Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

Conservation Guidance for Utility-Scale Solar Projects

Cover photo: Agricultural production and electricity generation from solar photovoltaic (PV) panels can often take place on the same piece of land. Shown here, sheep grazing is common in dual use systems and provides an effective means of vegetation management. Photo credit – Preston Irwin, USDA-NRCS

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Introduction

Solar Development on America's Farms and Ranches

Advances in solar siting and array construction are creating opportunities for farmers and landowners to diversify how land is managed. There are many considerations that can go into the design, installation and maintenance of solar array equipment and facilities, including an opportunity to consider natural resource conservation at the front end when planning solar projects that impact America's farmland and ranchland. The United States Department of Agriculture's Natural Resources Conservation Service (NRCS) offers this guide, *Conservation Guidance for Utility-Scale Solar Projects*, for implementing conservation practices that address natural resource concerns, meet the on-site conservation and agricultural goals, and are compatible for use in and around utility-scale solar array structures and equipment. Although the considerations found in this guide are provided with the landowner in mind, the considerations found in this guide may also be helpful to other entities looking to increase conservation outcomes on solar projects of any size, including solar developers, state and local officials, siting or planning committee officials, and resource managers.

Intended Use

This guide provides voluntary natural resource conservation considerations for a broad range of stakeholders interested in the development of utility-scale (1 MW or larger[1]) solar energy facilities on agricultural land. Consider that every site has unique characteristics and conditions and not every conservation practice is applicable to any given site. This document provides a broad overview of possible conservation opportunities, considerations, and potential benefits of solar projects, including:

1. Conservation principles that **protect or enhance natural resources** at each stage of a solar project lifecycle: site selection; construction; operation and maintenance; decommissioning and potential return to agricultural use.
2. Conservation practices that could be used to address natural resource concerns or issues related to soil health, soil erosion, stormwater management, vegetation management, and wildlife habitat – that expound upon the NRCS document *Conservation Considerations for Solar Farms*.
3. Additional considerations and practices that support continued agricultural use of the land during the life of the solar array.

NOTE: This document is not intended to define or provide guidance on agrivoltaics[2] or ecovoltaics[3] specifically, though some practices and considerations may overlap and align with these systems.

The guidance provided in this document is not intended to supersede or override state, local, or regional zoning, siting, or environmental regulations, including the implementation of National Environmental Policy Act (NEPA) and the Farmland Protection Policy Act (FPPA) regulations.[4]

[1]A 1MW solar power plant of 1-megawatt capacity can run a commercial establishment independently. This size of solar utility farm takes up 4 to 5 acres of space and produces about 4,000 kWh of low-cost electricity every day.

[2]Agrivoltaics is defined as agricultural production, such as crop or livestock production, underneath or between rows of solar panels.

[3]Ecovoltaics are solar installations designed to create or restore habitat, improve soil, and provide other ecosystem services.

[4]For more information on the National Environmental Policy Act (NEPA) and the Farmland Protection Policy Act please visit: ceq.doe.gov or the NRCS Farmland Protection Policy Act site.

National Environmental Policy Act (NEPA)

NEPA requires all Federal agencies to consider the effects of their projects and programs on the environment by completing an environmental review prior to approving a project or program.

Section 101 of NEPA declares that the national policy is "to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and [to] fulfill the social, economic, and other requirements of present and future generations of Americans."

All policies and programs of the various USDA agencies shall be planned, developed, and implemented so as to achieve the goals and to follow the procedures declared by NEPA in order to assure responsible stewardship of the environment for present and future generations.

Farmland Protection Policy Act (FPPA)

The FPPA is intended to minimize the impact Federal programs have on the unnecessary and irreversible conversion of farmland to nonagricultural uses. If agricultural farmland (cropland, forest, pasture, or other land) will be converted to a non-agricultural use, producers, landowners, and developers can consider ways to minimize the impact and maintain the possibility for the land to be converted back to agricultural use.

To protect future agricultural suitability, consider limiting use of concrete and cement footing or pads; for example, consider using driven-post structures to limit the size of concrete footings. Consider solar development using existing buildings, structures, idle or marginal lands, or water bodies such as irrigation ditches.

Additionally, effective conservation planning requires local expertise and considers site-specific characteristics to determine the best locally compatible practices to achieve the resource conservation goals and objectives. Planning and decision making within the scope of solar array development and conservation planning require input and guidance from a wide range of stakeholders, including the landowner, producer, local permitting officials, the solar developer, and more. Ensuring there is clear communication early in the process can result in better conservation outcomes.[5]

Potential Land Use and USDA Program Eligibility

Farm Service Agency (FSA) Land-Use Classification

When considering a solar energy project, landowners and producers are encouraged to visit their local USDA Service Center[6] to discuss the potential program and land use classification impacts of siting solar facilities on their land before committing to a solar land lease or installing an on-farm solar array. Producers who actively participate in Farm Bill programs will need to ensure that the Food Security Act's highly erodible land conservation (HELC) and wetland conservation (WC) provisions are not being violated prior to construction or manipulation of the site.

Land-use classification is one factor in determining FSA program eligibility. Using national guidance, changes to land use classification are determined at a local level by the FSA County Committee[7] based upon the current use and suitability for agricultural production.

Natural Resource Conservation Service (NRCS) Technical Assistance and Program Eligibility

The NRCS may provide technical assistance to help a landowner or producer plan conservation practices to minimize natural resource damages or farmland degradation in conjunction with installing a utility scale energy facility on their land. NRCS program eligibility depends upon several factors including the designated land use, therefore, landowners and producers should work closely with their local NRCS conservationist and FSA staff to determine program eligibility.

