Solar Pollinator Vegetation
Implementation Manual

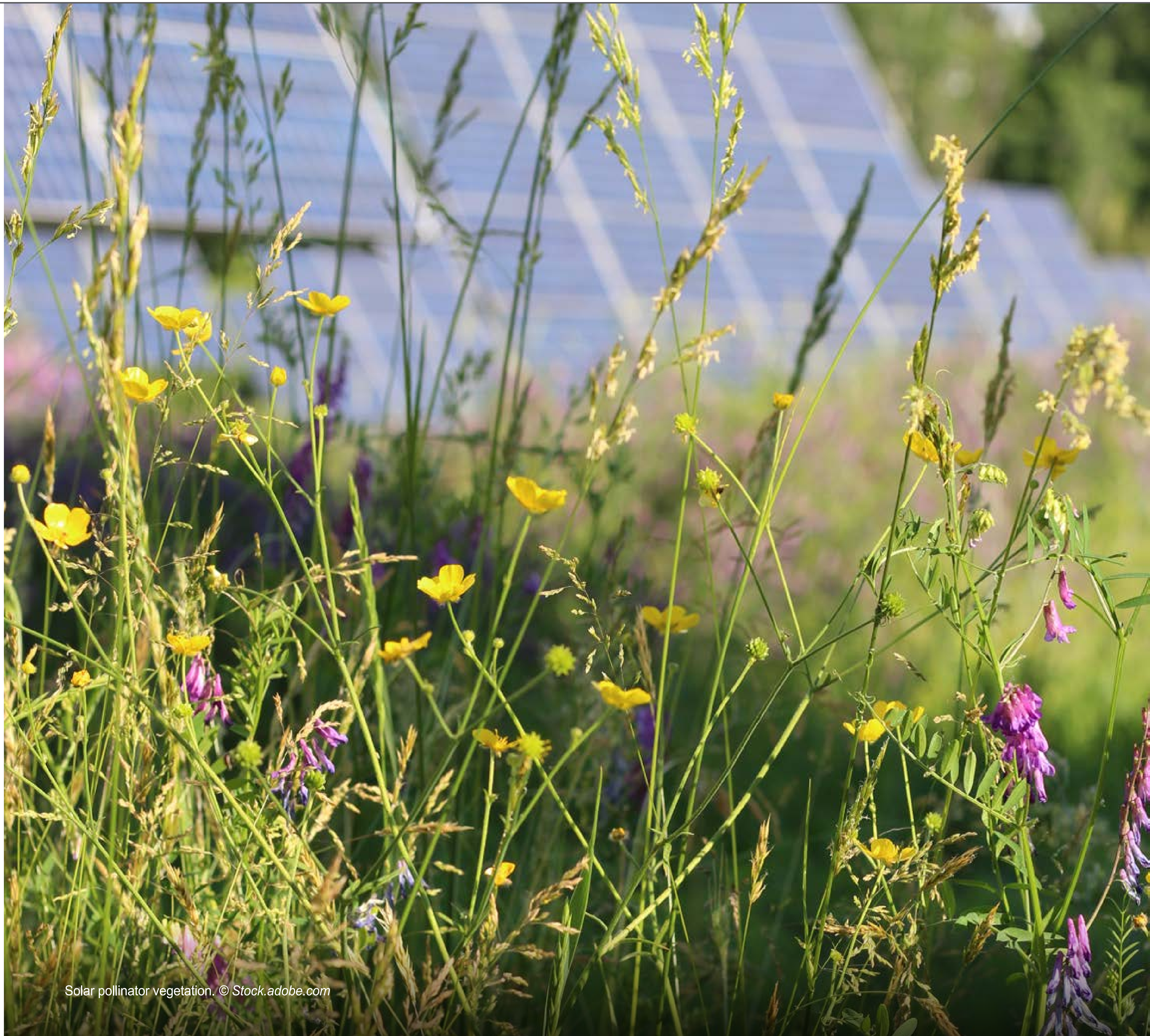
UIC ENERGY RESOURCES CENTER

Stantec

About This Manual

This material is based upon work supported by the United States (U.S.) Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Number DE-EE0009371 titled *Evaluation of Economic, Ecological, and Performance Impacts of Co-Located Pollinator Plantings at Large-Scale Solar Installations.*

This manual is intended as a decision support guide to project teams tasked with planning and implementing pollinator vegetation on utility-scale solar projects. Vegetation involves planning, managing, and adapting living organisms subject to subtle changes in conditions, climate, and disturbance regimes. While comprehensive, it is not intended as a substitute for first-hand knowledge of individual project conditions or constraints. It is ultimately the responsibility of project managers and vegetation specialists to have the appropriate technical knowledge and understanding of their own sites and apply the information within this manual in the most appropriate manner.



Solar pollinator vegetation. © *Stock.adobe.com*

Contents

Executive Summary

Utility-scale solar is a critical component of the clean energy transition occurring across the U.S. In addition to generating clean renewable energy, utility-scale solar operations also hold potential for providing ecological and economic benefits for the communities within which they operate. This manual supports utility-scale solar development in considering one area that can provide ecological and economic benefits – pollinators.

The widespread decline of pollinator species across North America over the past few decades is well-established. Declines of insect pollinators have been attributed to threats from habitat loss, pesticide exposure, diseases, climate change, and other causes. Utility-scale solar provides an opportunity to contribute positively to pollinator protection and conservation through habitat creation, reduced pesticide use, and the establishment of resilient landscapes that buffer against the effects of disease, climate change, and other stressors. Of course, actions taken for pollinators may support other aspects of biodiversity and ecosystem services sustained by healthy species and resilient habitats.

Whether pollinator conservation is a primary concern, or simply a component of wider project objectives, this manual is intended to offer guidance and direction to technical users working directly on vegetation management planning, contracting, or implementation for utility-scale solar developments. Section 1 describes how to approach this manual and guides users to the appropriate sections for key interests and questions. Sections 2 and 3 help users identify key constraints and goals for planning vegetation for pollinators. Sections 4 through 11 inform vegetation planning, establishment, and maintenance from site preparation through site decommissioning. Because contracting is an integral part of providing the personnel and expertise needed for successful solar pollinator vegetation management, Section 12 includes a series of suggested practices to help guide contracting.

A theme throughout this manual is encouraging thoughtful planning and clearer communications regarding solar pollinator vegetation. Successful and efficient vegetation management on a utility scale requires planning and preparation early in project development and adaptive strategies throughout the project lifespan. While often only a portion of a utility-scale solar project's budget, vegetation success or setbacks can have a significant impact on maintenance and operations costs, ecological and economic benefits, and public perception of the project.

Guidance provided in this manual is intended to apply to a range of landscapes and scenarios. Not all examples and suggestions may apply to all projects. Like many aspects of solar pollinator vegetation – adaptation is key. We encourage users to use and adapt guidance within this manual to achieve their goals for pollinator habitat wherever they are working.

Aerial view of solar farm. © *Stock.adobe.com*

Section 1
Introduction

WHAT'S IN THIS SECTION?

- Purpose and Need
- How to Use This Manual
- Acknowledgments

Purpose and Need

Establishing and maintaining vegetation can be challenging in any context. From a formal landscaped garden to an ecological restoration of a specific plant community, each setting presents a series of goals and preferences as well as practical constraints. Utility-scale solar development is a relatively new landscape facing a similar array of opportunities and challenges.

This manual is intended for practitioners supporting vegetation establishment at utility-scale solar sites in non-arid regions of North America. While many of the considerations discussed in this manual may be applicable to arid regions, some vegetation management and planning considerations will likely require adaptation based on climate differences and local conditions. Adaptation may include vegetation specialists tasked with supporting vegetation management planning, or it may be project managers reviewing vegetation plans and making key decisions on projects. In either perspective, this manual is a tool to aid in decision making associated with planning, design, and implementation of vegetation that is tailored to support pollinators – both native, wild species as well as commercially-managed ones, like honeybees.

How to Use This Manual

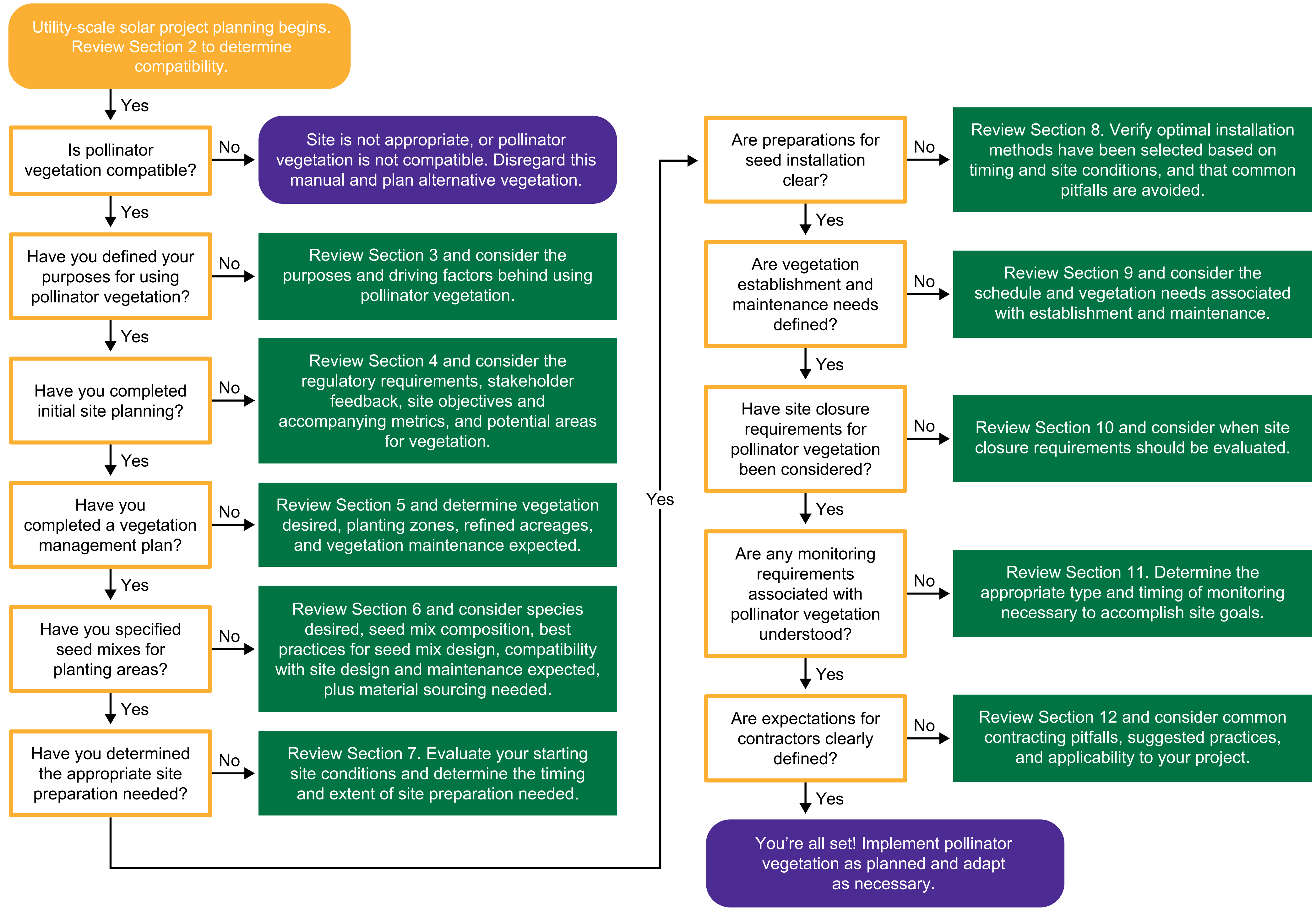
This manual is organized into sections aligned with the decision making process commonly used on utility-scale solar projects. Utility-scale solar project planning can be dynamic. Changes in site designs, community feedback, public service filing provisions, and other factors may alter project plans up until final approvals are obtained. These may cause vegetation specialists and project managers to reconsider decisions over the course of a project. We encourage users to revisit sections of this manual when making initial, or adaptive, decisions regarding pollinator vegetation implementation and management.

The decision tree in Figure 1.1, on the next page, provides users with a quick reference for common decision points in planning pollinator solar vegetation. This can help practitioners identify the sections most applicable to the stage of decision making needed on their projects.

Vegetation beneath solar photovoltaic panels. © *Stock.adobe.com*

Solar farm with pollinator vegetation throughout. © *Stock.adobe.com*

Figure 1.1. *Pollinator solar vegetation planning decision tree and quick reference guide for manual sections.*



Acknowledgements

This manual is also the result of input and collaboration across many industry, agency, and conservation organization partners, including (in alphabetical order):

Alchemy Renewable Energy

American Clean Power

Argonne National Laboratory

Avangrid

Clearway Energy

Duke Energy

EDP Renewables North America

Electric Power Research Institute (EPRI)

Enel

Energy & Wildlife Action Coalition

ENGIE

Evergy

Greenbacker Capital

Illinois Department of Natural Resources (IDNR)

Illinois Natural History Survey

Inovateus

Invenergy

Lancaster University

Lightsource BP

Michiana Area Council of Governments

Michigan State University

Minnesota Board of Water & Soil Resources (BWSR)

Monarch Vegetation Services

National Grid Renewables

National Renewable Energy Laboratory

NextEra Energy

Pollinator Partnership

Renewable Energy Wildlife Institute (REWI)

Resource Environmental Solutions (RES)

Sol Systems

Solar Energy Industry Association (SEIA)

Stantec

The Bee & Butterfly Habitat Fund

TotalEnergies Renewables USA, LLC

University of Dayton

University of Florida

University of Illinois – Chicago (UIC)

University of Illinois Urbana-Champaign (UIUC)

U.S. Fish and Wildlife Service (USFWS)

U.S. Geological Survey / Cornell University

Xcel Energy

Carpenter Bees *(Xylocopa spp.)* Wild lupine *(Lupinus perennis)*. *Photo courtesy of Stantec*

Section 2
Is Pollinator Vegetation Compatible?

Honey bee on white milkweed plant. © *Stock.adobe.com*

WHAT'S IN THIS SECTION?

- Solar Vegetation Management
- Vegetation Requirements
- What is Pollinator Vegetation?
- What is Solar Pollinator Vegetation?
- How to Determine Pollinator Vegetation Compatibility?

Solar Vegetation Management

Vegetation management of solar sites represents a growing area of land management. In 2021, the utility-scale solar capacity was 80.2 gigawatts (GW) (SEIA/Wood Mackenzie 2021) and a recent study suggests that could increase to between 608 and 1,000 GW of capacity, if not more, by 2035 (US DOE 2021). It may require over 3.5 million acres of land to support solar energy capacity at this level (Ong et al. 2013; US DOE 2021). The growth in solar development across the U.S. has gained the attention of communities, conservation organizations, and government agencies interested in the potential co-located benefits of solar facility development for pollinators, carbon sequestration, and alternative agriculture systems (Dolezal et al. 2021, Macknick et al. 2013, Walston et al. 2021).

Decision making around which vegetation communities to establish, how to maintain operations compatibility, and when or where to incorporate pollinator vegetation (or other co-located uses) has long-term implications for site operations and maintenance.

Key Takeaways for Pollinator Vegetation Compatability

- Primary requirements of vegetation on solar facilities are to support safe operations of the energized facilities onsite.
- Co-located benefits, including pollinator habitat, must be compatible with the constraints and configurations posed by regulations, site design, and operational needs.
- Solar pollinator vegetation includes a spectrum of vegetation types – each providing certain types of pollinator benefits.

Vegetation Requirements

Establishing and maintaining vegetation on a solar facility is a common requirement for many solar projects, regardless of size, scale, and location. Utility-scale solar projects are constructed in landscapes throughout North America. In some locations, as with pasture, hayfields, or semi-arid rangelands, vegetation may already be present at the time of construction. On the other hand, many other projects involve revegetating lands previously used for row crop agriculture with some form of perennial vegetation. Regardless of context, vegetation is an integral aspect of solar project planning and maintenance.

The primary requirements of vegetation on solar facilities are stabilizing soils and supporting safe operations of the energized facilities onsite. Co-located benefits, including pollinator habitat, must be compatible with the constraints and configurations posed by regulations, site design, and operational needs.

Addressing these requirements makes solar vegetation management both a short-term and long-term priority for projects. A National Pollution Discharge Elimination System (NPDES) permit, often regulated in the form of a local or state stormwater permit, is a significant driver during the construction phase of the facility. Project developers are required by regulations to limit stormwater discharges and non-point source pollution by preventing soil erosion from occurring. Establishing permanent vegetative cover in disturbed areas is a key metric required to stay compliant with an active stormwater permit and for closing NPDES permits after construction is complete. Federal NPDES specifications require the establishment of at least 70% permanent vegetative cover, although some states may have higher cover targets. Specific permit conditions will vary state by state. Following closure of authorizing permits, vegetation management over the duration of solar facility operation is required for the safe, reliable, and cost-effective energy capture and generation along with maintaining vegetation-related compliance included in a project's individual operating permit.

Defining Terms

Pollinator vegetation - Plant communities that contribute to foraging, nesting, and/or overwintering resources for wild or commercial insect pollinators.

Solar pollinator vegetation - Plant communities that are compatible with solar facility operations and contribute foraging, nesting, and/or overwintering resources for wild or commercial insect pollinators.

Compatible vegetation - Plant species and growth forms that are consistent with the intended use of the site (Miller 2021).

Pollinator-friendly vegetation - Pollinator vegetation that has met specific criteria outlined by an organization or agency.

Native vegetation - Plant species indigenous to a location that developed over hundreds or thousands of years in a specific geographic region or ecosystem.

Naturalized vegetation - Non-native plant species introduced intentionally or by accident that can persist in ecosystems with little to no human intervention. Ecologically, naturalized species may have beneficial or negative effects. Invasive species are a sub-category of naturalized plants that cause disruption or degradation of a plant community.

Invasive species - A plant that is both non-native and able to establish, grow and spread quickly, causing disruption to native communities or ecosystems.

Noxious weed – Non-native, invasive plant species regulated by federal or state law because of the potential to cause environmental damage.

What is Pollinator Vegetation?

Recent studies suggest that both wild and commercially managed invertebrate pollinator species are suffering widespread declines in population (Koh et al. 2016, Montgomery et al. 2020, Potts et al. 2016). These declines are driven by several factors including habitat loss and fragmentation, exposure to pesticides and pathogens, invasive species, climate change, and the interaction of these (Dave Goulson et al. 2015, LeBuhn and Vargas Luna 2021, Potts et al. 2010). Conversion of land for utility-scale solar developments is recognized as an opportunity to conserve invertebrate pollinators and restore ecosystem services through vegetation management that aims to create and maintain pollinator habitat (Blaydes et al. 2022; Walston et al. 2018). Laws and policies are actively changing in response to this need. From 2000 to 2017, there were 109 pollinator-oriented laws or policies passed by state legislators. This number does not include the myriad of federal, tribal, or municipal laws and policies also enacted (Hall and Steiner 2019).

