions	Argonne National Laboratory	https://blmsolar.anl.gov/program/avian-solar/docs/Avian-Solar_Data_and_Monitoring_Report.pdf
Desert Renewable Energy Conservation Plan Proposed Land Use Plan Amendment and Final Environmental Impact Statement	Bureau of Land Management	https://eplanning.blm.gov/public_projects/lup/66459/20012655/250017239/Appendix_H_CMAs_Documentation_Revised_for_LUPA.pdf
Desert Renewable Energy Conservation Plan Overview	Bureau of Land Management	https://www.energy.ca.gov/sites/default/files/2019-12/DRECP_Overview_Fact_Sheet_ada.pdf
Western Solar Plan	Bureau of Land Management	https://blmsolar.anl.gov/
Desert Renewable Energy Conservation Plan Data Supporting Volumes	Bureau of Land Management	Desert Renewable Energy Conservation Plan Proposed Land Use Plan Amendment and Final Environmental Impact Statement (blm.gov)

Desert Renewable Energy Conservation Plan	California Energy Commission	https://www.energy.ca.gov/programs-and-topics/programs/desert-renewable-energy-conservation-plan
Best Management Practices for Solar Energy Development	Colorado Parks and Wildlife	https://cpw.state.co.us/Documents/Conservation-Resources/Energy-Mining/Solar-Energy-BMPs.pdf
Gopher Tortoise Permitting Guidelines	Florida Fish and Wildlife Conservation Commission	http://www.myfwc.com/license/wildlife/gopher-tortoise-permits/
Gopher Tortoise Management Plan	Florida Fish and Wildlife Conservation Commission	https://myfwc.com/wildlifehabitats/wildlife/gopher-tortoise/management-plan/
Species Conservation Measures and Permitting Guidelines	Florida Fish and Wildlife Conservation Commission	https://myfwc.com/wildlifehabitats/wildlife/species-guidelines/
Florida Wildlife Conservation Guide	Florida Fish and Wildlife Conservation Commission	https://myfwc.com/conservation/value/fwcg/
Florida Cooperative Land Cover Map	Florida Fish and Wildlife Conservation Commission	https://myfwc.com/research/gis/regional-projects/cooperative-land-cover/
Solar Farm Best Management Practices for Wildlife	Florida Fish and Wildlife Conservation Commission	https://www.fishwildlife.org/download_file/view/3391/3094
Solar Energy Project General Resource Guidance and Recommendations	Maine Department of Inland Fisheries and Wildlife	https://www.fishwildlife.org/application/files/2616/2878/3861/MDIFW_Solar_Project_Guidance_05March2020.pdf
BioMap 2	Massachusetts Department of Game and Fish	https://www.mass.gov/service-details/biomap2-conserving-the-biodiversity-of-massachusetts-in-a-changing-world
Minnesota Vegetation guide for solar	Minnesota Department of Commerce	https://mn.gov/eera/web/project-file/11702/

Minnesota Solar Pathways: Illuminating Pathways to 10% Solar	Minnesota Department of Commerce	https://www.osti.gov/biblio/1668834
Solar on Closed Landfills	Minnesota Environmental Quality Board	https://www.eqb.state.mn.us/solar-closed-landfills
National Ecological Observatory Network	National Science Foundation	https://www.neonscience.org/
Oregon Renewable Energy Siting Assessment	Oregon Department of Energy	https://www.oregon.gov/energy/energy-oregon/Pages/ORESA.aspx
Oregon Conservation Strategy	Oregon Department of Fish and Wildlife	https://www.oregonconservationstrategy.org/
COMPASS: Mapping Oregon's Wildlife Habitats	Oregon Department of Fish and Wildlife	https://www.dfw.state.or.us/maps/compass/
Pennsylvania Solar Stormwater guidance	Pennsylvania Department of Environmental Protection	https://files.dep.state.pa.us/Water/BPNPSM/StormwaterManagement/ConstructionStormwater/Solar_Panel_Farms_FAQ.pdf
Solar Massachusetts Renewable Target (SMART) Program	State of Massachusetts	Website: https://www.mass.gov/info-details/solar-massachusetts-renewable-target-smart-program#general-information- Legal text: https://www.mass.gov/doc/225-cmr-2000-final-071020-clean/download
Texas Natural Diversity Database	Texas Parks and Wildlife Department	https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/txndd/