[5] Association of Fish and Wildlife Agencies developed a Communication Framework. See Appendix for additional information.

[6] Find your local service center at https://www.farmers.gov/working-with-us/service-center-locator.

[7] County Committees represent their Local Administrative Area and are elected by eligible voters who participate or cooperate in any FSA program that is provided for by law. For more information on County Committees and Elections: https://www.fsa.usda.gov/news-room/county-committee-elections/index.

Natural Resource Considerations

Natural Resource Conservation

The NRCS' objective in conservation planning is to help the client manage resources for sustained use and productivity while considering economic and social needs. The NRCS conservation planning process helps identify resource concerns and formulate alternatives (conservation practices) that will address those resource concerns, achieve the client's objectives, and take advantage of opportunities to improve or protect resource conditions.

Protecting Soil Health - Soil-related resource concerns include erosion by water and wind, compaction, water ponding, pollutants, and loss of organic matter. Healthy soils are critical for proper function of the water cycle and for providing habitat for a diversity of organisms. Four principles that guide land management to support healthy soils are: (1) maximize soil cover, (2) minimize soil disturbance, (3) maximize living roots, and (4) maximize biodiversity. These principles can apply to solar farms during planning, construction, operation, and even decommissioning activities.

Minimizing Soil Erosion and Protecting Water Quality - Soil erosion by water or wind is a key resource concern that is often a consequence of construction and infrastructure projects. Erosion generally occurs when soils have been heavily disturbed or left bare. With solar farms, wind erosion can cause problems when wind-blown soil ends up on the surface of panels, reducing their electricity output and possibly leading to permanent damage. Water erosion from runoff and concentrated flows can damage infrastructure, equipment, and facilities, leading to increased maintenance and repair costs. It can also lead to detrimental offsite environmental effects including gullies and the transport of sediment to surface waters. Maintaining vegetative ground cover, reseeding bare or disturbed soils, and minimizing soil disturbance as much as possible will help limit soil erosion and protect local water quality.

Vegetation Management

Establishing Vegetation - The establishment and maintenance of perennial vegetation is paramount for ensuring the health and function of both the land and the solar farm. Sites are sometimes cleared of all vegetation and subjected to substantial land manipulation during construction. Bare, disturbed soil creates conditions favorable for erosion and the establishment and spread of undesirable, noxious, or invasive species.

Perennial herbaceous vegetation should be reestablished immediately following initial site preparation; however, annuals can also be used to establish short-term cover and stabilization. Planting can take place prior to or after construction. Pre-construction plantings have the benefit of not having to navigate around solar arrays and supporting infrastructure and can use large-scale agricultural equipment, but the newly established plants can be damaged during construction activities and sometimes require replanting. Post-construction plantings are less likely to be damaged by vehicles and equipment, but planting operations may be more difficult and time consuming due to narrow row widths between solar arrays and obstructions such as cable housings, gear boxes, and other infrastructure that may necessitate the use of smaller, more maneuverable equipment.

Species Selection - Select plants that are adapted to the local soils and climate, and which can easily be maintained by mowing or grazing. Select a mix of warm and cool-season plants, if the site and climate allow. Consider the shade cast by the solar panels when selecting species for revegetation efforts. Add shade-tolerant species to the seed mix where appropriate to help establish vegetation in the areas shaded by the panels. When practical, include native forbs that attract pollinators, promote soil health, and offer aesthetic value. If livestock will be used for vegetation management, be sure to include species that are palatable to the kind and class of livestock used and avoid species that are unpalatable or toxic.

Vegetation Management and Maintenance – Keeping vegetation at an optimal height is crucial for proper operation and function of the facility. Unmanaged vegetation can grow over and into electrical equipment and infrastructure, potentially causing damage, creating a fire hazard, reducing performance and efficiency, and increasing maintenance costs. Woody brush species can be particularly problematic, especially those that readily colonize disturbed ground, are fast-growing, and resprout from the base following top kill. A vegetation management plan that identifies the key plants, treatment thresholds, and management methods is a vital component of the facility's overall plan of operations.

It is critical to understand the characteristics of the species present both on the site and the adjacent areas to develop effective vegetation management plans. Herbaceous vegetation can usually be managed with mowing or livestock grazing, however woody species usually require mechanical removal or chemical treatment with herbicides. Brush management should be planned to remove unwanted woody species while densities are low and before they become a major problem.

Be aware of potential threats from noxious and invasive species, prioritize the prevention of their establishment, and ensure effective treatment if discovered. This is particularly important if livestock are used to manage herbaceous vegetation.

Diverse seed mixes with both cool and warm season species and shade-tolerant species should be used if the site conditions and climate allow.
Photo credit – Preston Irwin, USDA-NRCS

Technical Resources - The NRCS offers technical resources to help with planting and vegetation management operations. The Web Soil Survey (WSS) application can be used to identify on-site soil type and characteristics, including ecological sites. Each NRCS Ecological Site Description (ESD) contains a list of plants that are adapted to the ecological site, and each state's Field Office Technical Guide (FOTG) contains planting guides and conservation practice standards used for establishing and managing vegetative cover.

Livestock Considerations

Planning for Livestock Grazing - Livestock can be used to effectively manage herbaceous vegetation within a solar array and can often reduce the need for mechanical or chemical methods of vegetation management. Solar panels provide livestock with shade from the sun and shelter from adverse weather. Sheep are commonly used for grazing vegetation underneath and around solar arrays, and most standard utility-scale solar panel heights can accommodate sheep grazing with little or no modification. Larger animals such as dairy or beef cattle generally require elevated panels and reinforced structures to ensure safety of the livestock and prevent damage to the array. Develop a grazing management plan to ensure proper utilization of forage species, maintain adequate herbaceous cover, and ensure ecological, economic, and management objectives are met.

