Big Game Guidelines for Utility-Scale Photovoltaic Solar Development

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1.0 Background and Purpose

Photovoltaic solar is a reliable and cost-effective form of renewable energy that is rapidly expanding in the U.S. All projected pathways to carbon neutrality within the U.S. rely heavily on ground-mounted, utility-scale solar energy (USSE) development, with widespread deployment that will have large land requirements (Larson et al. 2021, U.S. Department of Energy 2021). The Princeton University "Net-Zero America" study outlines energy development requirements to achieve net-zero emissions of greenhouse gases by 2050. Their report estimates that that the land requirements to produce energy in the U.S will need to quadruple, including approximately 17 million acres of new USSE solar development (Larson et al. 2021). More recently, the U.S. Department of the Interior (DOI) Bureau of Land Management (BLM) released its proposed update to the Western Solar Plan in January 2024. They estimate an additional 700,000 acres of USSE development is needed on BLM-managed lands to help meet the nation's renewable energy goals, and they propose to open 22 million acres to USSE solar development to meet future demand (U.S. Department of the Interior 2024).

The development of USSE facilities is currently regulated by a patchwork of federal, state, and local agencies. Development on federal lands is regulated primarily by BLM through its Western Solar Plan (U.S. Department of the Interior 2012) and related regulations on the issuance of federal leases and new federal right-of-way (ROW) for renewable energy development (43 CFR 2800). The development of USSE facilities on private lands is regulated by a combination of state and local laws. Many states do not require a separate state permit for the siting and development of USSE facilities. In these states, local jurisdictions (counties, townships, or cities) regulate these facilities.

Regardless of whether a state permit is required, state fish and wildlife agencies are often given an opportunity to provide input to the appropriate federal, state, or local permitting jurisdictions regarding measures to avoid, minimize, and mitigate impacts to wildlife resources during the siting and development of USSE facilities. Some state wildlife agencies have developed their own siting guidelines or best management practices (BMPs) for the development of USSE facilities. These state-specific siting guidelines and BMPs have been compiled and made available by the Association of Fish Wildlife Agencies Energy and Wildlife Policy Committee.

The purpose of this document is to supplement these state-specific guidelines and BMPs to provide state wildlife agencies, as well as industry, non-governmental organizations, and members of the public who engage in solar development projects, with additional science-based recommendations specifically for western big game species (i.e., ungulates), including mule deer, elk, and pronghorn – many of which migrate long distances between seasonal ranges. Big game represent a highly valuable resource to the public, both socially and economically (Arnett and Southwick 2015). As evidenced by Secretarial Order 3362, western states have invested considerable resources into enhancing and protecting the winter ranges and migratory routes of big game (United States Department of the Interior 2018). Given the projected increase in USSE deployment, there is growing interest about how big game populations might be affected and how potential impacts from USSE can be avoided or minimized. For a primer on big game ecology and management challenges in the western U.S., we refer readers to the hyperlinked report here.

2.0 Potential Impacts to Big Game

2.1 ***Direct Habitat Loss:*** The direct loss of habitat occurs when suitable habitat is converted to infrastructure or fenced off so that it is no longer available to animals. USSE facilities pose a unique threat to big game due to the amount of direct habitat loss and movement barriers associated with these facilities. Although some forms of livestock fencing are wildlife-friendly and permeable to big game (Paige 2012, 2020), the 7- to 8- ft. fences required around USSE projects (National Electric Code 2017) are impermeable to big game such that all habitat inside the project boundary is effectively lost and access to adjacent habitats is impeded (Figures 2.1a, 2.1b). Direct habitat loss has consistent and ubiquitous negative effects on wildlife (Fahrig 2003). For big game, direct habitat loss is concerning because it reduces the number of animals that a particular area can support and can lead to population declines, depending on the amount and quality of that habitat (Bolger et al. 2008, Jones et al. 2015, Sawyer et al. 2017, Williams et al. 2021).

Figure 2.1a. Example of a perimeter fence surrounding USSE facility in Wyoming, USA. Photo credit H. Sawyer.