Greening the Grid: REZ Toolkit	U.S. Agency for International Development	https://greeningthegrid.org/Renewable-Energy-Zones-Toolkit
Land-Based Wind Energy Siting: A Foundational and Technical Resource	U.S. Department of Energy	https://windexchange.energy.gov/files/u/publication/document_upload/6872/78591.pdf
RE-Powering America's Land Program	U.S. Environmental Protection Agency	https://www.epa.gov/re-powering
Energy Development Permits, Policies, and Authorities	U.S. Fish and Wildlife Service	https://www.fws.gov/ecological-services/energy-development/laws-policies.html
Land-Based Wind Energy Guidelines	U.S. Fish and Wildlife Service	https://www.fws.gov/ecological-services/es-library/pdfs/weg_final.pdf
NRCS Soil Maps	US Department of Agriculture	https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/use/maps/
Birds of Conservation Concern	US Fish and Wildlife Service	https://www.fws.gov/migratorybirds/pdf/management/birds-of-conservation-concern-2021.pdf
Information for Planning and Conservation	US Fish and Wildlife Service	https://ecos.fws.gov/ipac/
Clearance Letter for Potential or Proposed Solar Power Generation Projects	US Fish and Wildlife Service	https://www.fws.gov/southeast/pdf/letter/south-carolina-solar-power-clearance.pdf
Status of the Desert Tortoise and Its Critical Habitat	US Fish and Wildlife Service	Status-of-the-DT-CH-with-solar-table-08162021.pdf (fws.gov)
Western Migrations: Wildlife Corridors and Route Viewer	US Geological Survey	https://westernmigrations.net/

Virginia Pollinator Smart	Virginia Department of Conservation and Recreation	https://www.dcr.virginia.gov/natural-heritage/pollinator-smart
Virginia Scenic Rivers Program	Virginia Department of Conservation and Recreation	https://www.dcr.virginia.gov/recreational-planning/srmain#mechcorr
Conserve Virginia	Virginia Department of Conservation and Recreation	https://www.dcr.virginia.gov/conservevirginia/
Virginia Natural Heritage Data Explorer	Virginia Department of Conservation and Recreation	https://vanhde.org/content/map
Virginia Wildlife Action Plan	Virginia Department of Wildlife Resources	http://bewildvirginia.org/wildlife-action-plan/
Critical Habitat Assessment Tool	Western Association of Fish and Wildlife Agencies	https://wafwa.org/initiatives/chat/
Guidelines for Wind and Solar Energy Development	Wyoming Game and Fish Department	https://www.fishwildlife.org/application/files/6816/2878/3902/WGFD_Wind_and_Solar_Energy_Development_Guidelines_Final_January2021.pdf

Non-Governmental Resources

Resource Name	**Organization**	**Link**
Farms Under Threat: The State of the States	American Farmland Trust	https://farmland.org/project/farms-under-threat/
Solar Power and Wildlife/Natural Resources Symposium	American Wind and Wildlife Institute	https://awwi.org/solar-symposium/
Pollinator-Friendly Solar Scorecards	Center for Pollinators in Energy	https://fresh-energy.org/beeslovesolar/pollinator-friendly-solar-scorecards

Minnesota Solar Guide	Clean Energy Resource Teams	https://www.cleanenergyresourceteams.org/minnesota-solar-guide#wildlife
Solar and the San Joaquin Valley Identification of Least-Conflict Lands Project	Conservation Biology Institute	https://sjvp.databasin.org/pages/least-conflict/
California Statewide Energy Gateway	Conservation Biology Institute	https://caenergy.databasin.org/
California Energy Infrastructure Planning Analyst	Conservation Biology Institute	https://ceipa.databasin.org/
Solar Computer Vision	Defenders of Wildlife	https://osf.io/dau8w/
Case Studies	Fresh Energy	Case Study: 907 acres of pollinator-friendly solar https://fresh-energy.org/case-study-900-acres-of-pollinator-friendly-solar Case Study: The 9.9 MW Solar Project in Science Magazine https://fresh-energy.org/case-study-the-9-9-mw-solar-project-in-science-magazine Case Study: NextEra Energy's Marshall Solar Array on Prime Farmland https://fresh-energy.org/case-study-nextera-energys-marshall-solar-array-on-prime-farmland
Voluntary Best Management Practices for Solar Development	Gopher Tortoise Council	https://www.fishwildlife.org/application/files/3216/2878/3832/GTC_Solar_Developer__BMPs.pdf