Design Considerations - In many cases, traditional utility-scale solar infrastructure does not need to be modified significantly to support livestock grazing. However, dual-use arrays should be designed with consideration of animal handling, livestock water needs, manure management, fencing requirements, and clearances for agricultural equipment.

Regardless of the animal, if grazing activities are planned, the system's design should ensure that wires, conduit, electrical boxes, and other equipment are inaccessible to the animals,

Sheep are commonly used for vegetation management underneath and around solar arrays. Most standard utility-scale solar panel heights can accommodate sheep grazing with little or no modification.
Photo credit – Preston Irwin, USDA-NRCS

and mounting systems are constructed to withstand abuse by livestock. Be sure to work with the solar array designer and installer to ensure provisions are made for watering facilities, handling facilities, and fencing.

Wildlife Considerations

Planning for Wildlife Habitat - Many types of wildlife, including pollinator species, can coexist on solar farms without conflict. Incorporating locally adapted, pollinator-friendly forbs and grasses into seed mixes is an effective strategy for creating habitat for pollinators and promoting the environmental benefits provided by these species. Pollinator-friendly mixes should include native, perennial forbs and grasses with diverse blooming periods. Adapt vegetation management strategies to ensure plants are allowed to bloom throughout the growing season.

Fencing – Perimeter fencing around solar facilities is primarily designed to provide high security and prevent unauthorized human access. Unfortunately, these fences are also highly effective in excluding many types of wildlife. Consider raising the bottom of the fence a few inches off the ground to allow passage of small to medium species of wildlife. Rather than using chain-link fencing, consider using high-tensile woven or net wire fences with larger mesh sizes. These durable fences provide a high level of security and are more permeable to small and medium-sized species of wildlife. Consider the safety and security of grazing animals when planning for and installing perimeter and interior fencing.

Protect and Connect Wildlife Habitat - Perimeter fencing of solar facilities can significantly impede the movement of larger wildlife species, resulting in reduced landscape permeability and habitat fragmentation. Key wildlife habitat areas should be identified and delineated during the planning process and set aside or left undisturbed during the development of the project. When practical, establish wildlife

Small to medium wildlife species can move through high-tensile woven wire fences much more easily than chain-link style fences.
Photo credit – Preston Irwin, USDA-NRCS

Set aside key wildlife habitat areas and design fences to create corridors that facilitate wildlife movement.
Photo credit – Cornell University

travel corridors between key habitat areas by designing fences to facilitate the movement of migrating animals around or through sections of utility-scale solar facilities.

Many types of wildlife, including pollinator species, can coexist on solar farms without conflict. Incorporating locally adapted, pollinator-friendly forbs and grasses into seed mixes is an effective strategy for creating habitat for pollinators and promoting the environmental benefits provided by these species.

Mitigation of Wildfire and Other Disturbances

Wildfire Mitigation - Regularly mow or graze herbaceous vegetation to reduce the risk of fire. Install firebreaks around the facility's perimeter, especially along adjacent roads and railroads, to protect the facility from external wildfires. Construct interior firebreaks for additional protection and to help contain fires that get started on site, and limit impacts to a portion of the facility instead of the entire site. Both firebreaks and access roads can be used by ground-based firefighting equipment to attack fires.

Security and Access Control - Anticipating and planning for unexpected disturbances, such as wildfire, severe weather, and vandalism is crucial for maintaining equipment and ensuring the continuity of operations. Access to the site should be controlled with secure perimeter fencing to protect assets and prevent unauthorized human access. Ensure fence integrity through regular patrolling and inspect fences for damage following severe weather events.

Design access roads to provide dedicated travel ways for heavy equipment and vehicles and to allow easy access to facilities and infrastructure for maintenance and repairs. Plan heavy use area protection for sites frequently used by vehicles, equipment, and machinery and for stockpiling supplies and spare parts or discarded components.

Resource Concerns and Conservation Practices

Soil, water, vegetation, and wildlife considerations vary extensively from region to region. Decision-makers should follow state-specific guidance and seek local expertise (such as from NRCS experts) when making decisions. Table 1 contains a list of resource concerns commonly encountered on utility-scale solar projects, and conservation practices that are commonly used to address them. Nationally developed practice overview documents that communicate basic information about these conservation practices are available on the NRCS website: https://www.nrcs.usda.gov/resources/guides-and-instructions/conservation-practice-standards

This list is not exhaustive, and additional conservation practices may be appropriate to address site specific resource concerns. For state-specific conservation practice information, visit your state's NRCS Field Office Technical Guide, Section 4 or contact the NRCS office at your local USDA Service Center for information on local and state level criteria.

USDA encourages producers and landowners to work with NRCS to utilize the complete conservation planning process to address natural resource concerns through the implementation of conservation practices. Producers and landowners should work with FSA regarding program eligibility.