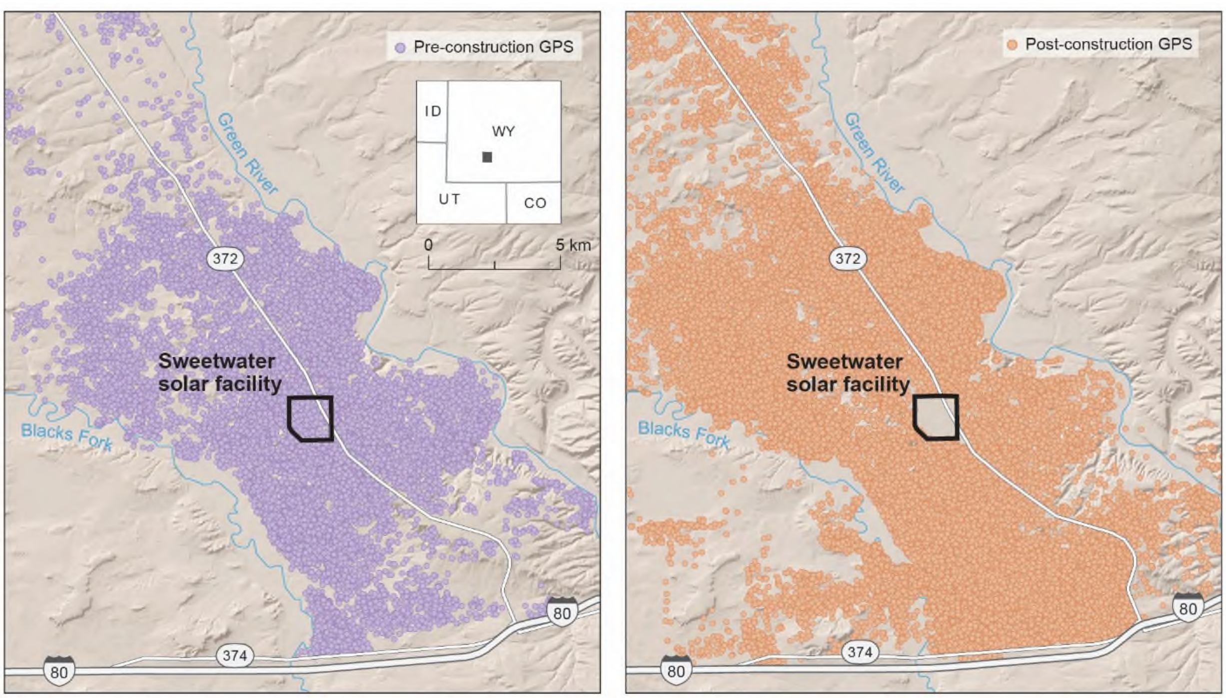

Figure 2.1b. The perimeter fences required for USSE are impermeable to big game and result in the direct loss of habitat. Pronghorn locations before (left) and after (right) construction of the Sweetwater solar facility in Wyoming, USA (from Sawyer et al. 2022).

2.2 ***Indirect Habitat Loss:*** Indirect habitat loss can occur when animals avoid available habitat because of nearby human disturbance (Polfus et al. 2011). Big game and other wildlife commonly respond to human disturbances with increased vigilance and/or avoidance behavior (Gavin and Komers 2006, Stankowich 2008), which can lead to the indirect loss of habitat that can be much larger (e.g., 4x) than the associated direct habitat loss (Northrup et al. 2015, Sawyer et al. 2017, Dwinnell et al. 2019). Also, the level of behavioral response exhibited by animals is often associated with level of human activity (e.g., traffic, noise), where lower levels of disturbance lessen the response (Sawyer et al. 2009*a*, Leblond et al. 2013). This type of scaled response is often evident in temporal patterns, where avoidance behavior is lessened during the night when human activity is reduced (Dzialak et al. 2011, Northrup et al. 2015, Gaynor et al. 2018).

Animals also tend to have stronger responses to unpredictable disturbances (e.g., vehicle off-road or hiker off-trail) compared to predictable disturbances (Miller et al. 2020). Big game responses to human disturbance tend to be reduced in areas with dense vegetation or diverse topography compared with flat open areas where visual and auditory cues are unobstructed (Coe et al. 2011, Montgomery et al. 2013, Northrup et al. 2015). For example, studies of mule deer in areas with natural gas development found avoidance distances in Pinyon-juniper woodlands were ~600 m (Northrup et al. 2015), compared with ~900 m in open sagebrush habitats (Sawyer et al. 2017). In general, avoidance is a common behavioral response of big game species to oil and gas development (Sawyer et al. 2006, 2017, 2019, Northrup et al. 2015, Dwinnell et al. 2019), recreation (Rogala et al. 2011, Wisdom et al. 2018), and to a lesser extent with wind energy (Smith et al. 2020, Milligan et al. 2021, 2023). However, the infrastructure, noise levels, and visual cues from USSE are clearly different from oil and gas development, recreation, and wind energy. Thus, inferences of avoidance behaviors and indirect habitat loss from those studies may be limited but should not be overlooked.