Within this manual, the term "pollinator vegetation" refers to plant communities that contribute foraging, nesting, and/or overwintering resources for wild or commercially managed insect pollinators. One of the primary commercial pollinators, honeybees *(Apis mellifera)*, are native to Europe and utilized for pollinating over 100 commercial crops in the US (Hristov et al. 2020), contributing an estimated $3 to $15 billion of economic value annually (Losey and Vaughn 2006 as cited by Hopwood et al. 2015; USDA 2020). In addition to honeybees, the U.S. is home to thousands of wild, native pollinators including bees, flies, butterflies, moths, wasps, beetles, ants, bats, and hummingbirds (Buchmann and Nabhan 1997).

The vegetation needed to support these species can vary depending on the species or groups targeted. When considering vegetation for pollinators, it is important to define the project's goals, understand the target pollinator's biological needs, and determine the compatibility and maintenance requirements of vegetation selected.

Pollinator vegetation's ability to contribute foraging, nesting, and/or overwintering resources is determined by several plant characteristics. What is considered "pollinator vegetation" can vary. Many definitions of pollinator vegetation recognize the importance of having diverse, perennial vegetation supplying nectar and pollen to various insect pollinators throughout the year. Some definitions also cite the importance of other characteristics such as presence of host plants for certain insects or provision of overwintering or nest sites (Battle et al. 2021, Blaydes et al. 2021, Fiedler et al. 2007, NAPPC 2017, Natural Resources Conservation Service (NRCS) 2009, Rowe et al. 2018). Understanding what type of vegetation pollinators are using and how requirements may differ by species or groups is important to effective management of pollinator vegetation. In general, a site with more diverse vegetation (and thus, characteristics represented) can provide benefits to a wider, more diverse, suite of pollinators as compared to sites with limited vegetation diversity (as summarized by Blaydes et al. 2021). However, some pollinators (like honeybees) are generalist foragers and can thrive in plant communities more frequently treated with mowing and other disturbances (Carman and Jenkins 2016).

The following characteristics are important to understand when considering pollinator vegetation on utility-scale solar projects.

Monarch butterfly on purple coneflower.
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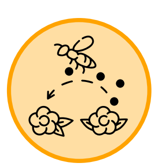
Bloom Time

Widespread reduction of flower availability has been suggested as a contributing factor to pollinator declines (Baude et al. 2016, Scheper et al. 2014). Research suggests that landscapes with resources available throughout the growing season may be beneficial in supporting pollinator populations (Scheper et al. 2015 Timberlake et al. 2019). Spring blooming plants such as spring ephemerals and flowering trees and shrubs are often the most limiting resource available to pollinators (Timberlake et al. 2019). Early blooming plants provide critical food sources for insects that overwinter as adults or for larvae that have recently hatched (Carvell et al. 2017; Moquet et al. 2015). During the summer months, diverse landscapes that provide flowering resources throughout the different life stages of pollinators have been shown to support rich and abundant communities of invertebrate pollinators (Mallinger et al. 2016 as cited by Hopwood et al. 2015). Fall blooming plant species are also important for overwintering pollinators to build up energy reserves that will help them survive until the following spring, including bumble bees which require late season energy for colony development (Pywell et al. 2005 as cited in Hopwood et al. 2015, Sakata & Yamasaki 2015).

Nectar and Pollen Production



Pollinators use nectar and pollen produced by flowering plants as food resources (Parreño et al. 2022). Pollen contains protein, fat and other micronutrients, while nectar provides primarily carbohydrates (sugars) for energy (Parreño et al. 2022). Nectar and pollen quality and quantity vary greatly among plant species (Hicks et al. 2016). Thus, a diverse plant community is more likely to provide a wider variety of resources for a larger number of pollinator species (Fründ et al. 2010). A recent meta-analysis of pollinator management on solar facilities demonstrated increased populations of bumble bees resulting from higher quality nutritional resources from native plantings (Blaydes et al. 2021). Managing for some species like bumble bees, which are largely generalists, may entail planting species with the greatest nectar rewards (Goulson et al. 2005). However, many other pollinators are specialists (i.e., they associate with a specific plant species or group) and thus it may be necessary to plant a diverse array of species depending on the goals of the project and the biological needs of target pollinator species (Fowler 2016a, Fowler 2016b, Fowler 2020a, Fowler 2020b).

Host Plants

Many species of butterflies and moths use specific plant species for egg-laying, larval and adult feeding, or overwintering while others are more generalized and use a wider range of plants for these purposes. Specialized relationships between pollinators and host plants can exist at different scales. On the individual level, an individual requires a specific plant species to pollinate. At the community level, certain pollinator species will pollinate certain plant species that may be different from the other pollinators in the community (Dormann 2011). An example of a well-known specialized relationship is the monarch butterfly (Danaus plexippus plexippus). Adult butterflies lay eggs on milkweed plants, which larvae feed on after hatching. Specialist pollinators may be at greater risk of decline than generalist species. These specific plant species relationships make them more vulnerable to alterations in vegetation communities (Potts et al. 2010).

To support the maximum diversity of pollinator species, seed mixes with a diversity of plant species should consider floral needs of generalist and/or specialist pollinators (Fründ et al. 2010) and how these needs align with project goals and compatibility.

Floral Structure

Flowers vary in their physical structure, which in-turn influences the location and accessibility of nectar and pollen for different insect pollinators. Some flowers such as asters have a simple structure with easy to access nectar used by a wide range of generalist pollinators. Other plant species have flower structures that limit access to select pollinator species, promoting a specialized relationship between plant species and a species or group of pollinators (as summarized by Schiestl and Schlüter 2009). An example of this specialized relationship is the violet miner bee (Andrena violae), a specialist which almost exclusively pollinates violets (Viola sp.; Fowler and Droege 2020). Reduced competition for pollen and nectar may benefit the pollinator, while increasing visits by specific species ensures reliable pollination for the plant, which benefits plant reproduction. Potts et al. (2003) found that floral community composition (i.e., the quantity and quality of forage resources present) and the geographic locality of bee communities affect the structure of bee communities and their diversity. When planning pollinator habitat, consider whether specialist species will be priority target, and what plant associations they may have.

Nesting and Overwintering

The importance of vegetation features and diversity to pollinators extends beyond their flowers. Stems, leaves, accumulated thatch woody and pithy materials, and bare soil patches surrounding the plant may offer resources for nesting or overwintering (Blaydes et al. 2021). For example, bumble bees often nest in insulated cavities such as abandoned rodent nests in vegetation or in tunnels burrowed under thatch (Liczner and Colla 2019). A thatch layer may also provide overwintering areas for eggs, larvae, immature, and adult insects. Approximately 1,200 native bee species in North America are tunnel nesting, solitary species (Mader et al. 2013). Nesting locations include abandoned tunnels created by other insects in logs, stumps, dead wood and pithy wildflower or shrub stems, or artificial nest boxes. Approximately 2,800 species of North America's native bee species are ground nesting species, requiring access to the soil surface to excavate a nest (Larsen 2020). One regulatory driver of vegetation management for solar sites is the need to minimize the amount of bare ground to meet local or state stormwater standards. Providing pollinator vegetation for ground nesting bee species may be somewhat limited and is likely dependent on site-specific variables such as soils and vegetation density. While a diverse array of habitat options for nesting and overwintering is likely beneficial to pollinator populations, more research is needed to fully understand the direct benefits of these features to different taxonomic assemblages (Blaydes et al. 2021). When considering nesting and overwintering habitat on utility-scale solar projects, consider including features that provide different nesting conditions such as a grass or leafy thatch layer, plants with hollow or pithy stems, or nesting boxes.

What is Solar Pollinator Vegetation?

In the previous section, we defined pollinator vegetation as plant communities that contribute to foraging, nesting, and/or overwintering resources for wild or managed commercial insect pollinators. In contrast, solar pollinator vegetation is plant communities compatible with solar facility operations that contribute foraging, nesting, and/or overwintering resources for wild or commercial insect pollinators. Solar pollinator vegetation must be compatible with critical energy infrastructure and operations. Compatibility is driven by considerations for the lowest (or leading-edge) panel height, accessibility for maintenance vehicles and personnel, and other safety or security concerns. See Table 2.1 for additional compatibility considerations."

Compatibility of vegetation within a solar facility may differ across an individual site. Certain species such as trees, shrubs, and tallgrass prairie plants may intrinsically not be compatible within a solar array due to height restrictions. However, this vegetation may be compatible in other areas outside of arrays such as perimeter or buffer areas, open space along wetlands or waterways, or as visual screening.

Compatibility must be considered alongside other site conditions such as region, topography, hydrology, and soil type, which may further restrict the list of species or vegetation types. It is important for vegetation planners to identify the various constraints for each project area and identify compatible vegetation based on the site's characteristics and project's goals.

Section(s) 3 through 6 provide additional considerations for compatibility during the vegetation planning process.

Defining Solar Pollinator Vegetation For Solar Facilities

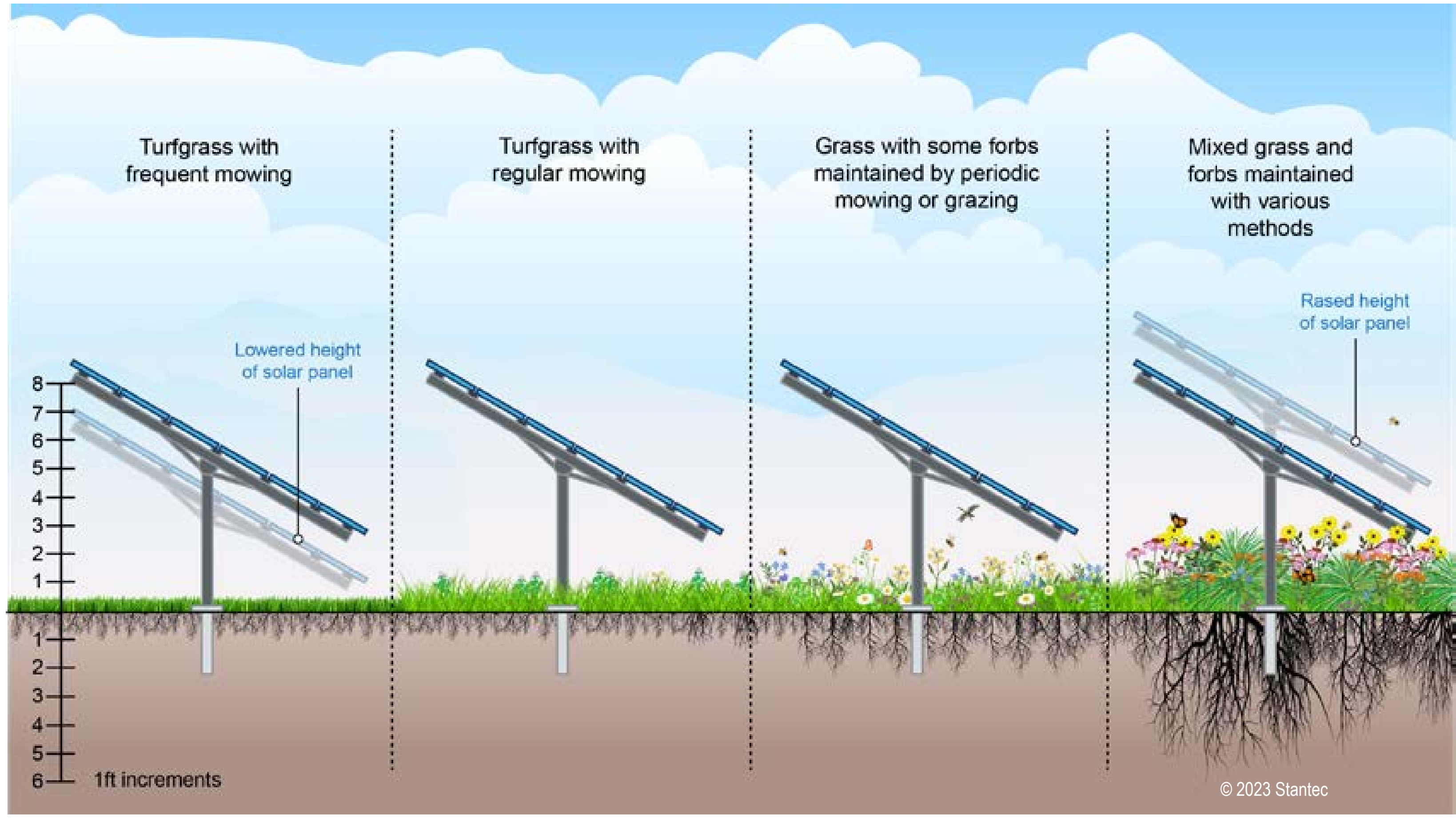
For utility-scale solar projects, defining what pollinator vegetation means for a particular site can help avoid misunderstandings. We encourage vegetation planners to define and communicate:

- ☐ What are the pollinator-related goals and objectives for a solar site?
- ☐ Which specific species, groups, or types of pollinators will be targeted by pollinator vegetation?
- ☐ Are there scorecards in states where projects are located, and do their definitions of "pollinator-friendly" vegetation align with project-specific goals and objectives?
- ☐ How do site constraints and site characteristics influence pollinator vegetation decisions on a project?
- ☐ How does pollinator vegetation contribute to regulatory compliance, company commitments, stakeholder interests, or other objectives?

Section 3 provides additional guidance on defining purposes, identifying goals, and setting objectives. Section 4 gives guidance on addressing constraints, characteristics, and conditions in planning solar pollinator vegetation.

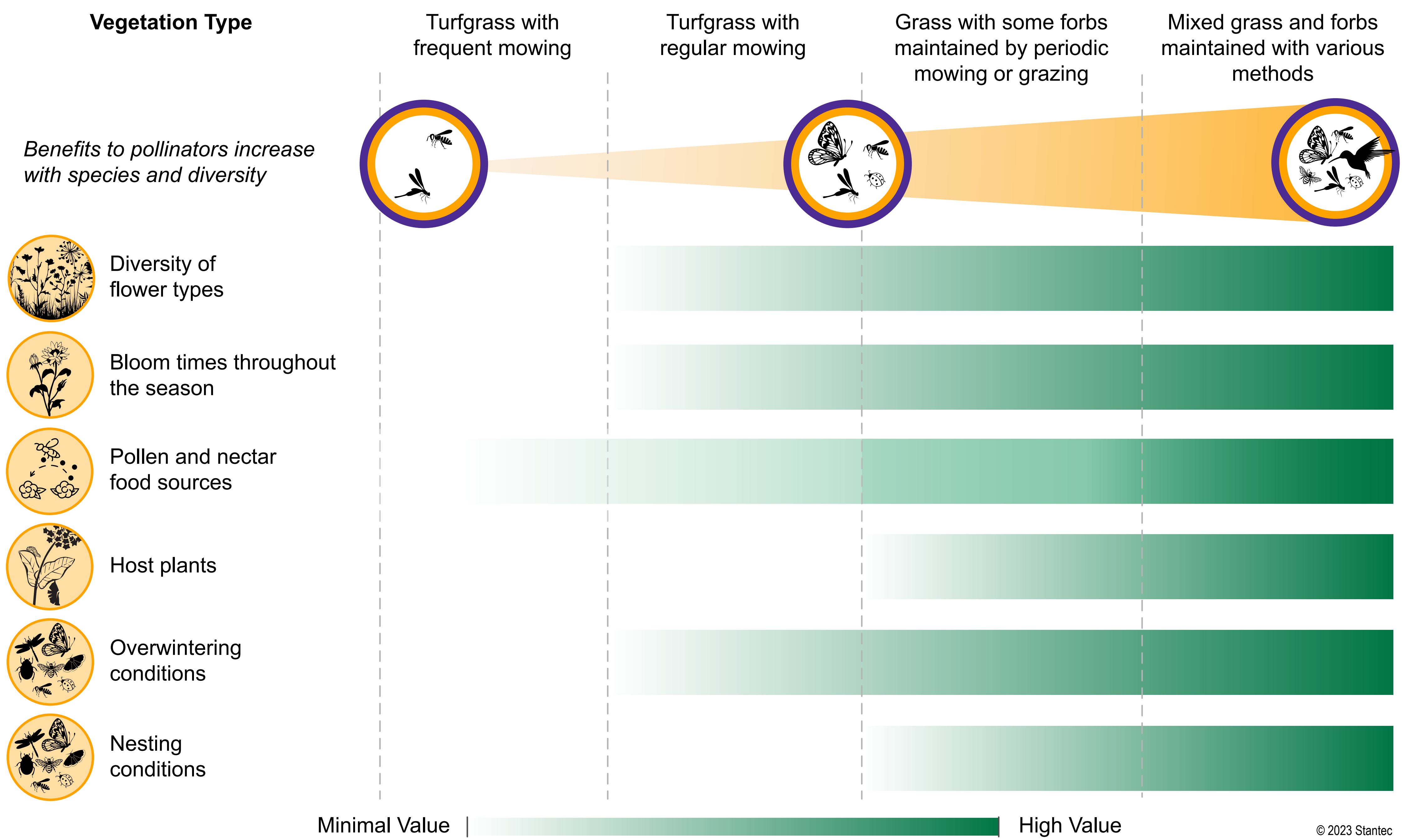
Figure 2.1 illustrates a spectrum of potential vegetation management scenarios associated with the operation of a solar facility. While terminology may differ regionally or across companies, this graphic illustrates how solar pollinator vegetation can exist along a spectrum of vegetation types – each providing certain pollinator benefits depending on the structure, management used, and species present.

Figure 2.1. *The range of groundcover vegetation types commonly found on solar sites.*



There is not a one-size fits all solution to providing pollinator vegetation. Different vegetation types can support one or more of the pollinator benefits described earlier. While some vegetation types may primarily offer forage resources for pollinators, other needs like nesting and overwintering areas may be supported by other areas onsite, including buffering lands. Figure 2.2, on the next page, illustrates how these various cover types can contribute to the pollinator requirements highlighted earlier.

Figure 2.2. *The spectrum of pollinator benefits that can be provided by various vegetation types commonly found on solar sites.*



A variety of solar pollinator vegetation to attract pollinators.
Photo courtesy of Stantec

How To Determine Pollinator Vegetation Compatibility?

When planning for solar site vegetation, developers must ask, "What pollinator vegetation is compatible with the proposed solar facility?"

There are two broad influences on compatibility, external and internal constraints. *External* constraints may be determined by an outside agency, a purchasing company, or the physical setting of the site or infrastructure and must be accommodated. External constraints like regulations, risk management and liabilities, panel designs and array layouts are often most constraining and should be quantified first. Internal constraints may be site design constraints or voluntary additions. *Internal* constraints, like planned maintenance regimes and operating costs can be assessed after addressing the external constraints.

Black-eyed Susans *(Rudbeckia hirta). Photo courtesy of Stantec*

Table 2.1 summarizes some of the common influences on compatibility. Except for requirements posed by permitting agencies, providing pollinator vegetation is not an all-or-nothing outcome but a spectrum of options. The intersection between influencing factors and vegetation management determines the amount, location, configuration, and types of solar pollinator vegetation compatible for a solar facility.