Table 1: Resource Concerns and Conservation Practices

Potential Conservation Practices (Code) Grouped by Resource Concern
Reduce or Prevent Sheet and Rill & Wind Erosion
• **Access Control (472) -** The temporary or permanent exclusion of animals, people, vehicles, or equipment from an area. • **Conservation Cover (327) -** Establishing and maintaining permanent vegetative cover. • **Conservation Crop Rotation (328) -** A planned sequence of crops grown on the same ground over a period of time (i.e. the rotation cycle). • **Cover Crop (340) -** Grasses, legumes, and other forbs planted for seasonal vegetative cover. • **Critical Area Planting (342) -** Establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical, or biological conditions that prevent the establishment of vegetation with normal seeding/planting methods. • **Diversion (362) -** A channel usually constructed across the slope with a supporting ridge on the lower side. • **Grassed Waterway (412) -** A shaped or graded channel that is established with suitable vegetation to convey surface water at a nonerosive velocity using a broad and shallow cross section to a stable outlet. • **Dust Control on Unpaved Roads and Surfaces (373)** – Treating unpaved roads and surfaces to reduce dust. • **Field Border (386) -** A strip of permanent vegetation established at the edge or around the perimeter of a field. • **Heavy Use Area Protection (561) -** Stabilization or protection of an intensively used area. • **Mulching (484) -** Applying plant residues or other suitable materials to the land surface. • **Pasture and Hay Planting (512) -** Establishing adapted and compatible species, varieties, or cultivars of perennial herbaceous plants suitable for pasture or hay production. • **Range Planting (550) -** The seeding and establishment of herbaceous and woody species for the improvement of vegetation composition and productivity of the plant community to meet management goals.
Reduce or Prevent Sediment Transported to Surface Water
• **Access Control (472) -** The temporary or permanent exclusion of animals, people, vehicles, or equipment from an area. • **Anionic Polyacrylamide (PAM) Application (450) -** Application of water-soluble anionic polyacrylamide (PAM) to the soil. • **Conservation Cover (327) -** Establishing and maintaining permanent vegetative cover. • **Contour Buffer Strips (332) -** Narrow strips of permanent, herbaceous vegetative cover established around the hill slope and alternated down the slope with wider cropped strips that are farmed on the contour. • **Critical Area Planting (342) -** Establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical, or biological conditions that prevent the establishment of vegetation with normal seeding/planting methods. • **Field Border (386) -** A strip of permanent vegetation established at the edge or around the perimeter of a field. • **Filter Strip (393) -** A strip or area of herbaceous vegetation, located at the lower edge(s) of a field, that removes contaminants from overland flow. • **Grassed Waterway (412) -** A shaped or graded channel that is established with suitable vegetation to convey surface water at a nonerosive velocity using a broad and shallow cross section to a stable outlet. • **Lined Waterway or Outlet (468) -** Constructing an erosion resistant channel to provide safe conveyance of water flow concentrations.

Potential Conservation Practices (Code) Grouped by Resource Concern

Reduce or Prevent Sediment Transported to Surface Water

- **Sediment Basin (350) -** A basin constructed with an engineered outlet, formed by constructing an embankment, excavating a dugout, or a combination of both.
- **Stormwater Runoff Control (570) -** Measures or systems to control the quantity and quality of stormwater runoff.
- **Vegetative Barrier (601) -** Permanent strips of stiff, dense vegetation established along the general contour of slopes or across concentrated flow areas.
- **Water and Sediment Control Basin (638) -** An earth embankment or a combination ridge and channel constructed across the slope of a minor drainageway.

Reduce or Prevent Compaction

- **Access Control (472) -** The temporary or permanent exclusion of animals, people, vehicles, or equipment from an area.
- **Conservation Cover (327) -** Establishing and maintaining permanent vegetative cover.
- **Controlled Traffic Farming (334) -** Controlled traffic farming (CTF) is confining all high load wheel/track traffic from farm equipment to specific lanes or tramlines (traffic pattern) in crop fields year after year.
- **Deep Tillage (324) -** Performing tillage operations below the normal tillage depth to modify adverse physical or chemical properties of a soil.
- **Grazing Land Mechanical Treatment (548) -** Modifying physical soil and/or plant conditions with mechanical treatments.
- **Range Planting (550) -** The seeding and establishment of herbaceous and woody species for the improvement of vegetation composition and productivity of the plant community to meet management goals.

Reduce or Prevent Organic Matter Depletion & Soil Organism Habitat Loss or Degradation

- **Conservation Cover (327) -** Establishing and maintaining permanent vegetative cover.
- **Critical Area Planting (342) -** Establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical, or biological conditions that prevent the establishment of vegetation with normal seeding/planting methods.
- **Pasture and Hay Planting (512) -** Establishing adapted and compatible species, varieties, or cultivars of perennial herbaceous plants suitable for pasture or hay production.
- **Range Planting (550) -** The seeding and establishment of herbaceous and woody species for the improvement of vegetation composition and productivity of the plant community to meet management goals.
- **Soil Carbon Amendment (336) -** Application of carbon-based amendments derived from plant materials or treated animal byproducts.
- **Windbreak/Shelterbelt Establishment and Renovation (380) -** Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.

Potential Conservation Practices (Code) Grouped by Resource Concern

Improve or Maintain Terrestrial Habitat for Wildlife and Invertebrates

- **Brush Management (314) -** The management or removal of woody (non-herbaceous or succulent) plants including those that are invasive and noxious.
- **Conservation Cover (327) -** Establishing and maintaining permanent vegetative cover.
- **Early Successional Habitat Development/Mgt. (647) -** Manage plant succession to develop and maintain early successional habitat to benefit desired wildlife and/or natural communities.
- **Herbaceous Weed Treatment (315) -** The removal or control of herbaceous weeds including invasive, noxious, prohibited, or undesirable plants.
- **Structures for Wildlife (649) -** A structure installed to replace or modify a missing or deficient wildlife habitat component.
- **Upland Wildlife Habitat Management (645) -** Provide and manage upland habitats and connectivity within the landscape for wildlife.
- **Wildlife Habitat Planting (420) -** Establishing wildlife habitat by planting herbaceous vegetation or shrubs.
- **Windbreak/Shelterbelt Establishment and Renovation (380) -** Establishing, enhancing, or renovating windbreaks, also known as shelterbelts, which are single or multiple rows of trees and/or shrubs in linear or curvilinear configurations.