Nonetheless, avoidance of solar development has been identified as a likely or potential effect on wildlife (Lovich and Ennen 2011, Chock et al. 2021), but the only empirical evidence for big game avoidance and indirect habitat loss associated with USSE is limited to one study that focused on pronghorn (Sawyer et al. 2022). By following the same GPS-marked animals one season before and two seasons after construction, this study found the amount of high-use habitat used by pronghorn declined by approximately 40% within 1 and 2 km of the solar facility after construction (Fig. 2.2).

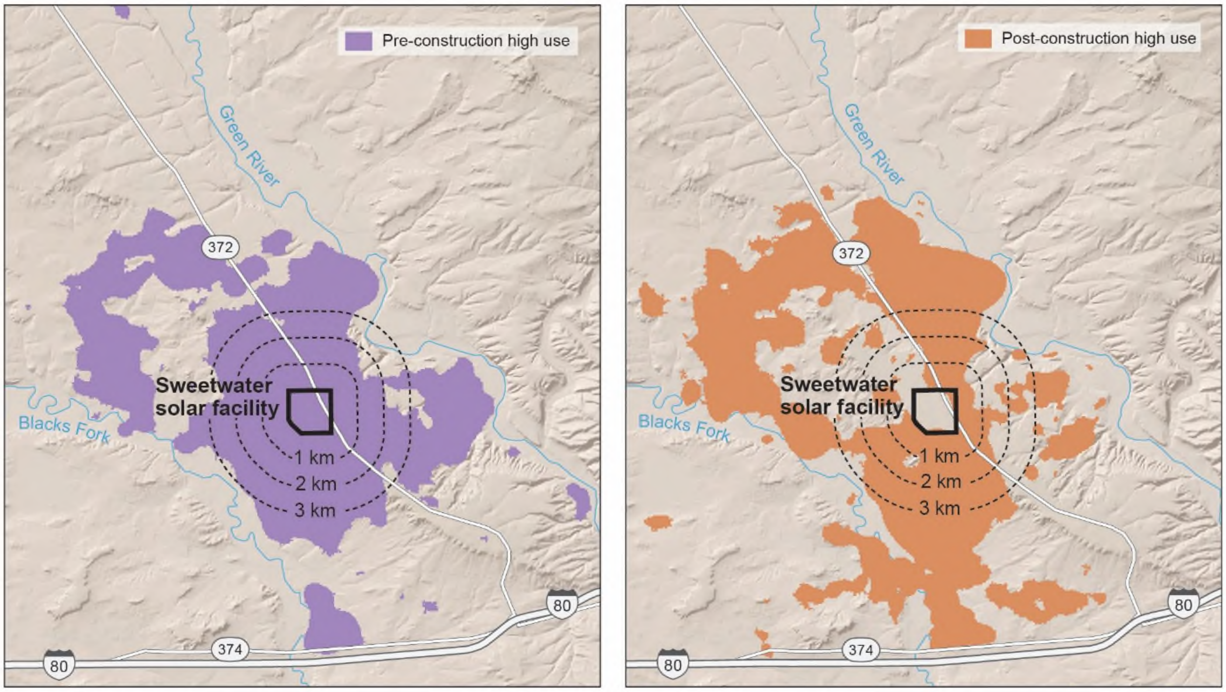

Figure 2.2 Indirect habitat loss occurs when animals avoid areas near human disturbance. Pronghorn use declined near the 80-mw Sweetwater solar facility in Wyoming for two years following construction (from Sawyer et al. 2022).

2.3 ***Movement and Barrier Effects:*** Movement is a key requirement for big game populations (Mueller and Fagan 2008, Searle et al. 2015), although the type and magnitude of movements can vary within and among populations (Cagnacci et al. 2011, Peters et al. 2019). Movement allows animals to access forage, respond to weather conditions and human disturbance, find mates, and avoid predation (Mueller and Fagan 2008, Teitelbaum and Mueller 2019). Human disturbance and development can broadly alter both the temporal and spatial movement patterns of wildlife (Gaynor et al. 2018, Tucker et al. 2018). The permeability of linear barriers (e.g., fences or roadways) or broader development footprints can range from highly permeable to impermeable (Sawyer et al. 2013, Robb et al. 2022), and can elicit a variety of behavioral responses ranging from altered movements to complete blockage (Xu et al. 2021). Security fencing associated with USSE is impermeable to big game and, depending on siting location, may reduce landscape connectivity and force animals to alter their movement patterns (Sawyer et al. 2022).