Table 2.1. *Common influences on solar pollinator vegetation compatibility*

Influence	Key Compatibility Questions	Considerations
External Constraints		
Regulatory compliance	Is pollinator vegetation required by federal, tribal, state, or local regulations?	Regulations can vary and may or may not include requirements for "pollinator-friendly" or native vegetation.
Risk management and financial liability	Do conditions of insurance providers or policies limit vegetation type or height, and to what extent?	Taller, dense vegetation needs to be considered relative to fire risks, sight line limitations, trip hazards, or other concerns depending on the site context and climatic conditions. Mitigating concerns about risks may influence vegetation management.
Prior land use	Does prior land use support the planned establishment or use of pollinator vegetation?	Existing vegetation in rangeland or pasture systems, and/or prior practices such as systemic herbicide use, may influence the timing and type of vegetation established onsite.
Panel design and array layout	Does the facility design provide conditions that support compatibility for pollinator vegetation?	Design of arrays are constrained by the size and configuration of parcels leased within the project area. Array design will directly influence the location and extent of vegetation zones onsite.
Panel height	What maximum vegetation height is compatible with planned leading edge panel heights?	Panel height is the primary physical constraint on the types of vegetation compatible within array areas. The lower the panel height, the more limited options there are for diverse vegetation and potentially more intensive maintenance required. Panel heights may be dictated by project costs, purchaser preferences, view shed concerns, permit and engineering constraints, and external regulatory requirements, among other considerations.
Internal Constraints		
Maintenance regimes	Does planned vegetation maintenance support solar pollinator vegetation?	Common site maintenance tools, like mowing or grazing, can either support or inhibit solar pollinator vegetation depending on its timing, frequency, and intensity. Developers need to consider the effects of maintenance practices on vegetation planned for their site.
Construction and operating budgets	Will planned vegetation cost(s) fit within the planned construction and post-construction maintenance budgets allocated for the project?	Projects may be constructed with lower costs upfront, which may or may not result in longer-term establishment and maintenance costs.
Safety and security	Does planned vegetation pose unacceptable safety or security hazards for operations?	Fire protection, OSHA recordable incidents resulting from stinging insects or poisonous plants, or impeded security viewsheds are some safety and security concerns that may limit when, where, or how pollinator habitat is incorporated into sites.

Regulatory Compliance

Regulatory requirements often drive the use and extent of native pollinator vegetation at a solar facility. The regulatory landscape as it relates to vegetation requirements on solar facilities is very diverse. Conditions included in the authorizing permits for solar facilities influence both short-term and long-term vegetation management.

Scorecards

The desire to implement pollinator vegetation has led to policies seeking to standardize or require pollinator planting. By 2022, eight states had passed legislation that allows solar projects to be recognized as "pollinator-friendly" if they meet standards outlined in an individual state's program. Criteria typically require certain amounts or types of pollinator vegetation to achieve a target score or threshold for being considered "pollinator-friendly" by the definitions used by the particular entity.

Some states may rely on scorecards during project regulatory review, even if not backed in state laws (Fresh Energy 2023, Terry 2020). For example, Minnesota requires vegetation management planning associated with solar facilities to consider practices that support pollinator and wildlife habitat along with protecting water quality (Minnesota Statue 2016. Section 216B.1642). At a local level, some municipal governments have developed ordinances or rules that require solar designs be "pollinator-friendly" based on state scorecard criteria or by directly stating the required quantity and characteristics of pollinator vegetation.

Some solar developers have expressed concerns over "pollinator-friendly" vegetation standards noting that some either promote incompatible vegetation requirements or lack description of the scientific rationale supporting scoring metrics included. In many cases scorecards developed for community-scale solar have been applied to utility-scale solar development. Thus, their scoring methodologies may not account for the size of utility-scale solar projects, design constraints for panel heights, or potential value added by buffer lands or woody vegetation used for landscape screening. Open communication between regulators and developers is beneficial to the planning process and ensuring successful, compatible outcomes.

Stormwater and Erosion Control

State and local stormwater permits typically require projects one acre or larger in size to minimize stormwater discharge and erosion. On large sites or where construction occurs over an extended period (i.e., months or years), a combination of short-lived cover crops and more persistent perennial vegetation may be used for stabilization. Permit obligations are often considered met once vegetation density and coverage standards outlined in the construction stormwater permit conditions are achieved.

Beyond construction, operating permits may require maintaining a density and coverage of vegetation to provide post-construction stormwater and water quality protection. Failure to meet both short-term and long-term permitting standards can have significant financial outcomes in the form of fines and delays. To avoid delays or permit non-compliance, vegetation plans should account for both short- and long-term site erosion control and stabilization needs.

Invasive Species

Many local and county governments are responsible for enforcing state noxious weed laws. Vegetation management practices that allow establishment of noxious or invasive weeds at a solar facility risk fines and mandated noxious weed treatments. Invasion by noxious weeds is a constant threat throughout any plant community over the operational lifetime of the facility. At a minimum, vegetation management planning should avoid inclusion of noxious or ecologically invasive species.

To aid operations and maintenance, vegetation management plans should consider resilience against future invasive and weed pressure. Studies have shown that established diverse plant communities can be more resistant to invasive species spread, which could include noxious weeds (Naeem et al. 2000, Hector et al. 2001, Levine et al. 2004, Beaury et al. 2019). Risks of noxious weed invasion can be minimized through the type of vegetation installed, the plant community's resistance to invasion, and the type and frequency of management.

Endangered Species

Solar pollinator vegetation may have potential to attract endangered species in areas where previous habitat may have not occurred. Federal and state endangered species regulations are often implemented through timing, activity, and other land use restrictions. Such restrictions may pose challenges to operators of a solar sites where regular operations and maintenance activities, such a mowing, maintenance, or vehicle traffic, are necessary.

Screening for and understanding the potential for endangered species in areas on or near a solar site should be done in the early stages of planning to understand the risk to which their operations will be subject to federal and state restrictions. The first step in this process is for planners to gain an in-depth understanding of the specific endangered species and their habitat suitability on and around their solar site.

Avoiding or minimizing species impacts is preferred when operations and maintenance can adapt to timing and activity restrictions to protect endangered species. However, if impacts cannot be avoided, owners and operators may pursue a site-specific conservation strategy with state or federal agencies. Companies can also obtain an incidental take permit through participation in federal conservation agreements such as habitat conservation plans (HCPs) and conservation benefit agreements (CBAs, previously known as candidate conservation agreements (CCAAs/CCAs) and safe harbor agreements (SHAs).

Some states may have programs and permits for state listed endangered resources; applicability of which will vary by location. These agreements often require some form of avoidance, minimization, or offsetting conservation be implemented in exchange for permit coverage or regulatory assurances. Conservation may be implemented through specific actions and measures, or through habitat mitigation on additional lands, both of which may increase overall costs associated with the project. Thus, it is pertinent that endangered resource risks and compliance factors be considered early in the planning stages so that planners, owners, and managers can solidify which strategy to pursue.

Rusty patched bumble bee *(Bombus affinis)*—the first bee to be listed as endangered in the continental U.S.

Endangered species present on a utility-scale solar site may also pose risks at the end of the project during decommissioning. Decommissioning concerns should be considered during planning stages as practicable. More information about endangered resources and decommissioning is described in Section 10.

Risk Management and Financial Liability

Insuring the investments made in energy infrastructure is an important aspect of any utility-scale solar development or any large construction project. The ability to obtain and maintain insurance is extremely important in determining if pollinator vegetation is compatible for a site. Vegetation height, density, and location will often influence what vegetation is considered of minimal risk to a site developer or owner.

This may cause vegetation managers to determine compatibility of vegetation types across the project area, or portions of it. **If an insurance policy requires that vegetation be maintained one foot or lower in height, a very limited number of pollinator vegetation species may be compatible within array areas.** However, if vegetation height is only restricted to the solar panel arrays, then taller growing vegetation may be focused along other areas such as array borders, fence lines, or buffering lands.

Damage to solar panels from maintenance equipment is another risk that could result in loss of operating capacity or costly repairs. Maintaining low-growing vegetation often requires repeated mowing or prescribed grazing. Use of an integrated vegetation management strategy may also include other mechanical and chemical controls.

Low growing cool-season grass mixes and/or native pollinator vegetation may reduce the need to mow during the maintenance phase of the project (Moore-O'Leary et al. 2017 as cited by Walston et al. 2018). Vegetation plans for sites must consider the design configuration of a site, accompanying insurance requirements, and then select plant communities compatible with those requirements.

Finally, safety of both the infrastructure and operators on-site are major considerations for compatibility of solar pollinator vegetation. Care must be taken to assess safety concerns including, but not limited to: risk of damaging fire, exposure of personnel to hazardous wildlife and plants, and sight-line limitations, among others.

Panel Design and Array Layout

The primary goal of a solar facility is to capture, generate, and distribute energy in a safe, reliable, and cost-effective manner. Panel height and type (fixed vs. tracking) and array layout can significantly influence the compatibility of vegetation used during construction and operation. Section 5 – Planting Plan Design discusses vegetation planning considerations for each facility feature and opportunities to provide pollinator vegetation.

Maintenance Regimes

Actions that disturb, remove, or otherwise manipulate vegetation in semi-natural grassland ecosystems can change the patterns of species diversity, abundance, and composition of plant communities over time (Jakobsson et al. 2018). Establishing vegetation inappropriate to the maintenance conducted can result in loss of seed cost investment, increased exposure to noxious or invasive weed establishment, less desirable plant communities, and increased maintenance costs. When planning vegetation for solar facilities, the expected maintenance regime (i.e., the approaches used and their timing and frequency) is an important consideration to determine whether solar pollinator vegetation is compatible.

Solar farm with many wildflowers to attract pollinators.
© *Stock.adobe.com*

Operating Costs

Vegetation selected for utility-scale solar sites must be cost-effective to be compatible with operations. Cost effectiveness of vegetation should be considered across the lifespan of the solar facility. Three main phases of solar vegetation management include installation, establishment, and maintenance.

Installation

Installation occurs either prior to, or during, construction of the facility and involves the site preparation and installation of plant material (typically seed) to establish the desired plant communities. Installation costs for most vegetation types will be similar as the steps to prepare a seedbed, install, and incorporate any seed will be similar. Timing of installation, such as pre- vs post-construction seeding and preseeding weed control typically have greater influences on cost than the type of vegetation to be installed.

Establishment

The establishment phase of vegetation typically begins once the desired seed is installed and germinates until the point of permit closures and/or a developer's contractual obligations have been met. For many projects, the establishment phase will range from two to four years. Costs associated with establishment usually include mowing to reduce opportunistic weedy coverage. Mowing regimes during establishment are typically similar across all vegetation types. If management during establishment is not performed correctly it can lead to insufficient coverage or unwanted noxious, invasive, or incompatible species.

Maintenance

Once permits have been closed and a developer's contractual obligations have been met, sites transition into maintenance. The maintenance phase will continue throughout the duration of the facility's lifespan. Maintenance regimes and accompanying costs vary depending on the types of vegetation established throughout the site. Considering the maintenance planned for a site can influence the target plant communities and species planned for a site.

When determining compatibility based on costs, each stage of vegetation management should be considered relative to the other factors outlined in this section and their cost implications. Short-term decisions based solely on cost may unintentionally result in long-term inappropriate or incompatible vegetation.

Determining Compatibility

At this stage in the vegetation planning process, define:

External Constraints

☐ Is pollinator vegetation required by federal, tribal, state, or local regulations?

☐ Do conditions of insurance providers or policies limit vegetation type or height, and to what extent?

☐ Does prior land use support the planned establishment or use of pollinator vegetation?

☐ Does the facility design provide conditions that support compatibility for pollinator vegetation?

☐ What maximum vegetation height is the compatible with planned leading edge panel heights?

Internal Constraints

☐ Does planned vegetation maintenance support solar pollinator vegetation?

☐ Will planned vegetation cost fit within the planned construction budget allocated for the project?

☐ Will planned vegetation cost fit within the planned post-construction maintenance budget allocated for the project?

May we suggest using the...

PHASE Cost Comparison Calculator

Goldenrod soldier beetles on goldenrod.
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Section 3
Defining Goals and Setting Objectives

WHAT'S IN THIS SECTION?

- Solar Pollinator Vegetation Goals and Objectives
- Defining Goals and Objectives
- Putting Goals and Objectives into Practice


Various pollinator vegetation attracting a wide range of pollinators. © Stock.adobe.com

Solar Pollinator Vegetation Goals and Objectives

It's important to define goals being addressed by planned solar pollinator vegetation. Goal setting should distinguish between overarching project goals, and those directly tied to the implementation of solar pollinator vegetation. For example, delivering safe and reliable energy is often the most important goal of the project as a whole. However, related goals specific to solar pollinator vegetation may be one or more of the following:

- ☐ Achieving regulatory compliance
- ☐ Enhancing ecological benefits
- ☐ Creating economic benefits
- ☐ Addressing aesthetic desires
- ☐ Providing agricultural benefits
- ☐ Contributing to sustainability policies

When not clearly defined, projects may implement conflicting strategies, which can lead to vegetation damage, additional work, and costly mistakes.

Defining Terms

Goals - General, directional statements describing a purpose or vision for a desired destination or end. Goals typically represent motivations for incorporating actions into a plan.

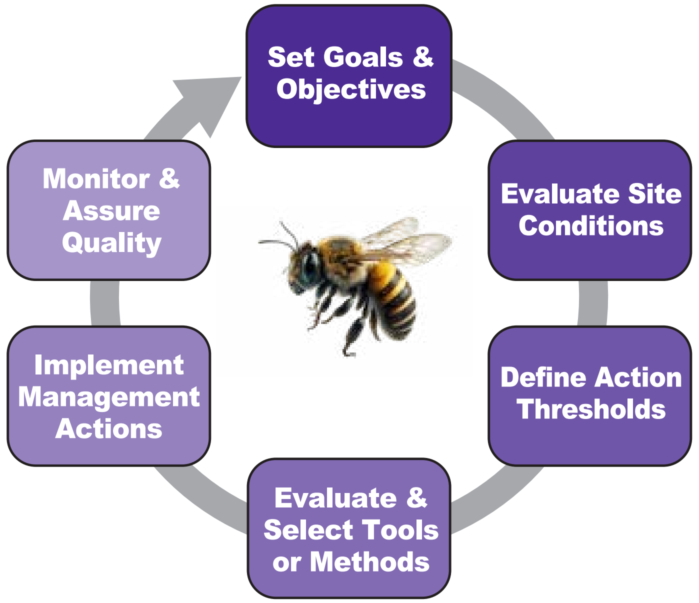
Objectives - Concise statement of a desired endpoint, benefit, or result. Objectives specify measurable targets for what, when, and how much will be accomplished. Planning guidance often recommends making objectives SMART (specific, measurable, achievable, result-oriented, and timebound).

Defining Goals and Objectives

Successful planting plan design starts with clearly defined goals and objectives for vegetation management. Vegetation management using integrated vegetation management (IVM) is grounded in setting goals and defining vegetation objectives. IVM includes a series of planning and evaluation steps that begin with defining goals and objectives (Figure 3.1).

Whether using IVM or another vegetation management approach, defining goals and objectives aids communication with project teams, external stakeholders, contractors, and vegetation specialists.

***Figure 3.1.** Simplified integrated vegetation management cycle (adapted from UAA 2023)*



Defining Goals

Goals may be company or program specific and may often reflect one or more of the examples of goals and objectives demonstrated in Table 3.2. Questions to consider when defining goals include:

- What is the desired end result(s) of vegetation for the developer and owner?
- Are there regulatory requirements that must be achieved for compliance?
- Are there ecological, economic, aesthetic, or agricultural benefits the vegetation is expected to provide?
- Are there pollinator commitments or corporate sustainability programs benefitting from vegetation?
- Goals are best defined in collaboration with project teams. Once identified, goals should be recorded for reference by the team in planning documents, slides, and communications.

Setting Objectives

Objectives represent the site-specific targets needed to achieve the stated goals. While not all sites may define objectives, doing so can help clearly set targets and management thresholds, which adds clarity to communications among project and maintenance teams. Objectives should consider both establishment and maintenance targets for vegetation management. A best practice for setting objectives is to make them SMART, or specific, measurable, achievable, result-oriented, and time-bound. Table 3.1 below provides a checklist for creating SMART objectives. This can be used in combination with the examples provided in Table 3.2 to define vegetation goals and objectives.

Table 3.1. *Checklist for creating SMART objectives for vegetation management*

Completed	Objective Component	Related Questions
☐	Specific	Does the objective describe: • Who is responsible? • What is desired? • How and when it will be achieved?
☐	Measurable	Does the objective define the targets for: • When it will be accomplished? • What condition is expected? • What units are used to measure the result? • What threshold may be used for a management trigger?
☐	Achievable	Is the objective written in a way that is practical and achievable?
☐	Result-oriented	What is the desired end result or benefit?
☐	Timebound	When are the measurable aspects of the objective expected or required?

Site specific objectives are a starting point for a continuous feedback cycle that orients management actions and provides a basis for evaluating management success. When combined with monitoring, they can be used as both an internal and external communication tool on vegetation performance and benefits (Figure 3.2 on page 21).

Additional guidance on using IVM to set site specific objectives for biodiversity and target species (including pollinators) can be found in other resources. The DOE's SolSmart Program highlights use IVM planning for solar facilities in their Land Use Considerations for Large-scale Solar (EPRI and The Solar Foundation 2020). Other resources include the Utility Arborist Association's Managing Compatible Vegetation for Targeted Species and Biodiversity: A Companion to the Integrated Vegetation Management Best Management Practices, 3rd Edition and integrated vegetation management tools. While originally developed for electric utilities, guidance provided in these resources can be equally applied within the utility-scale solar context.

Putting Goals and Objectives into Practice

Setting goals and objectives for a solar vegetation management program or individual sites is important to clearly communicating and aligning expectations. Using the information and examples provided in this section, project teams and vegetation managers can:

1. Define company, program, or site goals motivating solar pollinator vegetation.
2. Determine what objectives are needed to clearly communicate end targets, management triggers, or expectations for solar pollinator vegetation.
3. Consider if different phases of the project require their own objectives to aid planning and communications.
4. Consider goals expressed from stakeholder input gathered during internal planning and community outreach.
5. Communicate the goals and objectives with project teams in documents, project fact sheets, and other communications.

Key Takeaways for Defining Goals and Objectives

- Objectives can create clear expectations for desired outcomes and can help avoid conflicting strategies and costly mistakes.
- Successful planting plans start with clearly defined goals and objectives for vegetation management.
- Use of integrated vegetation management (IVM) is grounded in setting goals and defining vegetation objectives.