Improve or Maintain Plant Structure and Composition

- **Access Control (472) -** The temporary or permanent exclusion of animals, people, vehicles, or equipment from an area.
- **Brush Management (314) -** The management or removal of woody (non-herbaceous or succulent) plants including those that are invasive and noxious.
- **Conservation Cover (327) -** Establishing and maintaining permanent vegetative cover.
- **Critical Area Planting (342) -** Establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical, or biological conditions that prevent the establishment of vegetation with normal seeding/planting methods.
- **Fence (382) -** A constructed barrier to animals or people.
- **Grazing Land Mechanical Treatment (548) -** Modifying physical soil and/or plant conditions with mechanical treatments.
- **Grazing Management (528) -** Managing vegetation with grazing and browsing animals to achieve specific ecological, economic, and management objectives.
- **Herbaceous Weed Treatment (315) -** The removal or control of herbaceous weeds including invasive, noxious, prohibited, or undesirable plants.
- **Pasture and Hay Planting (512) -** Establishing adapted and compatible species, varieties, or cultivars of perennial herbaceous plants suitable for pasture or hay production.
- **Range Planting (550) -** The seeding and establishment of herbaceous and woody species for the improvement of vegetation composition and productivity of the plant community to meet management goals.

Potential Conservation Practices (Code) Grouped by Resource Concern

Reduce Wildfire Hazard from Biomass Accumulation (or address other safety concerns)

- **Access Control (472) -** The temporary or permanent exclusion of animals, people, vehicles, or equipment from an area.
- **Access Road (560) -** An access road is an established route for equipment and vehicles.
- **Brush Management (314) -** The management or removal of woody (non-herbaceous or succulent) plants including those that are invasive and noxious.
- **Dry Hydrant (432) -** A non-pressurized permanent pipe assembly installed to permit withdrawal of water by suction from a water source.
- **Firebreak (394) -** A permanent or temporary strip of ground cleared to bare soil or planted with fire-resistant vegetation meant to stop the spread of fire.
- **Fuel Break (383) -** A strip or appropriately sized block of land on which the vegetation, debris, and litter have been reduced and/or modified to control or diminish the spread of fire.
- **Grazing Management (528) -** Managing vegetation with grazing and browsing animals to achieve specific ecological, economic, and management objectives.
- **Herbaceous Weed Treatment (315) -** The removal or control of herbaceous weeds including invasive, noxious, prohibited, or undesirable plants.
- **Woody Residue Treatment (384) -** The treatment of residual woody material that is created due to management activities or natural disturbances.

Additional Conservation Considerations

This section provides examples of solar siting considerations and conservation principles that address a wide range of topics on solar farms. These considerations do not replace state-specific guidance or regulations, and it is recommended to seek local expertise when making conservation decisions.

Siting Considerations

Farmers and ranchers know their land best and should consider the intrinsic land characteristics, productivity, and location access in solar siting decisions on their land. Open agricultural land, such as cropland, is often highly desirable from a land and siting perspective. Access to high quality, low mineral content water should also be considered to ensure that cleaning and maintenance of the panels will be practical without compromising agricultural needs. Proximity to transmission infrastructure, topography, shading, land costs, and zoning ordinances are frequently considered by developers as primary factors that influence project siting. Additionally, providing a secure perimeter where only authorized visitors have access to the site should be prioritized to prevent damage to not only the solar panels and equipment, but also soils, vegetation, and other infrastructure.

Landowners, farmers, and ranchers can work with the appropriate solar development representative to find and agree upon alternative locations that protect the production potential of the best farmland, key wildlife habitat, or sensitive areas such as wetlands, and look to marginal land, unproductive or hard-to-farm fields, or abandoned fields that do not displace active production.

Additionally, when working with a solar developer to determine the solar array location, landowners may consider first contacting local NRCS staff or other conservation experts to identify resource concerns and to discuss location alternatives and conservation practices that maximize natural resource benefits and minimize the potential impacts to agricultural operations and farmland.

Consider the following:

- Protect prime farmland by prioritizing marginal, unproductive, or abandoned fields, when possible, for siting of solar arrays.
- Identify alternative siting locations on the farm that minimize impacts to highly erodible land, wetlands, threatened and endangered species, and other resource concerns such as soil erosion or water run-off.
- For continued agricultural use during the lifecycle of the solar array, also consider:
  - The location's access to water and other necessary farm infrastructure.
  - Working with NRCS conservation planners or other local experts to assess on-site resource status (soil health, rangeland health, pasture condition, etc.) prior to the start of construction.
  - Enhancing knowledge and understanding by accessing the many resources available to the public (a non-exhaustive list is included in the appendix of this document), such as the AgriSolar Clearinghouse which connects farmers, land managers, and researchers with trusted resources to support the growth of co-located solar and agriculture.

Design Considerations

Solar array design and structure vary greatly depending on the location, developer, and the landscape, as well as local zoning and relevant laws and regulations. Arrays can be constructed with small panel-row spacing to maximize solar energy generation per acre or spaced wider and elevated to accommodate for animal grazing, farm equipment access, pollinator habitat, and even crop production. Ground mounted solar arrays typically use steel or aluminum support structures. These structures must be fixed to the ground to secure the solar array. Support structures vary from minimally intrusive driven or helical posts to the use of deep-set concrete piers and other more permanent structures. The type of support structure (racking) also depends on the type of array and tracking system. Panels may be mounted vertically or at a fixed angle or move via single- or dual-axis tracking (see below for examples). Fixed-mount panels do not move, whereas single-axis trackers rotate on a single axis and dual-axis trackers move across two axes of rotation, following the path of the sun throughout the day. Visual examples of these different systems and designs are included below.