Explicit research on USSE barrier effects is limited to one study that simply documented the proportion of animals that had to modify their year-round use and migration routes following USSE construction (Sawyer et al. 2022). While solar-specific studies are limited, we know from other studies that barrier effects can influence ungulate survival (Xu et al. 2023), reduce the nutritional benefits of migration (Aikens et al. 2022), and limit migratory behaviors once certain development thresholds are exceeded (Sawyer et al. 2020, Lambert et al. 2022). Like other forms of development, the degree to which barrier effects associated with USSE reduce landscape connectivity will likely depend on the siting, size, and configuration of arrays.

2.4 *Wildlife-Vehicle Collisions:* USSE projects are often sited near roadways to access existing transmission lines and other infrastructure. Siting projects next to roads can be beneficial to big game (and other wildlife) by keeping undisturbed habitats intact and minimizing the amount of new road and transmission construction. However, USSE (or other development with 7-ft.–tall fences) may unintentionally push big game onto roads or rights-of-ways and increase the risk of wildlife-vehicle collisions (WVC) when 1) sited immediately adjacent to roadways with permeable right-of-way fencing (Sawyer et al. 2022), and 2) where big game move parallel to the roadway or cross the roadway at the project location (Fig. 4.3).

3.0 Avoidance Measures

Big game populations generally consist of: 1) resident animals that meet their year-round requirements in a relatively small area, 2) migratory animals that migrate between distinct winter and summer ranges, or 3) some combination of residents and migrants (Cagnacci et al. 2011, Lowrey et al. 2020). For migratory animals, habitat loss from USSE could occur on summer range, migratory routes, or winter range and the only way to avoid such habitat loss is to site USSE in areas that do not overlap these habitats. For this reason, USSE development proposals should be screened by project proponents and state wildlife agencies as early as possible to assess and avoid conflicts with known big game migration corridors and important seasonal habitats.

In general, informed siting practices will require accurate spatial data for big game populations to be readily available to developers, consultants, and agencies. Ideally, site evaluation should occur in coordination with state wildlife agencies prior to investing in access agreements, development leases, or plans of development. Most western state wildlife agencies have big game seasonal ranges mapped for each species, but the names, types, and relative importance of ranges may vary from state to state. For example, in Colorado alone, winter ranges may be classified as “winter range”, “winter concentration area”, or “severe winter range” (Colorado Parks and Wildlife 2020). In addition, there are other publicly-available sources, such as the USGS western migrations mapping effort (Kauffman et al. 2020), that continue to improve each year.

Digital resources of big game seasonal ranges and migration corridors should be viewed as living documents, because they will be continually updated and refined as states acquire more GPS movement data from ongoing and future studies (Kauffman et al. 2022). In practice, some regions have better data than others to delineate and map accurate seasonal ranges. For example, some seasonal ranges and migration corridors are based on fine-scale movement data collected from GPS studies (Kauffman et al. 2020), whereas other areas may rely on coarser wildlife observation data and/or expert opinion. Whenever possible, USSE development should be sited outside of known migratory corridors and crucial habitats to avoid adverse impacts to big game populations.

4.0 Minimization Measures

The first step of the mitigation hierarchy is attempting to avoid impacts altogether. Avoidance of mapped migration corridors and important seasonal habitats (e.g., winter range) for big game should be the priority when evaluating where to site new USSE facilities. If avoidance is not possible, then the second step of the mitigation hierarchy is impact minimization. For solar, impact minimization generally involves modification of project design and features. We highlight approaches that may be implemented during the development of USSE facilities to minimize impacts from direct and indirect habitat loss, barrier and movement effects, and wildlife-vehicle collisions.

4.1 *Minimizing Direct Habitat Loss:*

When complete avoidance of big game habitat is not feasible, micro-siting may provide a means to minimize impacts of direct habitat loss by siting projects in less-used or lower quality habitat. The quality of data used to delineate seasonal ranges and migratory corridors may determine whether micro-siting options are possible to minimize effects of direct habitat loss. For example, when GPS location data are available, generating heat maps (shades of colors to represent levels of species habitat use) of seasonal ranges can identify low, moderate, and high-use areas (Sawyer et al. 2009*b*, Kauffman et al. 2022). These maps help prioritize the habitats with the most conservation value (Middleton et al. 2020) and may provide opportunities to site USSE in less-used or lower quality habitat. Absent fine-scale GPS data, migration routes and winter range are often considered the most sensitive big game habitats because of their conservation value and limited availability (United States Department of the Interior 2018), but that may vary by population or region. Coordinating with state wildlife agencies is helpful for obtaining and interpreting site-specific big game habitat use information and identifying population-limiting seasonal habitats that should be avoided.