Defining the goals being addressed by use of solar pollinator vegetation into utility-scale solar projects is important to coordination and communication. Behind each goal, there may be one or more objectives. When defined, objectives can create clear expectations for desired outcomes and be used to measure if goals have been accomplished. Considering objectives can help managers better align expectations and understand the benefits that may be incurred by incorporating solar pollinator vegetation. Table 3.2, on the next page, provides examples of possible goals and objectives associated with solar pollinator vegetation. This list is not comprehensive and other goals and objectives may exist outside of what is listed in this section.

Table 3.2. Examples of Solar Pollinator Vegetation Goals and Objectives

Goals	Objectives
Achieving regulatory compliance	Maintain compliance with all federal, tribal, state, or local regulations over the project duration. Achieve the required cover of permanent vegetation by a specified date. Permit conditions will vary by state.
Enhancing ecological benefits	Create measurable soil health improvements in soil carbon, organic content, or permeability over the duration of the project. Avoid establishment of noxious weeds across more than a specified area or extent. Achieve targeted biodiversity enhancements by creating a specified number of acres of habitat represented by defined components.
Creating economic benefits	Lower operations and maintenance (O&M) costs as compared to another baseline or comparison scenario. Increased power production from panel efficiency based on production and efficiency modeling. Increased marketability to solar purchasers or communities addressing key decision factors or purchaser desires.
Addressing aesthetic desires	Inclusion of vegetation components requested by stakeholders. Demonstrated outputs or conditions desired by project teams, company standards, or other measure of aesthetic preferences. Implement strategies that reduce negative aesthetic impacts on neighboring landowners. Engage the public in determining best practices for integrating the project into the local landscape.
Providing agricultural benefits	Enhancement of surrounding crop yields based on modeling or trends in harvest yields. Creation of new local agricultural markets by incorporating agrivoltaics (defined on page 20) into projects. Direct yields of agricultural products produced onsite as part of solar pollinator vegetation management.
Contributing to sustainability policies	Alignment with, or enhancements supporting, corporate environmental sustainability policies and environmental, social, and governance disclosures. Direct measure of company or site-specific sustainability targets.
Health and safety compliance	Maintain occupational health and safety on worksites by recording a minimal number of incidents. Foster a culture of safety by engaging all project team members in relevant trainings that cover multiple health and safety concerns.

Health and Safety Compliance

Worker health and safety is a primary concern for any vegetation planning. Project safety objectives may include targets for worker health, zero Occupational Safety and Health Administration (OSHA) recordable incidents, and/or compliance with health and safety regulations and policies. Any vegetation can create a real or perceived risk of slip and trips, poisonous plants, or stinging insects.

Slip and trip concerns may be addressed through consideration in species selection and site layout. Avoid planting tall-growing species in high-traffic areas with growth forms that may obstruct access. Training workers to avoid common causes of slips and trips when working in tall vegetation can also increase risk awareness and vigilance.

Poisonous plants are plants that may cause itching, rashes, or blisters due to exposure to oils, pollen, or other chemical compounds naturally present in certain species. Training workers in poisonous plant identification and controlling poisonous plants through integrated vegetation management can reduce risks of exposure.

Stinging insects may nest in a variety of locations - in turfgrass, managed, or naturalized vegetation or in structures. Training workers in identifying potential hazard areas for stinging insects, use of insect repellents, plus use of other personal protective equipment (PPE) to minimize risks.

Bee pollinating common milkweed (Asclepias syriaca). Photo courtesy of Stantec

Achieving Regulatory Compliance

Regulations encouraging use of pollinator vegetation can vary by location and agency, and it may be necessary for managers to address multiple levels of compliance on their project sites such as federal, tribal, state, or local regulations. Many states may include guidelines for pollinator vegetation that either offer incentives or guidelines for regulatory agencies (Fresh Energy 2023, Terry 2020). These may or may not include requirements for "pollinator-friendly" or native vegetation. It's important to consider whether guidelines available have been developed with utility-scale solar constraints in mind.

Reputational benefits may also be incurred through implementation of a vegetation management regime that exceeds regulatory requirements rather than simply meeting minimum requirements. Incorporating solar pollinator vegetation into management plans may help exceed regulatory expectation.

As with other aspects of regulatory compliance, it's important to review requirements carefully and identify compliance needs when beginning vegetation management planning.

Enhancing Ecological Benefits

Decisions about the type and location of vegetation used on a solar facility extend beyond what benefits it brings to pollinators. Vegetation choices may be influenced by differences in the degree or extent of the services and benefits provided. Implementation of solar pollinator vegetation into a utility-scale solar system can offer myriad ecological benefits (i.e., ecosystem services).

Solar pollinator vegetation may offer increases in ecosystem services such as biodiversity, carbon capture and storage, soil retention and erosion control, water retention and infiltration, and pollination (as summarized by Walston et al. 2021). Utility-scale solar sites can create microclimates with increased humidity, increased soil water, and decreased temperature, all of which can positively impact vegetation growth, leading to an increase in carbon capture and storage in the form of biomass (Adeh et al. 2018, Choi et al. 2020). Species used for diverse solar pollinator vegetation typically have deep, complex root systems, which can increase both soil retention, water retention, and water infiltration, leading to decreased erosion and surface water runoff (Bharati et al. 2002, Hernandez-Santana et al. 2013). Established perennial native vegetation can also build soil health through increased soil organic matter accumulation, which sequesters carbon (Yang et al. 2019). Root systems can also filter out nutrients such as nitrogen and phosphorus before they enter streams, rivers, and lakes, resulting in improved water quality (Schulte et al. 2017).

Research evaluating the ecological benefits of solar pollinator vegetation is ongoing (Macknick et al. 2022). Since 2015, the U.S. Department of Energy (DOE) has funded research through the Innovative Solar Practices Integrated with Rural Economies and Ecosystems (InSPIRE) program (Macknick et al. 2022). Recent research has demonstrated increases in ecosystem services on solar sites that implement pollinator vegetation. In a study using the InVEST model, evidence suggests that use of solar pollinator vegetation on utility-scale solar operations in the Midwest U.S. may increase carbon storage, pollinator supply, sediment retention, and water retention compared to a solar operation with traditional managed turfgrass vegetation (Walston et al. 2021). To aid in evaluating ecosystem services in varied contexts, online tools like the PV-SMaRT Solar Farm Runoff Calculator (UMN 2023), ENCORE (Natural Capital Finance Alliance 2022) and InVEST (Natural Capital Project 2022) can help identify ecological opportunities and quantify ecological benefits. These and future studies will help utility-scale solar projects quantify ecosystem services and benefits conferred through the implementation of solar pollinator vegetation.

Creating Economic Benefits

Using pollinator vegetation may yield economic benefits both to the solar project operator as well as communities adjacent to utility-scale projects. Onsite benefits to the solar operator may include increased solar panel efficiency and decreased operations and maintenance costs compared to turfgrass plantings (McCall et al. 2023, Siegner et al. 2019). Microclimatic effects (covered under ecological benefits) primarily in the form of decreased temperature can confer increased solar panel efficiency, and thus increased revenue through energy production over the project lifetime (Adeh et al. 2018). Effects of vegetation-induced panel cooling on electricity generation are site-specific and can vary based on climate and soil properties (Choi et al. 2023).

While implementing solar pollinator vegetation plans may require greater upfront costs for site preparation, seeding, and establishment (Horowitz et al. 2020), evidence suggests that cumulative operational costs may be lower over the lifetime of the project. Cost reductions may occur through decreased mowing needs compared to turfgrass (Siegner et al. 2019). If appropriately addressed in stormwater modeling, pollinator and similar ground covers may help avoid capital costs of needing additional stormwater infrastructure (Great Plains Institute 2023).

Off-site benefits of solar pollinator vegetation implementation also include potentials to increase crop yields on farmland in proximity to the solar operation due to increased pollinator abundance in the area (Siegner et al. 2019, Walston et al. 2018).

Pollinator vegetation provides ecological and economical benefits to solar sites. © Stock.adobe.com

Addressing Aesthetic Desires

Aesthetics have been cited as a concern related to new solar developments. Integrating utility-scale solar into surrounding landscapes and agricultural operations can help gain community acceptance (Daniels and Wagner 2022, FFWC 2021). A recent European study suggests that public perception of solar facilities may be dependent on how the landscape around it is viewed. Findings of this study note that designs integrating the facility into the surrounding landscape tend to improve perception of the sites (Bevk & Golobič 2020). Aesthetic preferences can vary across cultures and geographies. Stakeholders in one locale may perceive utility-scale solar sites in a unique way from another. More research and community engagement will help understand these effects at local and regional scales.

Outside of research based on solar sites, recent studies have suggested that perennial, diverse grassland plantings (similar to solar pollinator vegetation) increase perceived quality of green-spaces compared to mowed turfgrass (Southon et al. 2017, Garfinkel et al. 2023). Further, depending on site characteristics, use of managed vegetation screens in buffers around solar arrays may provide benefits for pollinators while also limiting the view of mechanical facilities from the public.

Understanding the potential for vegetation to increase aesthetic appeal and public perception of targeted solar sites are important for vegetation managers. Implementation of these practices should consider the site context, surrounding communities, and other differences to help guide and manage stakeholder expectations.

Providing Agricultural Benefits

Agrivoltaics represents the combination of solar with agriculture. The dual-use of energy with land use for crops, grazing, and pollinator habitats under or between panels. Agricultural benefits of solar pollinator vegetation may occur either on or off-site. Onsite benefits may include direct agricultural production of crops, honey production, or forage for grazing livestock. Such agricultural production, if managed in a manner that sustains nectar and pollen forage for pollinators, can create agricultural benefits with solar pollinator vegetation. Walston et al. (2018) describes the pollination benefits to off-site crops surrounding utility-scale solar sites, suggesting that enhancing the presence of pollinators within utility-scale solar sites has potential to increase yields for crops off-site.

The InSPIRE project identified lessons learned and best practices when considering use of vegetation as agrivoltaics on projects (Macknick et al. 2022). Within the InSPIRE project, agrivoltaics includes crop or forage production, grazing, greenhouses, or creation of pollinator habitat. Key success factors identified in this research for agrivoltaics are consistent with those for solar pollinator vegetation discussed elsewhere in this manual:

- Vegetation selection should include vegetation species and cultivars that are appropriate under solar site conditions within that geographic location while maintaining compatibility.
- Vegetation establishment should aid the desired vegetation to thrive over undesirable species.
- Clearly define the end-use or market for the sale or distribution of agricultural products or goods produced.

Contributing to Sustainability Policies

The value placed on pollinator vegetation by a solar project's owner, developer, or operator may promote or constrain its inclusion as a primary consideration in project planning. Many businesses highlight pollinator contributions in company annual reports, or more formally in their Environmental, Social, and Governance (ESG) commitments reported in annual financial performance reports. In whichever approach, consideration for pollinators, plus other contributions to biodiversity or natural capital may influence vegetation selection and management decisions.

An assessment by Walston et al. (2022) revealed potential alignments with 15 out of the 17 total UN Sustainable Development Goals (SDGs). Incorporating co-benefits and multiple uses of land aligns with global biodiversity targets and UN's SDG 2, 8, 12 and 13 (Handler and Pearce 2022, UN 2022, UN 2015). Environmental commitments should be well defined, including the type of contribution, means of measurement, and goals for individual sites.

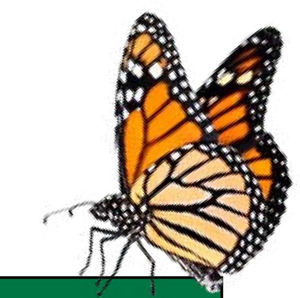
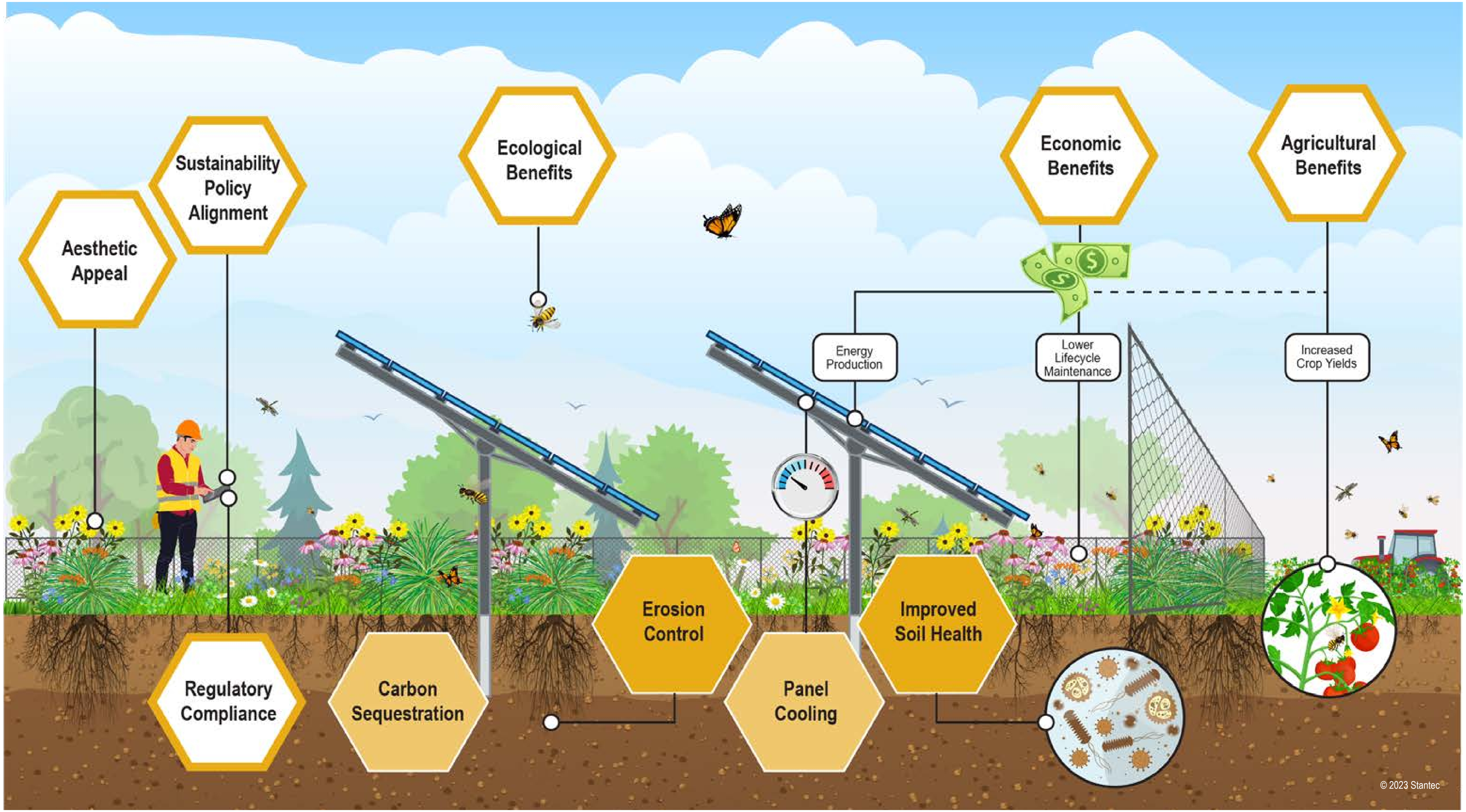


Table 3.3. Alignment of United Nations Sustainable Development Goals with agrivoltaic systems

Goal		Alignment with agrivoltaic systems
2 ZERO HUNGER	Zero Hunger	AV systems increases land productivity and can be used to increase food production
8 DECENT WORK AND ECONOMIC GROWTH	Decent Work & Economic Growth	AV systems contribute to economic growth by providing job opportunities and other sources of revenue in rural areas
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Responsible Consumption & Production	AV systems work to minimize inputs for energy and food production and biodiversity conservation, thereby exemplifying responsible consumption of resources
13 CLIMATE ACTION	Climate Action	AV systems contribute in both reducing climate change by reducing GHG emissions compared to other energy systems and improving the site's carbon sequestration through on-site habitat restoration (e.g., solar-pollinator habitat)
14 LIFE BELOW WATER	Life on Land	Incorporating diverse vegetation enhances biodiversity and provides habitat requirements for many species
15 LIFE ON LAND	Life in Water	Established perennial vegetation can stabilize soils, reduce runoff, increase infiltration, and filter pollutants resulting in cleaner water

Refer to this table for references on the ecosystem services of agrivoltaic systems that support these alignments.

Figure 3.2. *Ecological and economical benefits of solar sites.*



Section 4
Identifying Pollinator Vegetation Design Considerations

Choosing vegetation suitable for certain climates are important. © Stock.adobe.com

WHAT'S IN THIS SECTION?

- Understanding Site Characteristics and Conditions
- Gather Site Information
- Developing a Vegetation Management Plan
- Communicate Solar Pollinator Vegetation Considerations
- Site Planning Checklist

Understanding Site Characteristics and Conditions

In addition to design constraints, vegetation decisions are also influenced by other considerations including site characteristics and conditions.

Characteristics are aspects of a site that are determined by location and setting. Land use, soils, topography, and hydrology are three common characteristics that are considered in solar pollinator vegetation.

Characteristics often underlie the conditions of a site. Characteristics are macro-level influences that cannot be altered through management actions. Existing land use is outside of a project's control prior to landowner agreements, soil types located on a site cannot be altered to another, a site that is low lying and poorly drained may be susceptible to flooding or ponding.

Key Takeaways for Identifying Pollinator Vegetation Design Considerations

- Understanding site conditions is critical to planting design, seed selection, and establishment.
- Site conditions can inform the compatibility of the site with site goals and constraints.
- Characteristics and conditions may include both onsite physical elements alongside design influences from project teams and stakeholders.
- Communicating with the project team during early site evaluation can aid information gathering and sharing.

Conditions describe the current or expected state of the site characteristics when the vegetation installation occurs. Existing vegetation cover, degree of soil compaction, onsite drainage management, and presence or absence of pesticide residues are some examples of conditions.

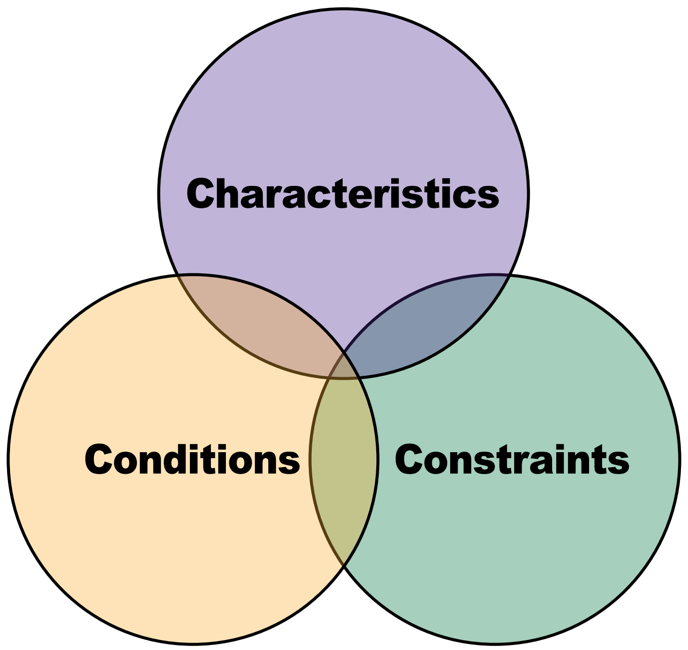
Conditions may be altered by management actions. Poor soils can be amended, some undesirable topography can be graded, and drainage adjustments can reduce flooding. Conditions may also change from season to season or year to year. Agricultural practices, construction activities, weather conditions, and vegetation growth can change a site's conditions.