Returning the land to agricultural use after decommissioning will require careful planning. This should be discussed very early in the initial planning stages. Array structures and designs can be chosen that are more conducive to full removal during decommissioning. The widespread use of gravel, concrete, and other permanent structures in the construction of solar arrays can severely inhibit the complete decommissioning after the end of the solar land lease. If the intent to revert back to agricultural land is communicated at the beginning of the process, steps can be taken to minimize the use of permanent structures and groundcover during construction.

Example of a portable, ballasted solar racking system. Photo credit – United Power Partners

Broccoli under raised single-axis tracking solar panel rows. Photo credit – American Farmland Trust.

Consider the following:

- Inform the solar developer (or representative) of land concerns or priorities.
- Discuss the use of solar array designs that support or improve the long-term potential for future agricultural use.
- Ensure the array structure is designed with driven-posts, helical anchors, or other minimally intrusive structural supports such as above-ground ballasts that are fully and easily removable during decommissioning.
- Design the site and array to address potential hydrological impacts to wetlands, streams, or buffer zones, and to protect water quality by managing runoff flow with vegetation, diversions, terraces, basins, and other earthworks.
- Ensure local wildlife movement is not critically impaired by the design or related characteristics such as perimeter fencing. For example, design solar arrays and boundary fences to maintain travel corridors between areas of key wildlife habitat.
- For continued agricultural use during the lifecycle of the solar array, also consider:
    - An array design that provides added row-spacing for equipment access, and appropriate panel height and spacing to provide adequate sunlight for vegetation.
    - A design that accommodates farmer access, farm machinery, and/or animal grazing and security, including secure fencing, adequate gate access, and safe operation and maintenance in and around panels.

Image of the back of a single axis tracker mount, gearbox and motor shaft. Panels rotate their current orientation to horizontal to continually maximize sunlight exposure and energy production. Photo credit – Preston Irwin, USDA-NRCS

- Working with local NRCS or other conservation experts to discuss the suitability for grazing, crop, or specialty crop production within the site.

Conservation During Construction

Solar projects are subject to state and local environmental permitting laws and regulations, however there may be some additional actions that can help preserve on-site resources. Developers typically subcontract with construction companies to design and construct the facility. Making sure all stakeholders, including subcontractors, agree on soil, vegetation, and storm water management plans, can improve environmental outcomes from construction activities.

Avoid construction activities during or right after significant rain events to minimize soil compaction. Soil compaction can be minimized during this phase of solar development by avoiding construction activities during or right after significant rain events, as soils are far more resilient in dry conditions. Also, having dedicated equipment staging and construction pathways helps limit widespread compaction.

Site preparation and construction are the most impactful phases of solar development on soils. Significant grading is commonplace, and more likely to be used for some types of photovoltaic systems than others (i.e., fixed/non-moving or single axis-tracking arrays were designed for flat terrain and often require more grading). Prioritizing the protection of soils, especially prime farmland soils, can help protect soil health and future agricultural productivity. Minimizing or eliminating grading altogether can preserve existing vegetation, which in turn protects the loss of topsoil from erosion. Where grading is necessary (for siting equipment or access roads, for example), maintain all topsoil, reapply on site, and cover with locally adapted vegetation to preserve this important natural resource.

Minimizing soil erosion during site preparation and construction also protects nearby waterways and wetlands. Vegetative ground cover works well to protect soils from erosion and may be planted and established prior to the start of construction, and damaged or bare areas can be re-seeded during construction. If possible, avoid areas where the ground is covered by a community of bacteria, lichens, or mosses (collectively referred to as a microbiotic soil crust), or at least minimize disturbance as much as possible since these beneficial communities take much longer to establish than vegetation.

Consider the following:

- Plan construction methods and equipment use carefully to minimize soil and site impacts during construction. Conduct remediation efforts to mitigate natural resource impacts upon completion of construction.
- Ensure heavy machinery that can cause soil compaction is used only when soils are dry and resilient, avoiding use after heavy rains when equipment can cause significant damage to soil structure and vegetation.
- Limit disturbance and compaction from heavy machinery to only the most necessary areas such as access roads and other areas with frequent or intense use. Designate specific refueling areas to limit fuel spillage and contamination.
- Protect and maintain soil integrity during construction. Minimize site grading as much as possible.
- Preserve topsoil by planting vegetation, applying mulches, and installing erosion control mats or socks.

Image of dual axis tracking mount. Panels rotate horizontally and vertically to continually maximize sunlight exposure to panels and surrounding vegetation. Photo credit - USDA Photo by Lance Cheung

Oat threshing between vertically mounted bi-facial panels. Vertical bifacial panels have photovoltaic cells on both sides of the panel and are installed facing east and west. They can generate electricity on the east facing side in the morning, and the west face in the afternoon. The vertical orientation allows for greater row spacing and flexible agricultural use simultaneously. Credit – Next2Sun

- Construct and maintain rainwater retention zones, such as bioswales, where necessary.
- For continued agricultural use during the lifecycle of the solar array, also consider:
  - Working with the developer to ensure that compaction and/or other negative impacts incurred during construction are remediated after construction is completed to a mutually agreed upon state.