4.2 *Minimizing Barrier and Movement Effects*

Like other forms of development, the degree to which barrier effects associated with USSE reduce landscape connectivity will depend on the siting, size, and configuration of arrays. For example, a small 200-acre project may be easy for big game to move around, but a 2,000-acre project will be more challenging. Relatedly, a 2,000-acre project split in half with a movement corridor in between should retain more connectivity compared to one solid project block with no movement options. The implementation challenge here is determining how wide and how many movement corridors are needed for big game to easily move through USSE projects. Determining minimum corridor widths is a recurring and debatable topic (Beier 2019, Ford et al. 2020), but the general rule of thumb is that wider corridors are more effective than narrow corridors, and corridors that span longer distances need to be wider than those that span short distances (Hilty et al. 2006, Brennan et al. 2022).

Recent meta-analysis suggests that width of functioning big game migratory corridors should be ~1,300 to 1,900 ft (Merkle et al. 2023), but migratory corridors generally span distances much greater than USSE sites (e.g., 10 to 150 mi). For guidance on minimum corridor widths and other USSE design features, we can draw on lessons from the roadway ecology literature where big game are known to move under or over roadways via specially designed movement corridors (Clevenger and Waltho 2000, 2005, Dodd and Gagnon 2011, Sawyer et al. 2016, Simpson et al.

2016). In Table 4.2 we highlight 9 general guidelines from studies of roadway crossing structures and list their potential application to USSE corridor and layout design (Table 4.2).

Table 4.2 Summary of roadway crossing guidelines and their potential application to utility-scale solar energy (USSE) corridor and layout design.

Roadway Crossing Guidelines	Recommendation for USSE
1) Crossing structures need to be built wide enough for big game to comfortably move through, understanding that crossing structures spanning longer distances need to be wider than shorter spans (Brennan et al. 2022). Common underpass widths range from 20 to 50 ft., but typically only span 60 to 80 ft. (Sawyer et al. 2012, 2016). In contrast, typical widths for roadway overpasses range from 100 to 200 ft. (Sawyer et al. 2016, Kintsch et al. 2021, Brennan et al. 2022), and can span multi-lane roadways that extend 300 to 700 ft. in length.	Big game are more likely to use wider corridors and corridors spanning longer distances through USSE likely need to be wider than those spanning short distances. The 100 to 200 ft. overpass widths could be used as starting points for designing USSE corridor widths, recognizing that roadway overpasses seldom span distances more than 700 ft. and the dimensions of USSE panel arrays will greatly exceed this distance. Unobstructed vision through movement corridors may be important for pronghorn (Sawyer et al. 2016).
2) Uplands adjacent to hydrological drainages can serve as effective big game corridors (Smith et al. 2015).	Hydrologic or dry washes are sometimes left unfenced through USSE projects because they are not suitable for PV installation. Rather than build or fence directly up to the wash, some space (e.g., 20 to 100 ft.) could be provided on the adjacent flat ground for big game to move next to the wash or hydrologic feature.
3) Vegetation reclamation practices on and adjacent to crossing structures can help attract and retain big game. Corridor designs are more effective when they consider habitat and behavioral requirements of focal species (Hobbs 1992, Hilty et al. 2006, Abrahms et al. 2017).	Could be used to consider what vegetation types might be most attractive for big game needing to utilize corridors through USSE. For example, in timbered regions it may be advantageous to retain some trees and shrubs in the corridors. In desert and basin regions, some combination of shrub, grass, or forb mix may help attract big game and encourage use of corridors. Species-specific vegetation preferences might also help encourage use by focal species, as pronghorn, deer and elk preferences can differ.
4) Big game are more likely to utilize crossing structures or corridors where human disturbances (e.g., vehicles, recreation) are limited (Barrueto et al. 2014, Denneboom et al. 2021, Hamilton et al. 2024).	The level and proximity of human disturbance (e.g., traffic, noise, recreation) to USSE corridors should be considered when siting, designing, or managing a USSE movement corridor.
5) Angled game-proof fencing can help funnel big game towards crossing structures (Clevenger et al. 2001, McCollister and van Manen 2010, Huijser et al. 2015, Denneboom et al. 2021).	Angled fences and funnel-shaped fencing at corridor entrances and exits to direct animal movement. This same practice of angled fences can also be used on USSE perimeter corners to facilitate movement around the project.
6) Passage rates, or the propensity of big game to utilize crossing structures tend to increase through time and level off at 2 to 3 years (Gagnon et al. 2011, Sawyer et al. 2012, 2016).	Acknowledges that big game may need some acclimation time to utilize movement corridors through USSE without hesitation.
7) The use of GPS movement data can help identify and inform crossing structure locations (Dodd et al. 2007, Coe et al. 2015, Kauffman et al. 2018).(Gagnon et al. 2011, Sawyer et al. 2012, 2016)(Gagnon et al. 2011, Sawyer et al. 2012, 2016)(Gagnon et al. 2011, Sawyer et al. 2012, 2016)(Gagnon et al. 2011, Sawyer et al. 2012, 2016)(Gagnon et al. 2011, Sawyer et al. 2012, 2016)	When available, GPS movement data can help determine the best location(s) for movement corridors through USSE.
8) General guidelines for crossing structure density or spacing along sections of roadway often equate to 1 structure every mile (Foster and Humphrey 1995, Bissonette and Adair 2008).	When GPS data are not available, then this may provide some general guidance as to how large a USSE needs to be before movement corridors are needed (i.e., perimeter side ≥ 1 mile) or how frequent corridors should be spaced (i.e., 1 every mile) in large USSE projects.