When selecting species for solar pollinator vegetation, each plant has unique tolerances to site characteristics and their conditions. Choosing vegetation that can tolerate the characteristics that are present and managing *conditions* that may impact establishment can set a site up for success.

Considerations for characteristics and conditions are often included in site vegetation management plans and should be communicated to contractors during site preparation and construction.

Both characteristics and conditions are subject to ***constraints*** that influence vegetation management planning. Constraints are discussed in depth in Section 2. Constraints may be inherited from site characteristics or conditions, or by solar facility design and operational needs. Figure 4.1 illustrates the interconnected relationship between site characteristics, conditions, and constraints.

Figure 4.1. Site characteristics and conditions influence solar pollinator vegetation planning.



Characteristics	Conditions	Constraints
Climate	Seasonal temperatures and weather patterns	See Figure 2.1
Soil Type	Compaction, nutrient availability	
Topography	Gradient, variability	
Hydrology	Flooding or ponding susceptibility, site drainage	
Land Use	Existing vegetation, pesticide residue, on/off-site seed sources	

Gathering Site Information

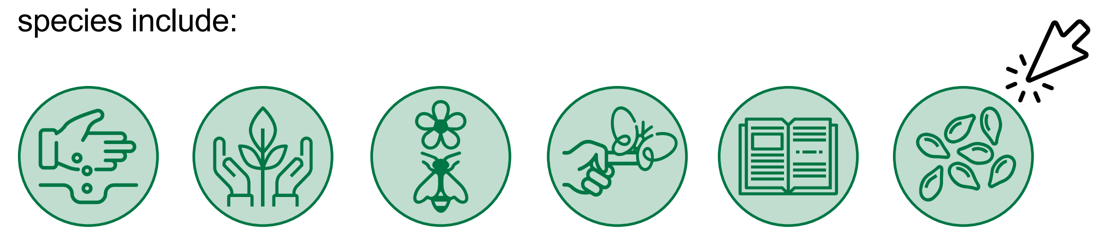
Site characteristic and condition information should be collected during early planning and verified prior to the time of installation. Other sources of site characteristic and condition information include:

- Preliminary siting desktop analysis reports
- Publicly available geospatial data on soils, hydrology, topography, and land cover
- Landowner descriptions or records of recent cropping history
- Wetland delineation and determination reports
- Botanical field surveys
- Soil sampling and geotechnical reports
- Growing conditions such as sun exposure, water availability, soil texture, and nutrient fertility
- Stakeholder knowledge
- Landowner experience

Conditions may be altered by grading during site preparation. Reliance solely on desktop or historical data may not be accurate or appropriate under these circumstances. If a site is to receive extensive modification, the grading plan may provide valuable details for vegetation planning. Grading plans typically include provisions for topsoil handling and note activities that may impact drainage. Consulting grading plans along with other site information resources can identify where conditions may be altered. For sites with little or no grading, soil testing, mapped soil data, and topographic maps may provide necessary information.

Right Plant for the Right Condition

The conditions under which vegetation establishes and grows is a primary concern in planning solar pollinator vegetation. Individual plants require different amounts of sun exposure, water availability, soil texture, drainage, and nutrients for optimal germination and growth. Species guides and vegetation specialists can be consulted for information on individual species and the conditions needed for optimal growth. Other published resources for identifying site condition requirements for plant species include:



PHASE Seed Selection Tool | USDA Plants | Xerces Society Pollinator-Friendly Plant Lists | Pollinator Partnership Ecoregional Planting Guide | Regional & State Pollinator Planting Guides | Seed Vendor Catalogs & Resource Guides

Factors that supply or limit these conditions should be identified during vegetation management planning. Planting plans, seed mix development, and site preparations can be adjusted to adapt to site conditions.

Developing a Vegetation Management Plan

Vegetation management plans identify the requirements and considerations for planned vegetation. Vegetation management plans typically include details from site preparation through site maintenance. Specific requirements may vary by location or company. Common components include:

- Summary of site **characteristics** and **conditions**,
- Vegetation goals and objectives,
- Planting plan design and site layout,
- Planned seed mixes,
- Site preparation and installation provisions,
- Establishment provisions,
- Anticipated maintenance provisions, and
- Associated inspections and monitoring expected.

When creating vegetation management plans, record the characteristics and conditions influencing the site.

When combined with constraint considerations (described in Section 2), it can be a helpful reference for solar pollinator vegetation planning.

Vegetation management planning may begin early in site development and be refined as site layout and designs are finalized. Regular communication between project teams and vegetation specialists can be important to producing vegetation management plans that help achieve site objectives and provide practical applications onsite.


Carpenter bee on purple thistle (Cirsium horridulum). Photo courtesy of Argonne National Laboratory

Communicate Solar Pollinator Vegetation Considerations

Communication between project design teams and vegetation specialists is important to successful outcomes. Once characteristics and conditions are identified and compiled into early vegetation management planning, communicating the initial findings helps verify expectations for vegetation. Communicating expectations can help:

Confirm goals and objectives are achievable. Communicating goals and objectives can verify their compatibility with current site layout and designs and allow for amending vegetation designs or site plans as needed to achieve the desired outcomes.

Ensure robust contracting. Incorporating provisions to review and adhere to vegetation management plans, vegetation inspections and reports, or communication milestones can help reduce the risk of overlooked details or mistakes.

Identify underlying assumptions. Vegetation planning may be based on a series of assumptions related to existing or expected conditions. Underlying assumptions may include soil conditions, site preparation activities, timing of installation, and accessibility for establishment maintenance. If any conditions are at risk of changing, adaptive management provisions should be considered.

Highlight critical needs. Discussions with project teams allows for communicating critical needs for successful vegetation outcomes. Critical needs like maintaining drainage, avoiding sensitive timeframes or conditions, and ensuring adequate decompaction are a few examples of critical needs that may be communicated. Needs and risks may vary by site. Vegetation specialists may need to identify critical needs to highlight with project teams.

Preventing mistakes. Miscommunication is a risk on any large, complex project. Avoiding miscommunication can prevent mistakes and unexpected conditions that may result from changes in site planning, design, or construction approaches. Incorporating communications between project design teams and vegetation specialists can help minimize the risk of miscommunication among parties.

Site Planning Checklist

When preparing for planting plan design or vegetation management planning, include the following:

- ☐ Summarize vegetation goals and objectives
- ☐ Identify external and internal constraints
- ☐ Evaluate site characteristics and their conditions
- ☐ Initiate vegetation management planning
- ☐ Communicate initial vegetation planning and assumptions with project teams
- ☐ Revise and finalize plans based on communications and review
- ☐ Share final vegetation management plans
- ☐ Adapt vegetation management planning if conditions change

Section 5
Planting Plan Design


A successful planting plan design starts with clearly defined goals and objectives. Photo courtesy of Stantec

WHAT'S IN THIS SECTION?

This section outlines the primary considerations for developing a planting plan for solar pollinator vegetation.

- What Drives Plant Selection?
- Steps to Designing a Planting Plan
- Additional Resources for Planting Plan Design

What Drives Plant Selection?

A planting plan should describe the extent and location of planned plant communities being established onsite. Planting plans may often be a component of vegetation management plans (VMPs) created for sites, which typically contain information not just on planting, but also the anticipated establishment and maintenance of vegetation. Vegetation decisions in planting plans are driven by:

- Compatibility with constraints posed by internal and external factors (see Section 2),
- Goals and objectives defined for the site vegetation (Section 3),
- Environmental site conditions (Section 4), and
- The characteristics of the plants that meet those needs.

Identifying these early in planning will provide direction during the seed mix and plant species selection, which is discussed in more within Section 6.

Key Takeaways for Planting Plan Design

- Goals and objectives should drive plant community design and species selections.
- Site infrastructure, characteristics, conditions, and constraints will inform what vegetation is compatible
- Planting plan designs will have short- and long-term implications for maintenance requirements.
- Plan for adaptation over the project lifespan.

Steps to Designing a Planting Plan

Planting plan designs often starts early in site planning. Planting plans are often iterative processes; as site designs and vegetation management goals and objectives are refined new information becomes available which can be incorporated into the planting plan as appropriate.

Once the drivers of vegetation decisions are identified, planting plans should be developed using the following process:

1. **Define** vegetation management goals and objectives for the site and components (arrays, perimeters, buffers, visual screens, stormwater features).
2. **Map** the location and extent of the project area(s).
3. **Establish** planting areas and their desired plant communities.
4. **Collect** data on site characteristics, conditions, and constraints.
5. **Determine** steps for preparation, establishment, and maintenance.
6. **Adapt** planting plan as conditions change.

Step 1: Define Vegetation Management Goals and Objectives

As described in Section 3, a successful planting plan design starts with **clearly defined goals and objectives** for vegetation management. Goals and objectives must also be considered compatible with the site constraints, like those identified in Section 2.

Goals and objectives need to be communicated. Vegetation planners should identify goals and objectives expressed by project teams in planting plans, or vegetation management plans. They may also be reinforced in:

- Project team meetings
- Stakeholder meetings
- Project documents and plans
- Contractor specifications
- Emails, phone calls, and other communications

Communicating goals and objectives for vegetation can help build buy-in, identify gaps, minimize risks, and avoid costly mistakes.

Step 2: Map the Location and Extent of the Project Areas

The project area extent, locations of array fields, and their context with the parcels leased play important roles in planting plan design. Creating or obtaining a map of the preliminary project area allows site planners to evaluate site context and potential planting areas. Contextual considerations for common solar facility planting areas are described later in this section.

Locations and layout may adjust over the course of project siting and design. Adaptation of planting plans in response to siting and design updates is important as projects are developed. While layouts may be adjusted, understanding the preliminary site location and configuration can inform the context, conditions, and constraints influencing the planting plans. Thus, preliminary plans should be created in a scale and format anticipating future revisions throughout the overall project development.

Planning Tip

- Mapping the potential planting areas early on in project planning can help communicate the scope, scale, and considerations for vegetation. It can also help identify pollinator opportunities early.
- Initial mapping of sites is likely subject to change over the course of project siting and design. Scale the level of detail used in mapping to account for adaptation needed during the planning process.

Step 3: Establishing Solar Facility Planting Areas

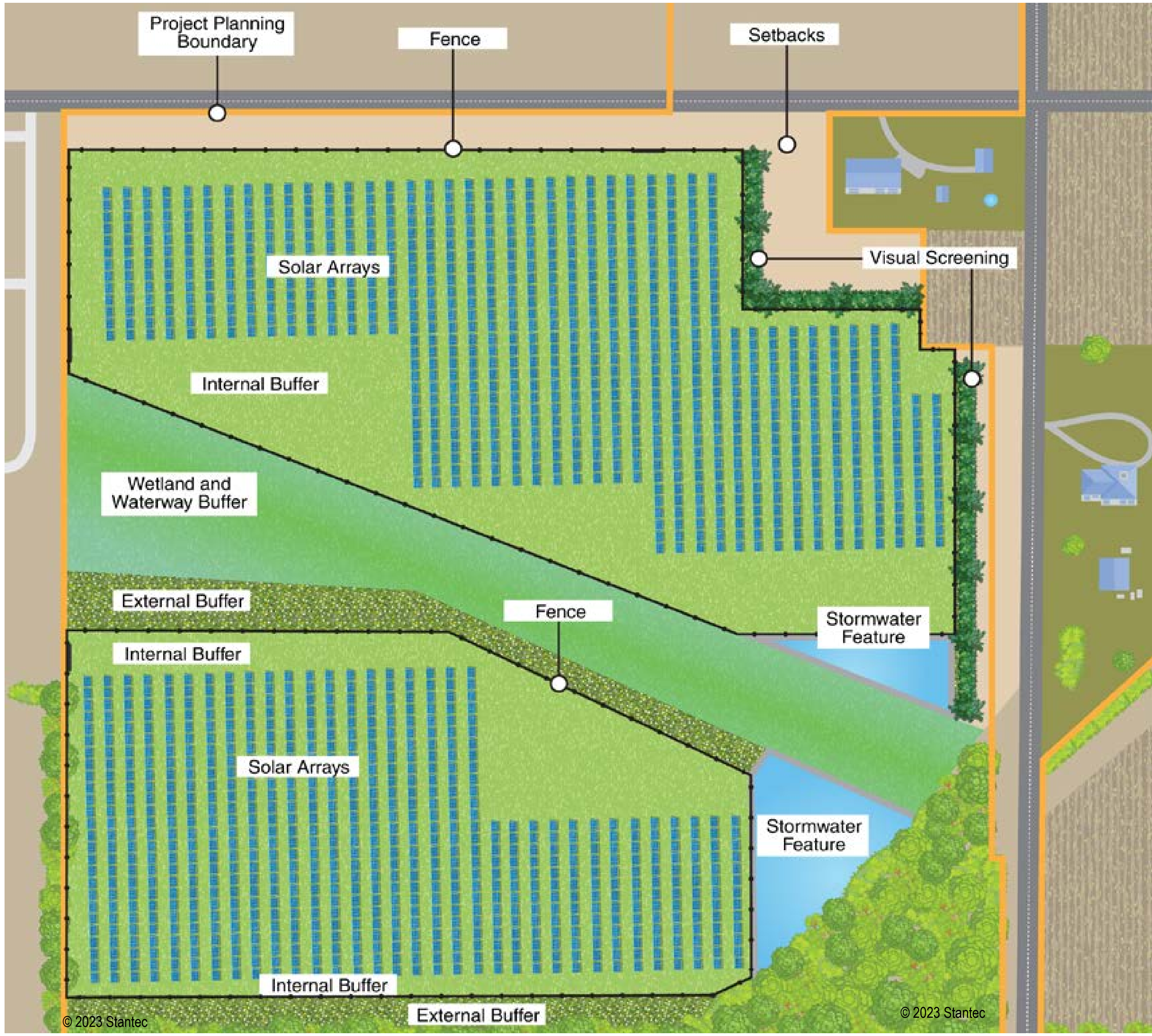
The spatial layout of solar facilities is an important aspect of planting plan development. Utility-scale solar facilities are often comprised of several zones that may have varying planting considerations for solar pollinator vegetation. This section describes different vegetated areas commonly included within a utility-scale solar facility along with a discussion of the roles, constraints, and opportunities of each in supporting solar pollinator vegetation. Section 6 discusses seed mix development and species selection in more detail.

Solar facilities vary in their size and design configuration, yet many include similar types of planting areas. Vegetation zones are often determined by the operational needs of the facility; the planting plan needs to consider what plant communities are most compatible for desired goals as well as site characteristics, conditions, and constraints. The planting plan should consider the desired plant communities to be established onsite within each planting area. At this stage, special attention should be given to considering the short- and long-term maintenance requirements needed to establish and maintain the desired plant communities.

Consulting experienced vegetation managers, contractors, or other stakeholders familiar with the desired plant communities and species included can provide valuable support in ensuring cost-effective and successful measures are described in the planting plan.

Figure 5.1 below illustrates a conceptual planting areas layout for a solar facility. While individual solar facilities may vary, this figure is intended to illustrate the spatial variations in layout that often influence pollinator vegetation compatibility, vegetation management, and planting plan decisions. Exact terminology used for each planting area may differ regionally, or across companies or project teams.

Figure 5.1. *Common planting areas relative to solar site and adjacent land use.*



Solar Arrays

Context

Vegetation included within array areas will comprise the majority of vegetation present at a solar facility. The primary function of vegetation under and between arrays is to protect panels from tall-growing weeds, prevent soil erosion, and minimize impacts from stormwater runoff. Limiting plant height to prevent shading of the solar panels is a key constraint to vegetation in array areas. Of all the areas within a solar facility, the array area vegetation is often the most intensely managed to prevent a loss of power production efficiency and to fulfill potential insurance requirements for fire risk reduction. Solar array vegetation can also be the least accessible for equipment for installation and maintenance due to access requirements within fenced areas, widths of vegetated areas between panel arrays, and presence of supporting infrastructure.

Planning Considerations

In locations where leading-edge panel heights limit vegetation height to 18 inches or less, regularly managed cool-season (or turf) grass can meet the basic requirements for array vegetation. Cool-season grass-dominated plant communities can prevent erosion and inhibit weed establishment and can be managed through routine mowing and/or grazing. However, reliance on cool-season or turf grasses may inhibit the diversity of flowering plant species available onsite (NRCS 2008) and may not be suitable in warmer climates or arid conditions.

Many plant species, native, naturalized, or non-native, can reach a height that may exceed the minimum panel height during the growing season if left unmanaged.

Typical plant height is a characteristic commonly identified in many resources such as nursery catalogs and plant selection websites. Many plant species have a height range that can vary between six inches to three feet or more depending on climate, local growing conditions, and vegetation management regimes. Understanding plant growth form and selecting species that typically grow to a height below the leading-edge (or lowest) panel height is a good start. Some species with growth heights higher than the panel height may not necessarily need to be excluded. Some plants with basal leaves or bunch-forming grasses may only exceed panel heights during primary growth stages and flower development. Consulting with vegetation management professionals and knowledgeable stakeholders can provide understanding vegetation growth forms and local site conditions that may allow for consideration of additional species.

Pollinator Opportunities

For pollinators, vegetation under and between arrays has the potential to provide a source of pollen and nectar forage resources via flowering plants, nesting and egg laying locations, and overwintering areas in thatch. Depending on site constraints, array vegetation may not be capable of contributing to all aspects of pollinator needs discussed in Section 2. Array vegetation may still present an opportunity to offer benefits to pollinators by incorporating some pollen and nectar resources and sustaining vegetation thatch.

Setbacks

Context

Setbacks include the areas between the project area and nearby roads, rights-of-way, or buildings. Setbacks may be driven by regulatory requirements, stakeholder feedback, owner or operator goals, or safety, security, and environmental best management practices.

State and local regulations or authorizing permit conditions may specify a minimum buffer width and constraint on type(s) of vegetation used. Operational policies, insurance requirements, and vegetation management goals determine the width of setbacks and type of vegetation used. Participating in a pollinator-friendly program may require using setback buffers to meet program standards intended to reduce pesticide exposure. Vegetated setbacks may be required next to adjacent existing natural vegetation or sensitive environmental features such as wetlands and streams.

Planning Considerations

Setback distances and requirements can vary from site to site and may overlap with required visual screening. Access for installation and maintenance is typically easy due to the proximity to roads and lack of fencing or other built infrastructure. Their location outside of fence lines may offer more flexibility in planting plan design choices and maintenance activities. Primary constraints may include compatibility with any visual screening and maintenance required for the establishment of trees and shrubs.