Compatible with Conservation of Gopher Tortoises		
Model Solar Ordinances	Great Plains Institute	https://www.betterenergy.org/blog/model-solar-ordinances/
Solar Park Impacts on Ecosystem Services	Lancaster University	https://www.lancaster.ac.uk/spies/
Audubon's Birds and Climate Change Report: A Primer for Practitioners	National Audubon Society	http://climate.audubon.org/sites/default/files/Audubon-Birds-Climate-Report-v1.2.pdf
Shifting Skies: Migratory Birds in a Warming World	National Wildlife Federation	https://www.nwf.org/~/media/PDFs/Global-Warming/Reports/NWF_Migratory_Birds_Report_web_Final.ashx
North Carolina Technical Guidance for Native Plantings on Solar Sites	North Carolina Pollinator Conservation Alliance	http://ncpollinatoralliance.org/wp-content/uploads/2018/10/NC-Solar-Technical-Guidance-Oct-2018.pdf
Oregon Biodiversity Information Center	Oregon State University	https://inr.oregonstate.edu/orbic
Landbird Conservation Plan	Partners in Flight	https://partnersinflight.org/resources/the-plan/
How to Solar Now	Scenic Hudson	https://www.scenichudson.org/our-work/climate/renewable-energy/howtosolarnow/
Integrated Value of Ecosystem Services and Tradeoffs (InVEST)	Stanford University	https://naturalcapitalproject.stanford.edu/software/invest
Mojave Desert Ecoregional Assessment	The Nature Conservancy	https://www.scienceforconservation.org/products/mojave-desert-ecoregional-assessment

		Reassessment of renewable energy sites: https://www.scienceforconservation.org/products/impact-solar-wind-mojave Data: https://www.scienceforconservation.org/products/mojave-desert-ecoregional-assessment-gis-packages), https://datadryad.org/stash/dataset/doi:10.5061/dryad.7g0f132
Power of Place: Land Conservation and Clean Energy Pathways for California	The Nature Conservancy	https://www.scienceforconservation.org/products/power-of-place
Solar Energy Development in the Western Mojave Desert	The Nature Conservancy	https://www.scienceforconservation.org/products/western-mojave-solar
Western San Joaquin Valley Least Conflict Solar Energy Assessment	The Nature Conservancy	https://www.scienceforconservation.org/products/western-san-joaquin-valley-assessment Data: https://www.scienceforconservation.org/products/western-san-joaquin-solar-data Webmap: https://www.scienceforconservation.org/products/Western-SJ-solar-assessment-webmap
Georgia Low-Impact Solar Siting Tool	The Nature Conservancy	https://tnc.maps.arcgis.com/apps/webappviewer/index.html?id=f989b93ec9e54488ba925b478b7dab9e

Long Island Solar Roadmap	The Nature Conservancy	http://solarroadmap.org/
Site Wind Right	The Nature Conservancy	https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/site-wind-right/
Millennium Ecosystem Assessment	United Nations	https://www.millenniumassessment.org/en/index.html
Nationwide Candidate Conservation Agreement for Monarch Butterfly for Energy and Transportation Lands	University of Illinois-Chicago	http://rightofway.erc.uic.edu/national-monarch-ccaa/
A Report on the Economic Impact to Wyoming's Economy From a Potential Listing of the Sage Grouse	University of Wyoming	https://www.uwyo.edu/haub/_files/_docs/research/2016-sage-grouse-report-web.pdf
Solar Development Potential on Contaminated Lands in Maryland	Utility-Scale Solar Energy Coalition of Maryland	http://www.mdcounties.org/DocumentCenter/View/2924/USSEC-Analysis-of-Solar-Potential-on-MD-Contaminated-Lands---FINAL-10918

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