4.3 *Minimizing Wildlife-Vehicle Collisions*

USSE projects are often sited near roadways to access existing transmission lines and other infrastructure. Siting projects next to roads can be beneficial to big game (and other wildlife) by keeping undisturbed habitats intact and minimizing the amount of new road and transmission construction. However, USSE fencing may unintentionally push big game onto roads or rights-of-way and increase the risk of wildlife-vehicle collisions (WVC) when 1) sited immediately adjacent to roadways with permeable right-of-way fencing (Sawyer et al. 2022), and 2) where big game move parallel to the roadway or cross the roadway at the project location (Fig. 4.3).

In scenarios where the right-of-way fencing is game-proof so that big game cannot cross the road or enter the right-of-way, then increased risk of WVCs should not be a concern. In scenarios with permeable right-of way fencing where big game move parallel to or cross the roadway, the increased risk of WVCs can likely be mitigated by siting the USSE an adequate distance away from the roadway, to provide space and security habitat for big game to move around the USSE and not be repelled into the roadway or right-of-way (Fig 4.3). This spacing distance, termed *roadway offset*, provides big game moving parallel to the roadway the option to continue that movement between the USSE and roadway, without being forced into the right-of-way (Fig 4.3). Animals that happen to cross the roadway and bump into the USSE may have the option to move around the facility rather than being repelled back to the other side of the road (Fig 4.3). To date, common distances used for USSE roadway offsets in the western U.S. range from 100 to 500 ft. (Western Ecosystems Technology 2023), but studies are needed to refine best management practices.