Pollinator Opportunities

Setbacks offer many opportunities for taller-growing pollinator plantings that may not be compatible within arrays. Less frequent or intense management of setbacks can also support the presence of a thatch layer important for nesting and overwintering of some pollinators. Reduced mowing can allow wildflower species to complete their life cycle (flower) and thatch that can provide overwintering and egg-laying vegetation to develop. Less frequent disturbance may also allow for the growth of species with woody, hollow stems, which can provide nesting habitat for pollinators as well.

When developing a planting plan design for vegetated buffers, review regulatory requirements for buffer width and vegetation selection along with the characteristics of pollinator-friendly vegetation discussed in Section 2 and previously in this section to evaluate if additional opportunities to provide pollinator-benefitting vegetation are available.

In arid regions, setbacks may require management as fire protection by incorporating firebreaks. Firebreaks may require being maintained with low-growing or minimal vegetation to protect the site against wildfires.

Visual Screening

Context

Visual screens consist of tree and shrub plantings that provide a physical and visual barrier between the solar array and adjacent lands. Visual screens may be standalone features or incorporated as part of vegetated setbacks, buffers, or fence lines. The area around screening trees may be either mulched or planted with vegetation.

Planning Considerations

Vegetation for landscape screening areas should be compatible with the maintenance of the trees and shrubs. Like setbacks, regulations or permit conditions may influence the species selection, height, location, and extent of visual screens. Adjacent land use, proximity to roads and buildings, and stakeholder feedback may also contribute to visual screening decisions.

Pollinator Opportunities

Visual screenings are often overlooked for pollinator enhancements. However, selection of trees or shrubs may provide pollen and nectar sources at times of year when other floral resources are scarce. Incorporating flowering species of trees and shrubs can provide important early growing season flowering resources during periods when risks of pesticide exposure is reduced such as winter and early spring. Some deciduous trees and shrubs (such as some willow and cherry species) flower during the early spring periods when other plants are still dormant or in vegetative growth, making them an important resource to pollinators. Coniferous (or evergreen) species may still provide some pollinator benefits, although there are large knowledge gaps regarding relationships between insect pollinators and conifers (Rivers et al. 2018). Trees and shrubs with soft, hollow, or pithy stems may support nesting or larval development locations required for some pollinators. Mulch beds and leaf litter around visual screens may also support ground nesting or overwintering conditions.

Internal Buffers

Context

Internal buffers are comprised of spaces located inside project fence lines between the panels themselves and the perimeter fences.

Planning Considerations

Greater distances between the fence line and the arrays allow more opportunities for diverse pollinator vegetation including taller-growing species not compatible within arrays. However, if the typical distance between arrays and a fence line is similar to the distance found between arrays, extending the array planting plans to adjacent fence lines may be preferred. Internal buffers are often used as temporary staging and receive high amounts of traffic during construction and thus compaction, if not remedied, may impact vegetation establishment. Access for installation and maintenance equipment is typically open and unobstructed.

Pollinator Opportunities

Internal buffers may provide opportunities for increased diversity in pollinator plantings. Increased plant diversity within internal buffer areas may contribute positively to overall scoring for projects participating in a pollinator-friendly scorecard program.

External Buffers

Context

External buffers are located between the perimeter fencing and the property or project boundary. External buffers can be subdivided into two categories. First, areas that will remain in the leased areas maintained by the project. The second being areas not included in the lease and thereby not maintained as part of the solar project area. These differences will influence strategies for installation, establishment, and maintenance over the duration of the project.

Planning Considerations

It's often easiest to include planting and management for all external buffers in initial planning and then further revise as project planning or lease agreements develop. External buffers that have existing perennial vegetation compatible with the project are usually preserved. Existing vegetation within external buffers may help preserve important habitats already supporting pollinators, including rare or unique natural features. If included in the long-term management plans for a site, external buffers can provide some of the best and unconstrained pollinator opportunities in a project area. Similar to setbacks, external buffers in arid regions may require management as fire protection by incorporating firebreaks.

Pollinator Opportunities

Vegetated buffers adjacent to existing natural features provide opportunities to create wildlife or pollinator corridor connections with adjacent natural lands. The increase in local plant diversity adds to the overall landscape plant diversity, which generally benefits pollinators. If the solar project is enrolled in a pollinator-friendly program using scorecard evaluations, including buffers near these features may contribute to a higher site score.

Wetlands and Waterway Buffers

Context

The size and configuration of utility-scale solar may include intersections with wetlands and waterways. Designs typically avoid placement of panels or other infrastructure within wetlands or waterways due to regulatory requirements and equipment risks from site hydrology.

Planning Considerations

Wetlands and waterways can exist both within and outside of perimeter fencing. If existing vegetation is compatible with the facility objectives, it is typically preserved. If incompatible, vegetation in these areas is often managed similarly to internal or external buffers.

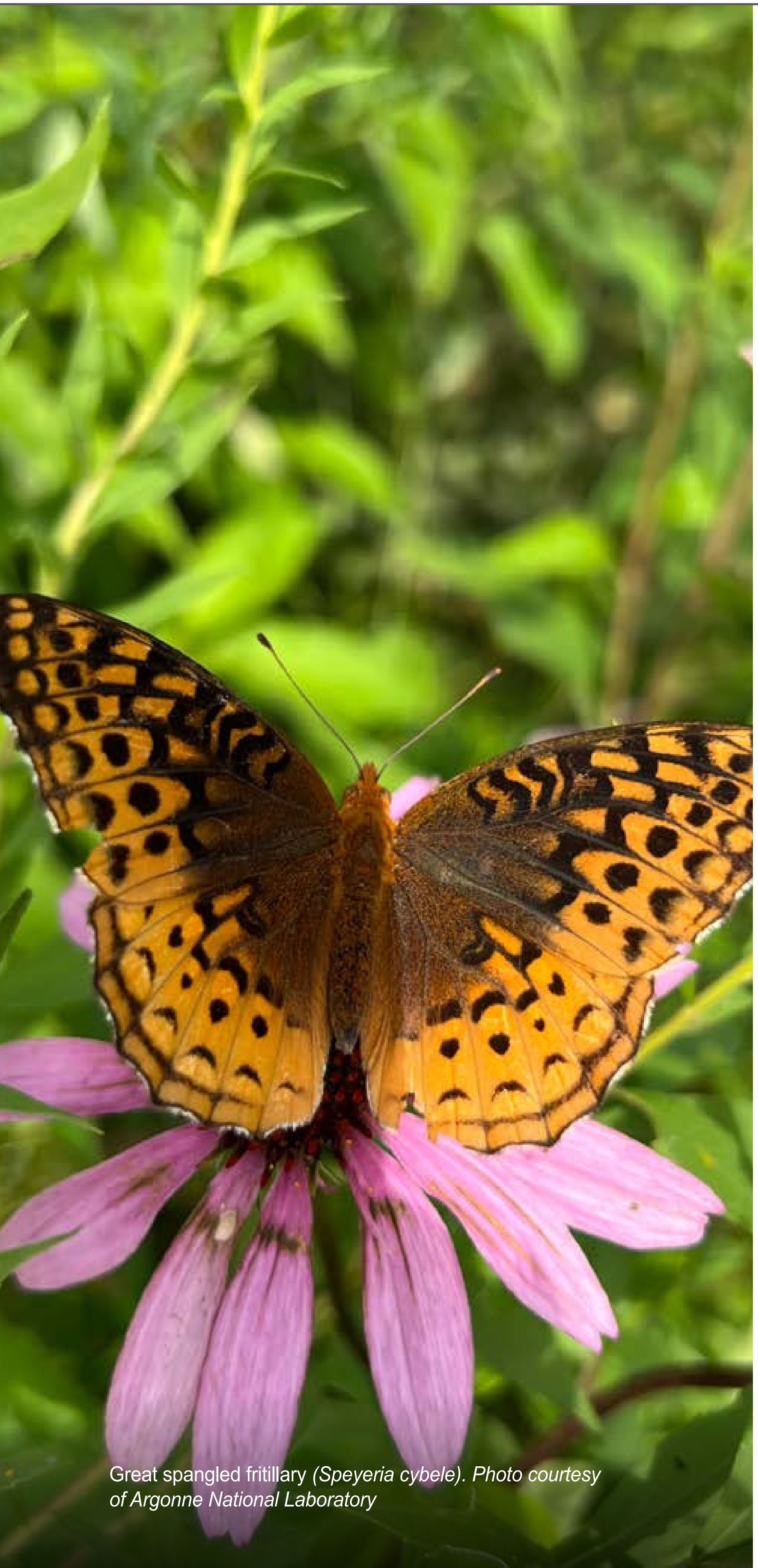
Pollinator Opportunities

Wetlands and waterway buffers provide similar pollinator opportunities as noted under internal and external buffers and have few constraints for management. Maintaining wetland and waterway buffers outside of fenced areas can also provide important movement corridors for other resident wildlife.

Stormwater Management Features

Context

Stormwater management features such as swales, ponds and basins are common elements to most solar facilities and are likely required under state or local ordinances. Stormwater features are designed to collect surface runoff and protect downstream water resources. The size, location, and type of stormwater features within a solar facility are primarily driven by state or local stormwater regulations.



Great spangled fritillary *(Speyeria cybele). Photo courtesy of Argonne National Laboratory*

Planning Considerations

Stormwater features are determined during the civil design process for a solar facility and consider site characteristics such as topography and soils for placement and type of feature used. Long-term vegetation management of stormwater features should be discussed during the civil design process. Including a vegetation management professional in the review of stormwater feature design is important to ensure vegetation management consistency with site goals and objectives.

Designing a planting plan for stormwater features requires special considerations. Design parameters such as residence time, average water depth, and anticipated water quality will be important to selecting resilient plant species. There are many resources available to support selecting appropriate plants. A good starting point is a state or regional stormwater best management practice guide for plant species in a particular region that will thrive in stormwater pond conditions.

The primary function of stormwater features is to treat stormwater before it leaves the site. Stormwater ponds and other stormwater features can provide additional pollinator vegetation that is separate from other solar facility areas. Site conditions around the perimeter and even within a swale, pond or basin provides different soil and hydrology conditions that allow for different types of plant species than what may be planned for other areas within the solar facility.

Pollinator Opportunities

Stormwater management features provide areas that can be maintained with taller growing vegetation not compatible in the arrays. Using such vegetation can increase floral resource diversity, create thatch for nesting and overwintering, and potentially support host plants. Stormwater management features typically feature open and clear access for installation and maintenance vehicles. Typical constraints include installation timing, establishment compatibility with regulations, and stormwater hydrology effects on species selection.

Demonstration Areas

Context

High profile areas such as along busy roads, at entrances to facilities, or at facility buildings or visitor tour locations represent an opportunity to provide pollinator vegetation while demonstrating the additional ecosystem services and environmental benefits provided by solar facilities vegetation management.

Planning Considerations

These areas may require added attention as high profile areas also have greater risk of negative public perception if vegetation is not successfully established or depending on local aesthetic preferences. Depending on the planned intended use of high-profile areas such as a visitor intake location, a landscape architect may be helpful to provide enhanced site design and visibility.

Pollinator Opportunities

Similar to vegetated buffers adjacent to natural areas, these areas may contribute to site evaluation and scoring for facilities participating in a pollinator-friendly program.

Step 4: Collect Data on Site Characteristics, Conditions, and Constraints

Section 4 discussed collecting data on site characteristics and conditions. At this stage of planting plan development, the information gathered then should be reviewed and inform decisions made regarding planned vegetation, planting areas, and establishment and maintenance. If information gaps or additional information is required, coordinate with project teams to address those needs accordingly.

Section 2 highlighted constraints that set sideboards for solar pollinator vegetation planning. These should be reviewed for compatibility in species selection, establishment approaches, planned maintenance, and risk mitigation strategies. If any constraints have changed since the start of vegetation planning, consider addressing those changes in the planting plan or in subsequent planning.

Step 5: Determine Preparation, Establishment, and Maintenance Actions

Preparation Timing and Sequencing

Construction schedules can be dynamic for any solar development. The planning and adaptation to timing of site preparation and construction is a critical element of the planting plan. Project location and species included in seed mixes have both optimal and less desirable times of year for successful site preparation, seeding, and establishment. Outline desired windows for each activity and location, as well as seasons or conditions to avoid.

Discussions with other site planners and project designers can inform planned construction schedules and sequencing. Planting plan designs developed in concert with the site design preparation and construction planning may require an iterative process but can lead to more successful outcomes.

When lease agreements and project authorizations allow, use of preconstruction seeding will almost always provide more cost effective and improved establishment as compared to post-construction seeding. The absence of built infrastructure allows for much more cost-effective installation. Preconstruction seeding has the added benefit of often shortening soil erosion permit closure timelines depending on subsequent disturbance during construction.

> **Planning Tip**
>
> - Communication between project team members, between developers and owners, or between planners and contractors is often where important considerations may be lost or overlooked.
> - Creating and communicating preliminary schedules for aspects of site preparation, establishment, and expected maintenance can be useful in communicating among all project stakeholders.

Determining Establishment and Maintenance Actions

Local conditions and practices appropriate for individual sites may vary by state or region. Recognizing this, some states and regions have published local guidance on preparation, establishment, and maintenance of vegetation on solar facilities. In addition to local guidance, consulting experienced vegetation managers, contractors, or other stakeholders can yield experiential knowledge that can greatly impact the success of vegetation establishment and maintenance.

Subsequent sections of this manual detail considerations for preparation, establishment, and maintenance. See Section 7 for construction preparation and planning details, Section 8 for seeding strategies and techniques, and Section 9 for establishment and maintenance expectations.

Step 6: Adapt Planting Plans as Conditions Change

Planning for adaptation is an important aspect of vegetation management planning, including in the planting plan development. Considering adaptation as part of planting plan development can account for changes that may occur. At other times, unforeseen changes may require revisiting and revising the planting plan to accommodate and incorporate new information.

Planning for adaptation should:

1. Identify areas of scope or timing uncertainty.
2. Describe conditions that will affect successful or undesirable outcomes.
3. Set triggers for when planning decisions may require reconsideration to avoid undesirable outcomes.
4. Communicate expectations across project team members and decision makers to build agreement and buy-in.

> **Planning Tip**
>
> - Adaptation may seem reactive, but when implemented as a practice, it can be a best practice and sign of mature planning or project teams.
> - Defining planning expectations and the triggers for re-visiting decisions are important to identify and communicate with project team members.
> - For utility-scale solar, common areas of uncertainty may include construction timing, seed mix availability, regulatory conditions, or contractor experience with vegetation requirements.

Solar facility in need of maintenance to prevent undesirable vegetation height and composition.
Photo Courtesy of Brodie Dunn, University of Illinois

Two-spotted bumble bee *(Bombus bimaculatus)* on top of a purple coneflower. *Photo courtesy of Stantec*

Adaptation in Planting Plans

Planting plans may require revisions as conditions change or project designs are finalized. Establishing the anticipated design schedule and milestones needed to inform updates to planting plans is important to scoping and being able to accommodate changes in site design and layout. Common milestones may include:

- **Initial concepts.** A high-level overview of potential planting areas used to identify preliminary cost estimates, potential seed mixes, and vegetation scope. Sometimes referred to as a "30 percent complete" plan. Initial concepts are typically prepared early in the site design preparation after preliminary layouts are first drafted.
- **Preliminary plans.** A drafted plan with proposed seed mixes, initial quantities, and preliminary schedules. Sometimes referred to as a "50-60 percent complete" plan. Details provided help inform site preparation and establishment planning but are still subject to changes from site designs. This may include initial drafts of a formal vegetation management plan for the site.
- **Revised plans.** Site design timeline and extent of revisions directly influence the amount of revised planning needed. As a result, there may be one or more iterations of revised plans. Sometimes referred to as a "60-90 percent complete" plan depending on the degree of completion. These versions should be well-refined at this stage with remaining key decisions or areas of uncertainty identified by vegetation specialists or project teams.
- **Final plans.** The final plan, which incorporates final decisions from project teams, and any regulatory entities reviewing. Plans are considered "100 percent complete" at this stage. Key decisions have been resolved. Areas of remaining uncertainty should have triggers and planned responses identified. These may include changes in construction schedule, species substitutions in seed mixes, or considerations for changes in site conditions over establishment and maintenance.

Adaptation During Establishment and Maintenance

Setting up adaptive management during establishment and maintenance requires planning ahead to inform when pivoting vegetation management tools or direction may be required to ensure success. Benefits of applying adaptive management over establishment and maintenance include identifying clear outcomes and triggers for management. They allow for redirection and adaptation when existing solutions are not producing the desired results. Adaptive management, when documented and communicated, can also build institutional knowledge within organizations to prevent remaking costly mistakes.

Adaptive management is suggested as a best practice by many land management guides for various purposes (Conservation Measures Partnership 2020; Salafsky & Margoluis 2003; Williams et al. 2009). The adaptive management framework (Figure 5.2) can be applied to management for solar pollinator vegetation on utility-scale projects.

Figure 5.2. Adaptive management framework

The guidance provided elsewhere in this manual can help inform adaptive management on projects. Sections 2 and 3 help define goals, objectives, and desired end goals that help set vision and targets for vegetation. Sections 4 through 10 help organize plans and implement actions. Sections 11 and 12 provide guidance in learning and adapting from experience and observations.

Additional Resources for Planting Plan Design

This manual provides a foundation for determining if and where pollinator vegetation is appropriate for a solar facility. Vegetation management is an evolving and adapting process that improves with experience and new knowledge gained. Vegetation management in solar facilities providing benefits to pollinators is a relatively new field of land management that blends vegetation management with conservation biology, restoration ecology, landscape design, and property management with energy development. During the planting plan design process, reference local and regional vegetation implementation manuals for refined guidance on everything from seed mix composition, seeding times, invasive species best management practices, and pollinator vegetation requirements. Below is a non-exhaustive list of state-specific resources examples available. We encourage users to search out the most recent guidance that may be available near their projects. However, we caution that not all resources have been developed with industry input, and may offer recommendations that may not be practical or appropriate for site-specific conditions.

Multi-state Guidelines

- Pollinator Habitat Establishment & Management Guide (covers 12 Midwestern states), Bee and Butterfly Habitat Fund, 2021
- Technical Guide: Establishment and Maintenance of Pollinator-Friendly Solar Projects (covers Northern Indiana and Michigan), Michiana Area Council of Governments, January 2020
- NRCS publishes resources in each state that provide state or region-specific technical guidance and specifications on selecting, installing, and maintaining natural vegetation including native species. These materials can be accessed via conservation practice standards each state's Field Office Technical Guide (FOTG).
- Managing Compatible Vegetation for Targeted Species and Biodiversity: A Companion to the Integrated Vegetation Management Best Management Practices, 3rd Edition, Utility Arborist Association, 2021

State-specific

- Illinois
  - Greening the Clean Energy Transition Smart Siting and Pollinator-Friendly Solar Energy in Illinois, The Nature Conservancy and Pollinator Partnership, March 2023
- Minnesota
  - Guidance for Developing a Vegetation Establishment and Management Plan for Solar Facilities, Minnesota Department of Commerce, March 2021
  - Prairie Establishment & Maintenance Technical Guidance for Solar Projects, Minnesota Department of Natural Resources, revised July 2020
- North Carolina
  - North Carolina Technical Guidance for Native Plantings on Solar Sites, North Carolina Pollinator Conservation Alliance, October 2018
- Virginia
  - Virginia's Pollinator-Smart Solar Industry, December 2019

Putting This into Practice: An Example

This is an example of how to apply the planting plan steps outlined into a layout with the different planting areas.