Operation and Maintenance

The land-use and local climate will be driving factors in determining operation and maintenance (O&M) of the solar array. If agricultural activities or production are planned on site, the landowner should work with the appropriate solar development representative to discuss agricultural plans and ensure O&M plans align with the planned production or land-use. If the landowner wishes to maintain the potential for future agricultural use, then the O&M plan should support soil health protection or improvement and not hinder any future agricultural potential. If there are no known plans for agricultural use, there is still a unique opportunity within O&M plans to maintain vegetation, improve soil health, and operate water management practices that provide enhanced ecosystem services and improved natural resource protections in and around the solar array. Healthy soils covered with vegetation can provide O&M benefits as well. Vegetative covers can reduce wind erosion and damage to panels from wind blown soil particles. Soils covered with vegetation are also more resistant to runoff and concentrated flows, which can damage infrastructure and equipment.

Solar panels can significantly affect ecohydrology by redistributing moisture from precipitation and casting a widely variable amount of shade. Fixed panel designs create a more static and densely shaded area, while tracking systems tend to create varied and less densely shaded areas. Consider using native plant species that are adapted to the site for ground cover or pollinator habitat and time the mowing to not adversely affect the blooming of pollinator species. Native species can provide soil health benefits and can also encourage local fauna to visit, inhabit, or nest within the array. Destructive or nuisance fauna may be planned for and excluded through fencing or other means.

Note: Sometimes, the developer will sell the facility after it is constructed or subcontract with an O&M company after construction. Understanding the role of all entities involved will help ensure expected outcomes from O&M plans.

Consider the following:

- Ensure management plans address the changes in site hydrology due to the redirected precipitation and impervious surface impact of the solar panels.
- Maintain a healthy perennial vegetative cover on the soil under and between solar panel rows to encourage infiltration and prevent erosion.
  - Desirable vegetation characteristics include native species, pollinator-friendly, perennial, cover crops, and/or plant species regionally important to wildlife.
- Plant windbreaks perpendicular to the prevailing wind direction to reduce wind erosion.
- Utilize dust control measures on unpaved roads and surfaces.

Established pollinator habitat in and around solar array. Photo credit: National Renewable Energy Laboratory

- For continued agricultural use during the lifecycle of the solar array, also consider:
  - Plant vegetation to enhance biodiversity, soil health, and other ecosystem services.
  - Avoid unnecessary use of chemical pest or weed management to protect wildlife, water quality, and soil health.
  - Manage vegetation to maximize soil health benefits, such as grazing of sheep on a regular basis, mulching vegetation in place after mowing, and avoiding soil disturbance such as tilling to manage vegetation.
  - Develop maintenance plans, including provisions for site access, in cooperation with the farmer or rancher to ensure compatibility with planned agricultural activities on site or to minimize disturbance to animals or crops.

Decommissioning and Return to Agriculture

Owning property on which a solar energy facility will be constructed presents unique issues related to project decommissioning. Landowners should proactively plan for the full life cycle of the project and ensure that the solar lease agreement has explicit roles and responsibilities for decommissioning, especially protections for the landowner, as labor and land restoration costs can be very high. The regulatory landscape varies from state to state. Many states have developed statutes or regulations that set forth requirements for decommissioning solar energy projects, which generally provide assurances to landowners that impacts to their property will be mitigated and the land will be reclaimed at the end of the project's life.[8] States continue to demonstrate interest in ensuring solar project applicants have effective and responsible decommissioning plans, reasonably estimate the decommissioning costs, and have the financial capability needed to implement the plan. Decommissioning requirements also vary from state to state, but the most common requirement is a demonstration of the developer's financial capability to decommission the project. Performance bonds, letters of credit, corporate guarantees, cash escrows, or other securities are often accepted by states to guarantee the removal of solar projects and the restoration of the land back to a predetermined condition. Bonding provisions often require proof of liability insurance for damages resulting from decommissioning activities.

As with construction, decommissioning of a solar array can have a significant impact on natural resources. The presence of heavy machinery and removal of in-ground structural supports, buried cables, and other equipment can cause significant soil disturbance, compaction, erosion, and damage to vegetation. Avoiding construction activities during or right after significant rain events and having dedicated equipment staging and construction pathways help limit widespread compaction and soil disturbance. Keeping vegetative ground cover in place or establishing new ground cover prior to or immediately following decommissioning can help protect the site from soil erosion during and after this vulnerable phase.

Consider the following:

- Review the statutes and regulations governing solar project decommissioning for the state and municipality and understand the roles and requirements of all parties involved.
- Work with the project owner during the initial planning to develop an agreement for decommissioning and land restoration plans.
- Retain legal representation to advise on decommissioning.
- Maintain or plant vegetative ground cover to protect bare soil and avoid erosion during array deconstruction and equipment removal.
- Discuss low-impact removal methods and equipment with responsible parties to minimize soil and site impacts during decommissioning.
- Ensure removal of all materials from the site and the proper disposal, recycling, or reuse of all materials.

Ensure there are planned remediation efforts to mitigate natural resource impacts upon complete removal of the array and restore property to an agreed upon condition within the provided timeframe for completion of decommissioning activities.

[8] See appendix for decommissioning related resources.

Conclusion

There is great opportunity to increase conservation outcomes on utility-scale solar projects. The NRCS conservation planning process can be employed to help landowners and solar facility operators meet their conservation goals. The NRCS offers a suite of conservation practices that can be planned to address natural resource concerns inherent in the siting, construction, operation, and decommissioning of solar projects. Many of the example practices provided in this document are compatible with solar arrays and associated equipment without requiring any major modifications and may be helpful in increasing the conservation outcomes on utility-scale solar projects.

It is not uncommon for solar arrays to have a useful lifespan of 20 to 30 years. Therefore, long-term planning is crucial to ensure the needs of both the solar facility and the natural resources will be met. Proactive planning for the project's full life cycle is important to ensure long term success, including decommissioning and land restoration at the end of the project's life. Many states have statutes and regulations governing the decommissioning of solar projects, removal of materials, and ensuing land restoration efforts.