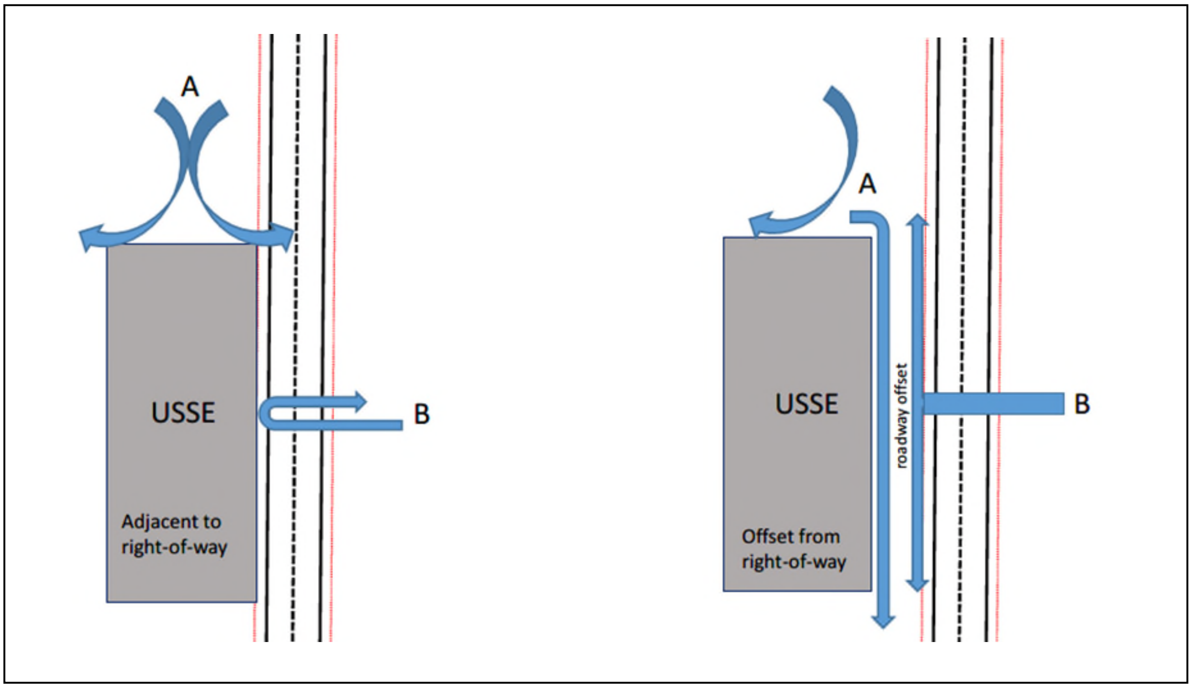

Figure 4.3 The left panel shows how risk of wildlife vehicle collisions might increase when a utility-scale solar energy (USSE) project is sited adjacent to roadway right-of-way (red) and (A) pushes animals moving parallel to roadway into the right-of-way, or (B) repels animals that attempt to cross roadway on opposite side of USSE. The right panel illustrates how a roadway offset (≥ 100 ft) between the USSE and right-of-way can provide (A) a safe movement corridor for animals moving parallel to highway and (B) animals crossing the roadway opposite of the USSE can exit the right-of-way and move around the USSE.

Other potential and complementary minimization measures for addressing WVC concerns include working with local transportation departments to reduce traffic speeds and/or warn motorists of potential dangers on roadway segments adjacent to USSE. Speed limits and warning lights/signs (including those activated by big game detection systems) can sometimes help modify motorist behavior and minimize WVC risk (Gordon et al. 2004, Riginos et al. 2018, 2022). Relatedly, there may be ways to modify roadside vegetation to reduce WVC risk, such as clearing certain areas to improve visibility for motorists (Montgomery et al. 2012, Meisingset et al. 2014).

4.4 *Summary of Minimization Measures and Design Guidelines*

The widespread deployment of USSE (Larson et al. 2021, U.S. Department of Energy 2021) is expected to have considerable overlap with big game habitat. Minimization measures for big game and USSE should improve in the coming years as more post-construction information is collected on big game. In the interim, we summarize impact minimization strategies to consider now that may help inform siting and layout designs in ways that reduce potential negative impacts to big game (Table 4.4).

Table 4.4 A summary of potential impacts and associated minimization measures for utility-scale solar energy (USSE) development when sited in big game range.

Potential Impacts	Are Impacts a Concern?	Minimization Measures
Direct Habitat Loss	Yes	• Minimize the overall size of the fenced area and project footprint. • If possible, site USSE in less-used or lower quality habitat.
Indirect Habitat Loss	One study suggests yes, but more research needs to be completed.	• Minimize onsite human activity when big game are nearby. • Consider structural or screening cover (e.g., vegetation) to mask potential visual disturbances.
Barrier And Movement Effects	Yes, but: • Less so for smaller (<1 mi^2) projects where animals can move around and access habitats on all sides of USSE. • More so for larger projects that reduce movement options.	• Design movement corridors into the layouts of USSE so that animals have the option to move through the project rather than around it. • Provide both north/south and east/west movement options. • Consider rounded or angled fence corners to encourage animal movement around the perimeter or into designed corridors.
Wildlife-vehicle collisions	No, if: • USSE is not sited adjacent to roadway. • Right-of-way fencing is not permeable to big game, so animals cannot move onto roadway. ——— Yes, if: • USSE is sited adjacent to roadway *and* big game move through the area *and* the right-of-way fencing is permeable to big game.	None needed ——— • Roadway offset – provide enough space between the USSE and roadway so that animals can safely move between the project and right-of-way. • Consider speed limit or warning signs on roadway adjacent to USSE. • Consult with state transportation department.

5.0 Compensatory Mitigation

Compensatory mitigation to offset unavoidable adverse impacts might be considered when avoidance and minimization measures do not adequately address the impacts that a USSE project has on big game. Of course, compensatory mitigation should only be pursued after avoidance and minimization options are exhausted. In the case of USSE development, the specific adverse impact most likely to require compensatory mitigation is the direct loss of habitat, especially native vegetation. To truly offset impacts to a particular big game population, compensatory mitigation should occur within its specific geographic range, so the benefits actually extend to the affected population. Some common forms of compensatory mitigation include 1) the preservation of existing habitat at risk from future development, 2) the enhancement or restoration of habitat, or 3) monetary payments to state wildlife agencies or third parties specifically charged with conserving big game populations in the area.