Step 1 is defining our vegetation goals and objectives. Example goals and objectives may include the following goals and objectives summarized in Table 5.1. Objective setting may be iterative. Targets and metrics included in objectives are often informed by site conditions, characteristics, and constraints summarized in Step 4.

Table 5.1. *Example goals and objectives*

Goal(s)	Objective(s)
Achieve NPDES permit vegetation requirements as soon as practicable.	Achieve required cover of seeded permanent vegetation by August of the first full growing season.
Create pollinator habitat to support company biodiversity goals.	By the end of the establishment phase, create 1,000 acres of low-growing pollinator habitat within array areas that is no more than 18 inches in max height and comprised of 10% cover of at least two flowering plants included in seed mixes. By the end of the establishment phase, create 100 acres of tall-growing pollinator habitat within setback areas that is between 18-36 inches in height and comprised of at least 30% cover of six or more native flowering plants included in seed mixes.
Create an opportunity for new agricultural markets.	Within the first three years after establishment, secure a local farming relationship that maintains at least 100 acres of array areas through prescribed grazing, or, Within the first three years after establishment, contract with local beekeeper and use the solar facility for honey production, and maintain several hives onsite.

Using the conceptual layout provided in Figure 5.1 (Step 2), we first establish the planned planting areas for the site (Step 3).

Monarch butterfly pollinating common milkweed.
Photo courtesy of Clare Longfellow

Next, in Step 4, we collect information on site characteristics, conditions, and constraints and then summarize the site requirements and constraints identified:

External conditions and constraints include:

- Prior site use was primarily row crop agriculture. Landowner agreements are allowing farming up until construction site preparation begins.
- County has required 50-foot setback from roads that is planted into native pollinator vegetation.
- County has required 100-foot setback from residential properties with visual screening for all residences.
- Vegetation under panels must not exceed 18 inches.
- Conform with the stormwater permit specific requirement of permanent vegetative coverage on-site prior to permit closure.

Internal conditions and constraints include:

- Biodiversity goals include 5% pollinator friendly vegetation incorporating all five of the pollinator characteristics on each site.
- Minimize long term maintenance costs.
- Minimize overall costs needed to achieve objectives.
- Engage local stakeholders.

Using this information, we can begin to identify the planned applications across planting areas as demonstrated in Table 5.2 to the right.

***Table 5.2.** Examples of applying site characteristics, conditions, and constraints to planting area planning.*

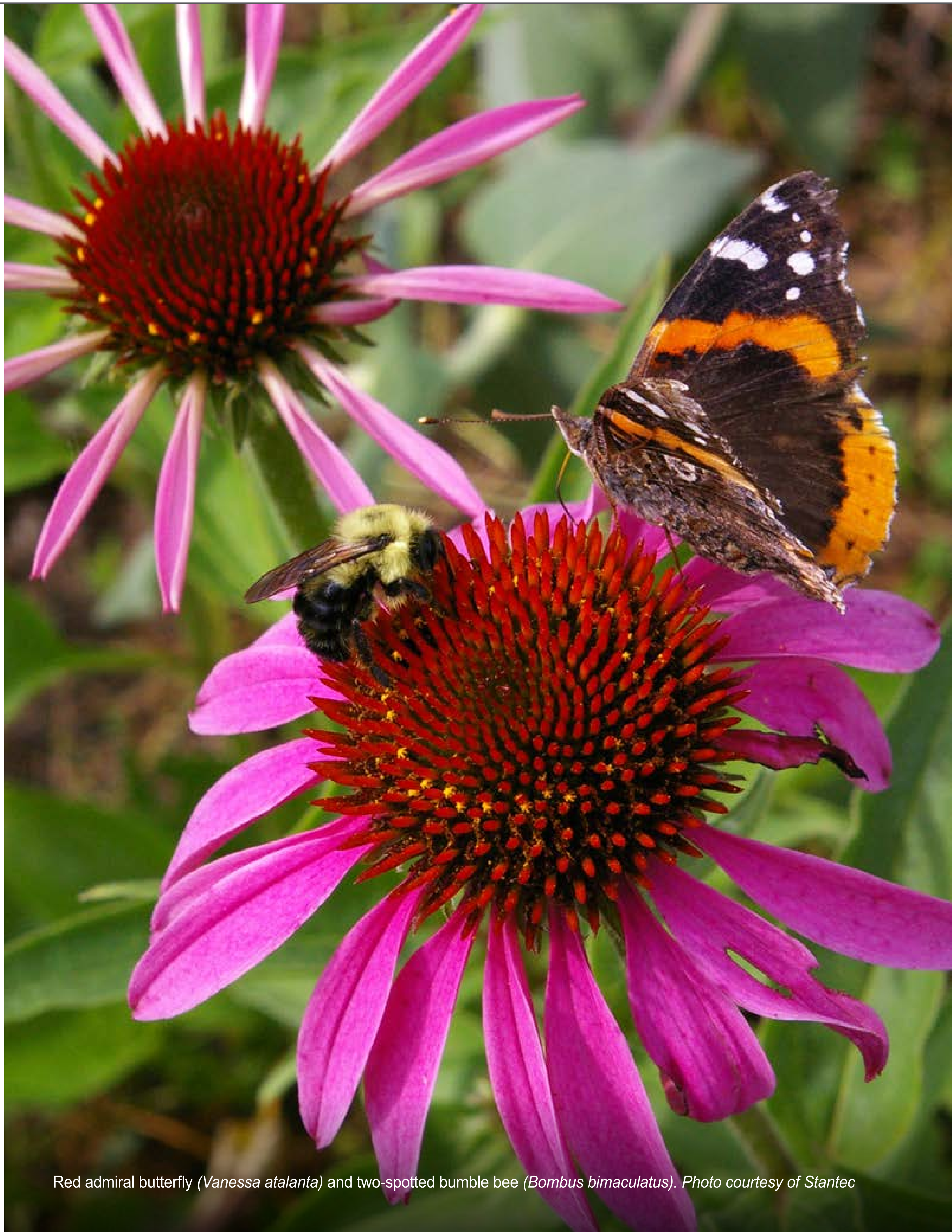
Planting Zone	Planned Application	Vegetation Types Planned
Arrays	In this example no external or internal constraints directly apply to the panel arrays. Plant selection will focus on the lowest maintenance costs and vegetation that will remain shorter than 18 inches. Some clovers and other low-growing flowering plants may be incorporated to provide nectar sources for some pollinators. Seed selection will be addressed in the next section.	Low maintenance; <18 inches
Setback	Setbacks are clearly defined in local ordinance and required to be native. In this case adding pollinator species to the native species will also contribute to the biodiversity goals. This area will be designated pollinator vegetation with species selected with an average height of 18-36 inches. Total setback areas comprise 2% of the total project area.	Native pollinator vegetation; 18-36 inches
Visual Screening	Visual screening is clearly defined and has no species-specific requirements. Early blooming native trees and shrubs can be used to contribute to the bloom time and nesting characteristics of pollinator vegetation as well as evergreen species for year-round screening.	Mix of evergreen and early blooming woody species
Internal Buffers	No external requirements are specified. The initial approach proposed to the project team suggests native pollinator vegetation. However, either the array mix or the setback mix could be used in the internal buffers depending on internal considerations or constraints. Keeping these areas consistent with either adjacent area can minimize the overall number of seed mixes and simplify installation. Internal buffer areas comprise 2% of the project area and thus can contribute to the biodiversity goals.	Native pollinator vegetation; 18-36 inches

Table 5.2. *Cont.*

Planting Zone	Planned Application	Vegetation Types Planned
External Buffers	External buffers can be either planted to solar pollinator vegetation or be used for agricultural uses. In this example, the local landowner coordination allowed external buffers to be used for hay production for a local farm. The farmer is willing to seed and maintain the area for the life of the agreement. However, the farmer wants to avoid planting until the area extent is finalized, so the developer has agreed to plant a temporary cover crop for stabilization during site preparation and construction until the landowner installs their desired hayfield mix. Other portions of the buffer areas is too narrow for farming equipment and thus difficult to maintain in hay production. The project team has decided to plant additional native pollinator vegetation in that area, thus contributing to the minimization of costs, local engagement, and increasing the total cover of solar pollinator vegetation.	Temporary seeding of a cover crop along a designated portion of the external buffer area. Native pollinator vegetation; 18-36 inches for all other external buffer areas.
Wetland and Waterway Buffers	The farmed waterway is currently a mix of existing vegetation and farmed areas currently in soybean stubble and not stabilized. Original discussions allowed the farmer to continue row cropping in this area, but the it frequently floods and harvesting crops would be unreliable due to the wet conditions. Thus, the remaining unvegetated buffer area will be seeded with a mix of grasses adapted for hydrology and selected to provide low maintenance stabilization, water quality, pollinator overwintering habitat. This area is designated as low maintenance native/non-native with no height restrictions.	Low maintenance all grass, water tolerant, no height restrictions
Stormwater Features	Stormwater features need to be established quickly as seed timing will be determined by the completion of the basin construction. Other than the stormwater requirements there are no constraints on vegetation selection. A temporary cover crop is included in the seed mix to establish quickly and an all-grass native/naturalized hybrid mix is intended to meet the establishment, management, cost objectives.	Fast establishing, fluctuating hydrology tolerant vegetation; <36 inches

We now have a planting plan with the planting areas identified and information needed to begin seed mix selection which will be discussed in Section 6.

- At least four perennial seed mixes will need to be developed: one for the array, one for buffer/setback areas, one for the waterway and wetland buffer area, and one for stormwater features, plus
- One temporary cover crop seeding mix for the external buffer area to be maintained by the neighbor.



Red admiral butterfly *(Vanessa atalanta)* and two-spotted bumble bee *(Bombus bimaculatus). Photo courtesy of Stantec*

Section 6
Seed Mix Selection

Solar pollinator seed mix. *Photo courtesy of Stantec*

WHAT'S IN THIS SECTION?

This section discusses considerations and steps for selecting appropriate seed mixes including:

- Determining Seed Mix Selection
- Procurement Recommendations

Key Takeaways for Seed Mix Selection

- Seed mix selection involves narrowing in on optimal species best suited for site goals, constraints, and conditions.
- Adaptation is important when selecting species for seed mixes. Changes in availability, timing, and conditions may require revision to mixes development.
- Working with seed vendors early in seed mix development can help avoid supply chain delays or costly changes

Determining Seed Mix Selection

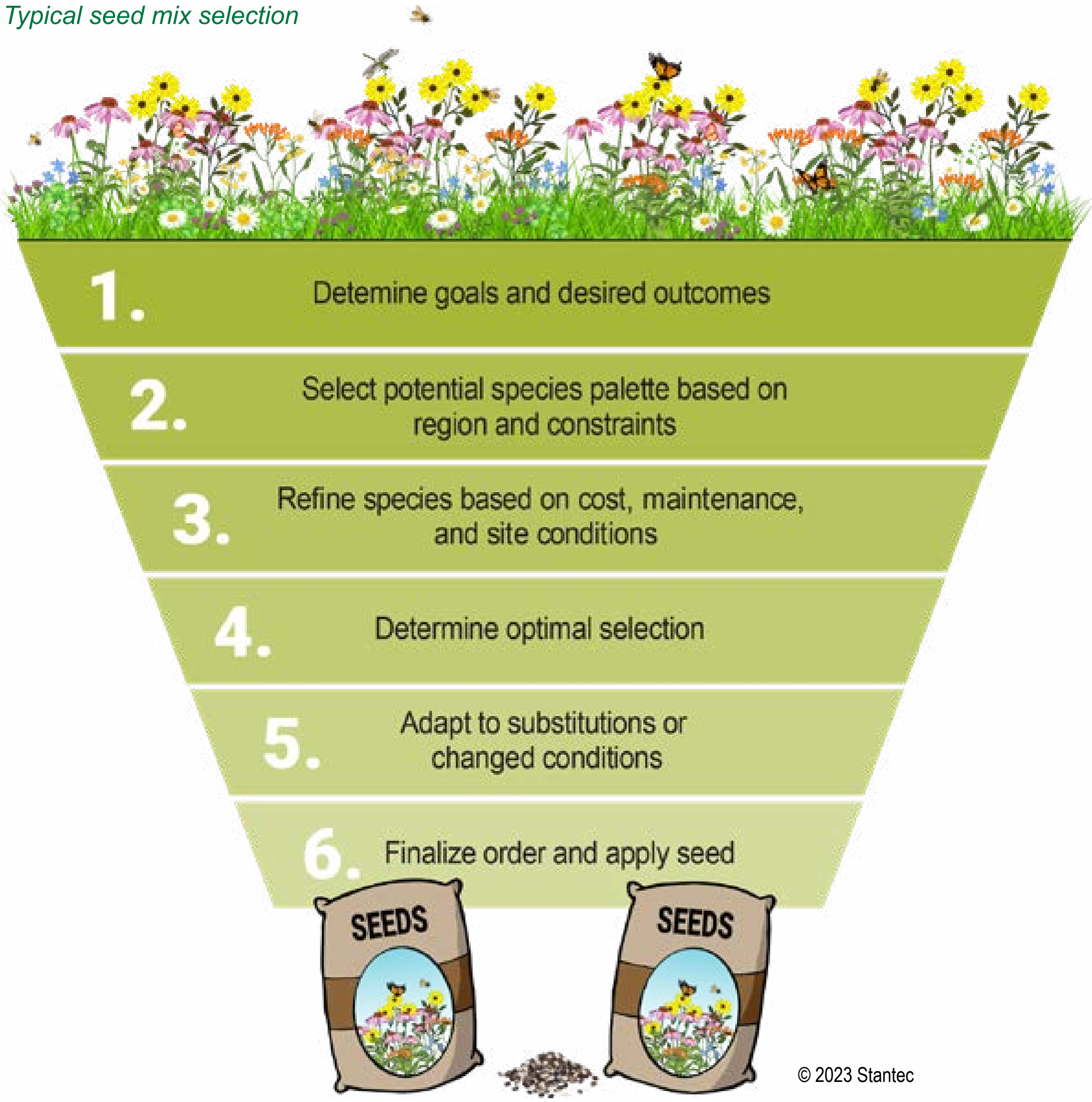
In the previous section, planting areas and their layout were made. Once seeding areas have been identified and the number of seed mixes determined, development of each mix begins. This describes the suggested decision-making process to select compatible species for solar pollinator vegetation planting areas.

Figure 6.1 summarizes the filtering process steps typically used to create seed mixes. Developing and obtaining approval for a seed mix is often an iterative process. Depending on design changes, market availability, timing, and cost it may require several revisions to finalize a seed mix.

May we suggest using the...

PHASE Seed Selection Tool

Figure 6.1. *Typical seed mix selection process*



Step 1. Determine goals and desired outcomes

Section 3 discussed the importance of identifying goals and objectives for site and use of solar pollinator vegetation. Goals are often directly tied to specialized land uses like mowed turf, grazing forage, and naturalized grasslands which inform seed mix development. Identified goals and objectives should be used to guide high-level considerations for mix grass and wildflower composition and possible species for consideration.

Step 2. Select potential species palette based on region and constraints

Ecoregions

All plants have a range of conditions that they are adapted to thrive within. Many of those conditions are driven by regional climates. Level 3 ecoregions as mapped by the Environmental Protection Agency (EPA) are a useful reference that account for both climate, geography, and landscape features (Figure 6.2, EPA 2006, 2013). Plant Hardiness Zones developed by the U.S. Department of Agriculture (USDA) are another helpful tool in comparing conditions across regions (Figure 6.3, USDA 2012).

Plants that adapted to warm ecoregions or zones are likely to die if planted in a colder one. In contrast, plants from colder ecoregions or zones may be less adapted to warmer climates and be outcompeted by other vegetation. While ecoregions and planting zone boundaries may shift with climate change, limiting species selections to those species present in existing mapped boundaries still provides the most suitable species for solar pollinator vegetation plantings.