When planning for continued agricultural use on solar operations, it is vital to plan not only for the existing agricultural practices and equipment, but any anticipated farming changes over the next two to three decades as well. As interest in agrivoltaics and ecovoltaics increases nationally, research on compatible agricultural production and the related impacts of integrating agriculture within solar electricity generating systems is also growing. This document outlines some of the challenges and opportunities associated with integrating agricultural production with utility-scale solar projects. Future publications may expand on other ways USDA may assist farmers and ranchers with agrivoltaics and ecovoltaics.

Appendix: Additional Resources

U.S. Department of Agriculture

NRCS Conservation Considerations for Solar Farms https://www.nrcs.usda.gov/sites/default/files/2024-03/Conservation_Considerations_Solar_Farms.pdf

NRCS Field Office Technical Guide – https://efotg.sc.egov.usda.gov/#/

USDA Service Center Locator Tool – https://www.farmers.gov/working-with-us/service-center-locator

Agrivoltaics: Coming Soon to a Farm Near You? - https://www.climatehubs.usda.gov/hubs/northeast/topic/agrivoltaics-coming-soon-farm-near-you

Agrivoltaics: Pairing Solar Power and Agriculture in the Northwest - https://www.climatehubs.usda.gov/hubs/northwest/topic/agrivoltaics-pairing-solar-power-and-agriculture-northwest

Common Ground for Agriculture and Solar Energy: Federal Funding Supports Research and Development in Agrivoltaics – https://www.ers.usda.gov/amber-waves/2024/april/common-ground-for-agriculture-and-solar-energy-federal-funding-supports-research-and-development-in-agrivoltaics/

Department of Energy and National Energy Laboratories

Farmer's Guide to Going Solar – DOE/SETO - https://www.energy.gov/eere/solar/farmers-guide-going-solar

InSPIRE - Innovative Solar Practices Integrated with Rural Economies and Ecosystems - https://openei.org/wiki/InSPIRE

Solar Soil: Ground-mounted Solar and Soil Related Ecosystem Services - https://solarsoil.evs.anl.gov/

Capital Costs for Dual-Use Photovoltaic Installations: 2020 Benchmark for Ground-Mounted PV Systems with Pollinator-Friendly Vegetation, Grazing, and Crops – https://www.nrel.gov/docs/fy21osti/77811.pdf

Department of the Interior

U.S. Fish and Wildlife Service (FWS) Energy Project Review – https://www.fws.gov/node/265743

Bureau of Land Management Solar Energy Resources – https://blmsolar.anl.gov/

External Resources

International City/County Management Association Solar@Scale project - https://icma.org/programs-and-projects/solarscale

American Planning Association: Visual Guide to Agrivoltaics and Wildlife-Friendly Solar https://planning.org/blog/9253223/visual-guide-to-agrivoltaics-and-wildlife-friendly-solar/

AgriSolar Clearinghouse: AgriSolar Ownership, Lease, and Land Planning https://www.agrisolarclearinghouse.org/agrisolar-ownership-lease-and-land-planning/

American Farmland Trust: Smart Solar - https://farmland.org/solar/

Farmland Information Center: Smart Solar® - https://farmlandinfo.org/solar-siting/

Pollinator Habitat Aligned with Solar Energy (PHASE) Tools and Resources – https://rightofway.erc.uic.edu/phase-toolkits/

Great Plains Institute's Best Practices: Photovoltaic Stormwater Management Research and Testing (PV-SMaRT) – https://betterenergy.org/wp-content/uploads/2023/01/PV-SMaRT-Best-Practice.pdf

University of Illinois, Sustainably Colocating Agricultural and Photovoltaic Electricity Systems (SCAPES) Project - https://scapes.illinois.edu/

Rutgers University Agrivoltaics Program - https://agrivoltaics.rutgers.edu/

Renewable Energy Wildlife Institute (REWI) – https://rewi.org/about-us/our-work/solar/

Association of Fish and Wildlife Agencies: Communication Framework for Solar Energy Proponentss – https://www.fishwildlife.org/application/files/6317/1770/4984/Communications_Framework_for_Solar_Energy_Project_Proponents_and_State_Fish_and_Wildlife_Agencies_.pdf

University of Massachusetts Clean Energy Extension: Dual-Use: Crop and Livestock Considerations – https://ag.umass.edu/clean-energy/fact-sheets/dual-use-crop-livestock-considerations

Solar Power Europe: AgriSolar Handbook – https://www.solarpowereurope.org/insights/thematic-reports/agrisolar-handbook-1

Center for Rural Affairs: **Best Practices for Adopting Dual-Use Solar Ordinances** - https://www.cfra.org/publications/best-practices-adopting-dual-use-solar-ordinances

Association of Fish and Wildlife Agencies (AFWA): Solar Beneficial Management Practice Database - https://www.fishwildlife.org/solar-beneficial-management-practice-database#home/

Lewis Roca: End of Life Panning for Renewable Energy Projects – https://www.lewisroca.com/industries-renewable-energy-end-of-life-planning

Solar and Storage Industries Institute: Understanding Barriers to Agrivoltaics: A Survey Approach - https://www.ssii.org/wp-content/uploads/2024/09/SI2_FARMS-Survey-Report_Final.pdf

Cornell University Campus Sustainability Office: Solar Energy Projects - https://sustainablecampus.cornell.edu/buildings-energy/solar-energy#SolarFarm

United Power Partners: Ballasted racking from PowerField Energy scales up to utility-scale installation - https://unitedpowerpartners.com/ballasted-racking-from-powerfield-energy-scales-up-to-utility-scale-installation/

Conservation Guidance for Utility-Scale Solar Projects