Habitat preservation can occur through restricting future development on a parcel of equal size and habitat value. For state or federal lands, this could be achieved through standard regulatory channels (e.g., administrative or leasing protections). For private lands, similar outcomes can be achieved by placing a conservation easement on a parcel of equal size and habitat value. Given the spatial scale of USSE (i.e., hundreds or thousands of acres per project), it may be difficult to enhance or restore an area that large, but there may be opportunities depending on the type of habitat and specific needs of the affected population. For example, thousands of acres could potentially be improved for big game in regions with widespread invasive plants (e.g., cheat grass), or problematic fencing could be removed or modified in areas where big game movements are restricted by fencing. Habitat enhancement and restoration projects implemented as compensatory mitigation should be designed to last the duration of the USSE development impact. This may require some active management or repeated vegetation treatments over the life of the enhancement or restoration project.

6.0 Data and Research Gaps

Data gaps or imperfect knowledge are often used as an excuse to dismiss wildlife or environmental concerns associated with development. The current state of knowledge relative to big game and solar development allows for informed decisions and recommendations but could be improved and refined by addressing the key data gaps. To date, the most common data and research gaps include:

<u>Indirect Habitat Loss and Behavioral Responses to USSE</u>

The one published study on USSE and big game suggests that avoidance may be an issue for pronghorn in open sagebrush habitats (Sawyer et al. 2022). However, big game responses to human disturbance can be highly variable across disturbance types, eco-regions, and species. Accordingly, there is a clear need to better understand when, where, whether, and to what degree avoidance behavior occurs with USSE. Addressing this data gap will require studies that explicitly evaluate how and why big game respond to USSE (e.g., Do animals forage near USSE? Do vigilance rates change near USSE? Do animals avoid USSE?). Given the challenges with measuring and quantifying big game responses to human disturbance (Gill et al. 2001, Clinchy et al. 2013, Miller et al. 2020), it is likely that meta-analyses (e.g., Tucker et al. 2018, Gaynor et al. 2019) or long-term studies (e.g., Sawyer et al. 2017, Northrup et al. 2021, Williams et al. 2021) will provide the strongest inferences for how big game behaviorally respond to USSE.

Corridor Movement Width and Spacing

Although inferences from roadway ecology and other disciplines can help inform USSE layout and corridor designs, there is a clear need to better understand effective corridor widths for big game movements through USSE and relatedly, determine the size and spacing of corridors required for a given area. Given the relatively large number of USSE projects planned for construction in the coming years that overlap with big game habitat, there is potential to quickly advance our understanding of effective corridor widths through simple camera-based, post-construction monitoring efforts. Similar to the study of indirect habitat loss, the strongest and most meaningful inferences will likely come from meta-analyses that combine corridor movement information from multiple sites and states. However, this effort will require considerable attention be given to identifying appropriate metrics to measure and how to standardize data collection across sites.

Roadway Offset Widths

Similar to questions around movement corridor widths, there is a need to better understand how wide roadway offsets need to be to minimize WVC risk and how they may vary with habitat type (e.g., forest vs open; Montgomery et al. 2012, Meisingset et al. 2014). Most state transportation departments maintain WVC information compiled by milepost, such that before and after USSE comparisons offer a simple way to evaluate roadway offsets. Additionally, most roadway offsets being constructed are narrow enough to monitor with multiple trail cameras and document big game use.

7.0 Conclusion

The potential impact of USSE development on big game is an important and emerging issue. This topic is especially relevant in the western U.S., where 1) big game species rely heavily on migratory and daily movements and intact seasonal ranges to meet nutritional and other life-history requirements, and, 2) current state and federal policies encourage the enhancement of big game habitats (United States Department of the Interior 2018) as well as the retention or improvement of landscape connectivity (United States Department of the Interior 2022). Because the required security fencing for USSE is impermeable to big game, the most obvious concerns are the direct loss of habitat and reduced habitat connectivity (Sawyer et al. 2022). We encourage careful planning and early consultation between solar developers and state wildlife agencies to help avoid or minimize these impacts.

Although solar-specific studies are limited, existing knowledge of big game ecology suggests that USSE impacts may be minimized through informed siting practices that consider both habitat type (e.g., winter, summer, or migration) and quality (e.g., less-preferred vs morepreferred), and modified layout designs that accommodate animal movement. As more USSE projects are deployed in big game ranges, avoidance and minimization measures are expected to improve with refined knowledge of big game behavioral responses, effective corridor widths, and roadway offsets.

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