Figure 6.2. *Level 3 Ecoregions of the U.S. (EPA 2006, 2013)*

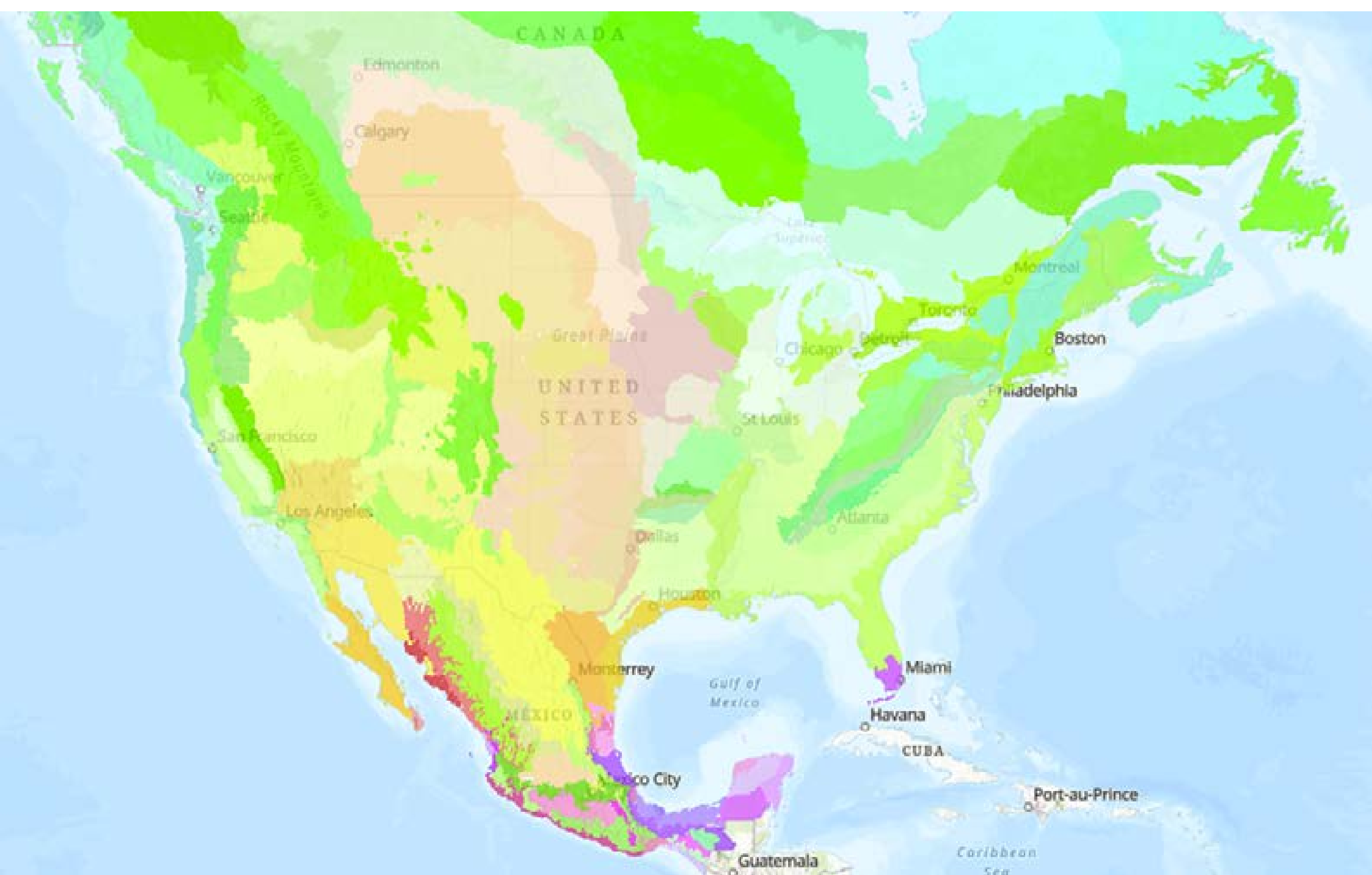
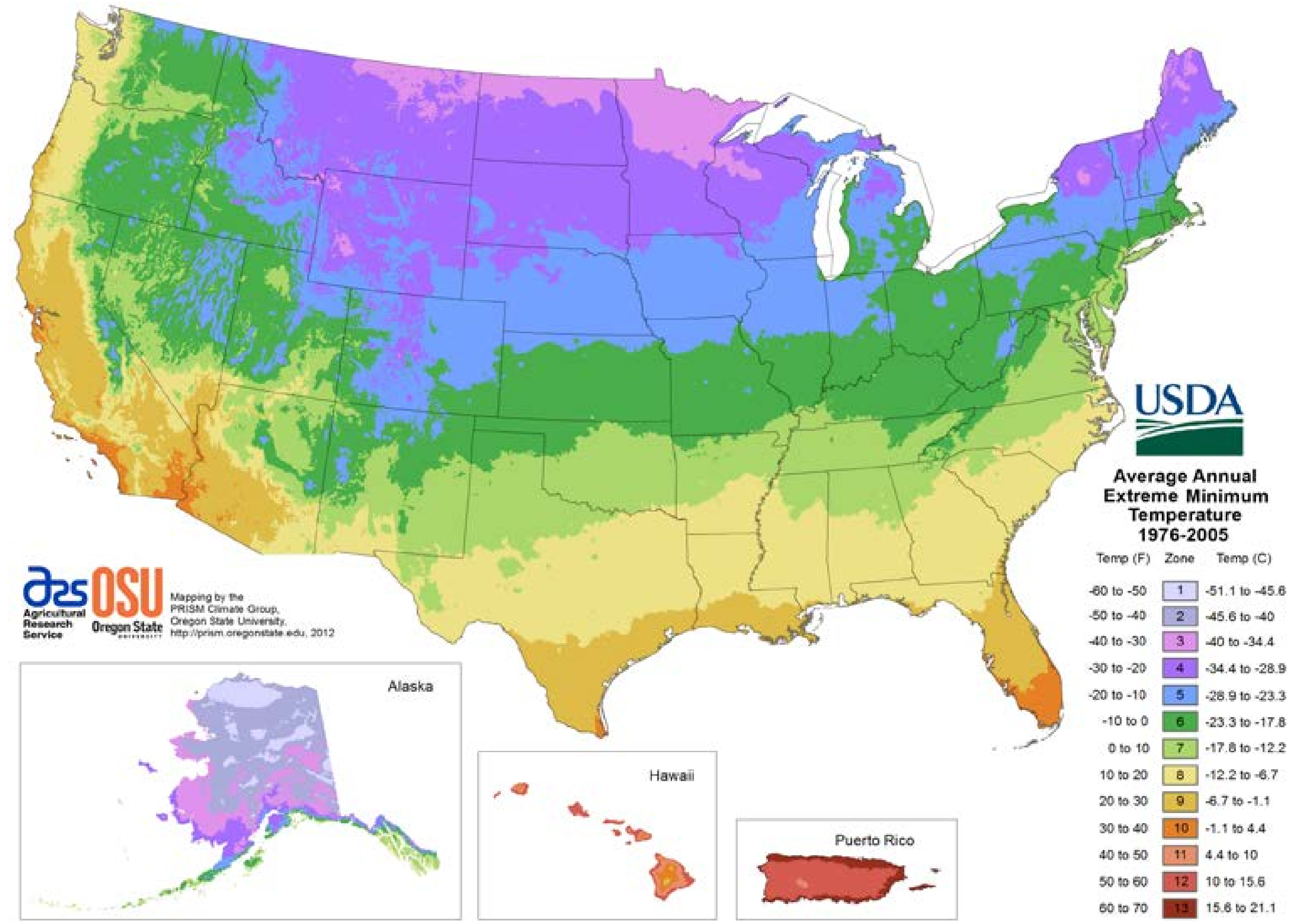


Figure 6.3. *USDA Plant Hardiness Zones*



Constraints

Section 2 described common external and internal constraints that affect solar pollinator vegetation. This section describes some of the specific considerations that constraints can have on seed mix selection.

Height

Every species has a range of heights that can be achieved when mature. In a moist high nutrient setting, a species may achieve a higher mature height than compared to a drier low nutrient environment. Work with an experienced and qualified seed supplier or vegetation specialist to evaluate the anticipated heights of species considered for a mix.

Within arrays, species that reach a maximum height greater than the leading edge of the panels, and will not be adequately maintained lower than that height through planned vegetation management actions, should be removed from consideration due to incompatibility.

Panel design and array layout

Site design can influence the planting areas established on a project site. Consider the planting areas identified and any constraints that may differ across each. Most notably, site design and panel layout will affect the extent of areas available and related constraints for access or maintenance requirements.

Regulatory requirements

Local ordinances, state permits, or scorecards may require use of certain types of species. Requirements for native vs. non-native species, amount of grasses or flowering species included, or number of species with seasonal bloom times are examples of mix requirements sometimes associated with permits and approvals.

Availability

Any species on the market that is not available in the quantities needed for a project may be eliminated from further consideration. Developing a species list with species that may not be available when the order is placed will only require subsequent planning for substitutions in final mixes. Including the acreage of the site and vegetation zones when sourcing seed allows suppliers to evaluate which species may be both suitable and available. Availability may need to be reviewed by a seed vendor unless vegetation specialists are familiar with current native seed supplies.

Step 3. Refine species based on cost, maintenance, and site conditions

Cost

Cost is often a primary constraint for seed mix selection. Project budgets often dictate an expected cost per acre or mega-watt (MW) for seed procurement. As a result, seed mixes are often constrained to the budget required for a site. Setting aside adequate budget for seed procurement can have a great impact on the types of mixes potentially available to a site and the capacity to adapt to changes in market costs and availability.

Maintenance Expected

Different maintenance regimes will influence what vegetation will be able to persist and thrive on a site.

Temporary cover crops

Temporary cover, or nurse crops include additional species planted alongside perennial seed mixes to provide quick-establishing coverage, stabilization, weed suppression, or as a carrier for consistent application of small native seeds. Typical cover crops include annual species that germinate, mature, flower and die in one growing season. Two attributes that are similar across most species used for this purpose are fast establishment and short persistence. The decision to include temporary cover crops crops depends on perennial species selected, construction timing, soil type, and installation equipment.

Some common scenarios where temporary cover crops are applied include:

- Areas that will be disturbed or exposed to construction traffic soon after seed install,
- Areas regulated by an erosion control permit that need vegetation coverage for compliance,
- Use as weed suppression for native and pollinator mixes that contain slower establishing species,
- When seed mix application rates are lower than the capacity of the equipment available, and
- When the consistency of the seed mix is difficult to feed though equipment. Temporary cover crops can act as a carrier; allowing the mix to flow through a hopper or meter more reliably.

Mowing

Grass-dominated plant communities (often naturalized cool-season grasses with a minor component of naturalized or native wildflower and legume species) are often suited for this purpose because of their lower maximum height and tolerance for repeated mowing to maintain a compatible vegetation height. Mowing is also recommended for the initial years of native species mixes as well. Using a combination of grass species accounts for variation in site conditions and provides species that will be actively growing over the duration of the growing season. For example, cool-season grasses stop growing when summer temperatures increase and soil moisture decreases. If only cool-season grasses are used, weeds and other unwanted plants can become established in the summer or drought periods when plant resources are scarce. Including warm-season grasses that are compatible with site management like mowing may help improve long-term stability of the vegetation.

Grass-dominated vegetation can provide some benefits to pollinators if managed properly. Native and non-native flowering plants are likely to establish in any grass-dominated system, albeit with less diversity and abundance than expected in plant communities seeded with a mix of grassed and wildflowers as a target composition. Minimizing the number of mowing events annually allows grass species to maximize plant height between mowing events and allows ancillary flowering species such as dandelions, violets, clover, and other native and naturalized species to flower are two ways to provide benefits to pollinators. Section 9 provides greater detail on how to manage grass-dominated areas for pollinators.

Maintaining a manageable vegetation height.
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Weed control with herbicide treatments.
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Grazing

Grazing as a management tool in a solar array is different from pasturing or haying in a conventional agricultural context. The goal of a solar seed mix is to stabilize the soils and use grazing to manage the height of a solar array mix. Most pasture and hayfields are designed to produce forage: the maximum amount of biomass practical to provide feed for grazing animals. Plant species and varieties that are marketed for pasture and hay may or may not have qualities that are compatible with a solar array. A solar array mix that is compatible, beneficial to pollinators, and palatable for grazing animals thus may have different considerations than a conventional pasture mix designed to generate forage. Pasture and hayfield mixes may contain varieties hybridized. Two varieties of the same genus and species can have very different heights and growth habits. Data for specific varieties must be evaluated prior to approval of mix selection.

Solar pollinator mixes intended for grazing must consider potentially toxic species for grazing animals. For example, milkweed species contains toxins that make them unpalatable or toxic to certain animals. If milkweeds are included as part of the pollinator program, care should be taken to avoid incompatibility with grazing animals as a vegetation control method. The PHASE Seed Selection Tool paired with this manual includes compiled data regarding plant species toxicity to livestock. If considering grazing as a management action, consult this and other resources in advance to verify potentially toxic plants are excluded from seed mixes used in grazing areas.

Endophytes are another hazard to foraging animals. Many grasses like fescues *(Festuca spp.)* have symbiotic relationships with bacteria or fungus, generally referred to as endophytes. Endophytes may be beneficial to individual plants, but can cause digestive, and reproductive issues with grazing mammals (Ball et al. 2015). If grazing is part of the vegetation management plan, care must be taken in seed mix development to ensure the species and varieties included in the seed mix are compatible with grazing animals.

Herbicide treatments

Herbicide is another common tool used on utility scale solar sites. Herbicides are designed to damage or kill plants. Thus, in solar pollinator vegetation ensuring that planned herbicide treatments will be compatible with flowering species is critical. While certain native species can demonstrate some tolerance to specific herbicide formulations (Corteva 2019), this should not be assumed for other herbicides. Targeted herbicide use as part of an overall integrated vegetation management strategy can provide compatibility with a wide array of vegetation types and species selections.

Site Conditions

As discussed in Section 4, site conditions and characteristics can have a major impact on species suitability. This section describes some of the specific considerations that site conditions can have on seed mix selection.

An individual species may be very tolerant of one condition but susceptible to another. In that scenario a site or weather condition that is stressful to that individual species could result in significant loss. A combination of species with differing tolerances will cover a broader range of site conditions. Such diversity builds resilience against unforeseen site conditions or severe weather or climate conditions. This resilience may be quantified by the number of species included in a mix with different tolerance ranges. Any seed mix applied to a large area will cover a wide variety of environmental conditions including sun and shade exposure, soils and hydrology, or potentially invasive or noxious species.

Sun exposure

Sun exposure may change across an array area depending on proximity to panels or adjacent tree cover. While portions under panels may be nearly completely shaded, most areas around panels maintain either full or partial sun exposure. Species that can tolerate either degree of sun exposure will establish and persist on sites more effectively than shade tolerant species.

Soils and hydrology

Individual species are closely associated with soils, soil moisture, and hydrologic regimes. Plant species can either tolerate or thrive under specific soil texture and drainage types. Closely related to drainage, soil moisture is another factor important in species selection. Individual plants range in their tolerance of wet-to-dry conditions. Selecting inappropriate species can result in poor germination or lack of establishment.

Soil drainage and moisture is often tied to the site hydrology. The position of the site within the landscape and how water infiltrates, drains, or runs off accordingly is an important influence on all these factors. Sites in flat low-lying areas may flood or pond more frequently than sites that are higher in the landscape, or those that contain some grade or sloping. Understanding the site hydrology is critical to understanding whether certain species will thrive in the environment they are being planted within.

Potentially invasive or noxious species

The presence of invasive or noxious weeds in or near a project site may require consideration in seed mix development. These undesirable species may be present in the existing seedbed or on nearby parcels. Their presence can pose a threat to the establishment of desirable vegetation. Inclusion of species that either individually, or collectively, can inhibit invasive or noxious weed invasion may be a mix consideration. Other plant species may not be categorized as an invasive or noxious weed but may behave aggressively under certain conditions. Experienced vegetation specialists can inform individual species suitability based on prior experience or reference examples based on site conditions.

Step 4. Determine optimal selection

Refinement

After narrowing down the available options to species that are appropriate for a site, final selection of the seed mix may be made. Determining the optimal selection of species for a site may be made by revisiting earlier steps in the selection process and considering which of the remaining species in consideration are best suited for construction plans and site conditions.

Different species will establish and mature at different rates. Optimizing seed selection considers the time it will take for plants to achieve maturity in relation to the overall mix, construction and stabilization requirements, and management schedules when designing a mix. Erosion control compliance often creates a preference for fast-growing, quick establishing species. However, seed mixes containing only quick establishing species may result in short-lived or less persistent species. By comparison, species with a longer establishment window (such as warm season grasses) can persist for the duration of a project. Refinements during optimal seed mix selection should consider a diversity of establishment times and persistence of species as vegetation matures after establishment.

Seeding Rate

Seeding rates are commonly expressed in pounds per acre. This method is useful when discussing individual species, predetermined seed mixes, and in seed application. Pounds per acre is less useful in seed mix development as it conveys little information about the quantity of seed in a mix.

Seed vendors and vegetation specialists often use the seeds per square foot, or number of plants per acre to determine optimal seeding rates. An optimal mix contains enough seeds to adequately cover an area without large quantities of additional seed that is wasted, nor too sparse leaving room for weeds and other opportunistic species to establish. Optimal seeding rates vary by seed type. Native seed mix recommendations often range from 20 to 80 seeds per square foot (NRCS New Mexico 2008, NRCS Iowa 2011, NRCS Texas 2011, Xerces 2022) depending on region, seed mix, and installation method. Cool season grass mixtures are often higher, typically ranging in hundreds of seeds per square foot (UW Extension 2014). Consulting with seed vendors and vegetation specialists can help select the proper seeding rate based on goals and site conditions.

Temporary cover crops should not be included in the seed per square foot calculations for perennial mixes. They are not intended to persist through to the established vegetation. Including temporary cover crops in seeding rates artificially reduces the expected plant density of perennial vegetation.

A selection of seed mixes. *Photo courtesy of Stantec*

Step 5. Adapt to Substitutions or Changed Conditions

Despite the best plans, timing and conditions change. Expecting adaptation upfront allows for increased resiliency and less delays in project timelines.

Installation Timing

Each region and individual species have periods when conditions are best suited for successful germination and establishment. Seeds need a certain temperature to germinate, sufficient moisture to support early growth, and enough time to establish until they can survive a range of conditions. Different classes of plants can have different tolerances for drought and cold that drive the ideal planting window for those species and a mix of combined species. Classes of plants like rye can germinate and be subjected to freezing conditions almost immediately and survive, while warm season grasses typically need several months to develop resistance to cold. Which species are included in a mix will determine when that mix can be installed and established successfully.

Added resilience in seed mix development through species diversity can help mitigate the negative effects from schedule changes and regulations that require planting outside of preferred planting windows. However, it cannot overcome them entirely. If planted outside a preferred timing, assume that supplemental seeding may be necessary to establish the intended vegetation regime. Optimal timing windows in the Midwest are generally late fall through late May depending on soil moisture and site conditions (Stantec 2023), other regions of the country may vary. For example, in south Texas, seed may be applied year-round with optimal timeframes being between August 20 and September 30 (Smith et al. 2016). Check with seed vendors, vegetation specialists, and local resources for regionalized recommendations.

Step 6. Finalize Order and Apply Seed

Once the optimal seed mix has been selected, finalize orders with selected seed vendors and schedule installation. Installation of seed will be discussed in Section 8.

View from underneath solar panels of planted vegetation. *Photo courtesy of Brodie Dunn, University of Illinois*

Procurement Recommendations

When locating a seed supplier, identify sources with material capacity to supply volumes needed for utility-scale solar. In some cases, seed may need to be sourced from multiple vendors. Working closely with suppliers will help streamline selection by leveraging industry knowledge of seed availability, cost, and suitability. Some seed suppliers may have predesigned mixes that meet site requirements, however, custom mixes will often be needed to achieve specific site objectives. Here are several recommendations for consulting with seed vendors:

Consult with Seed Vendors Early

Consulting with seed vendors early in seed mix development can help select species most optimal for the site. Seed vendors may also advise on species availability and expected supply chain or seasonal constraints. Some seed suppliers may require a deposit, or full payment in advance, to place an order for large quantities of seed, especially for custom blends.

Purchase Pure Live Seed (PLS)

Seed mix costs are determined by the cost of seed itself, which is often expressed in Pure Live Seed (PLS) or bulk volume (pounds per acre). Pure Live Seed (PLS) provides a standard quality assessment to allow customers to compare seed lots, especially across price variations, of the same species. PLS describes the viable germination percentage of a seed batch. In other words, if only 70% of pound of seed is viable based on PLS testing, then a pound of PLS seed would include 1.3 pounds by weight to compensate for the germination rate. A PLS weight of 100% indicates that all materials are anticipated to germinate.

By comparison, bulk pricing does not account for germination rates, which may result in lower volumes of viable seed per pound purchased. Bulk pricing can sometimes result in lower seed costs. Traditional turf and forage species have minimum purity and germination ratings. However, native seed stocks have more variation in germination rates, adding uncertainty that may pose an unnecessary risk to vegetation establishment if using untested bulk supplies.

Ask for Substitution Recommendations

Seed vendors have an active pulse on market availability of species. They can advise on substitutions that may be available early in seed mix development, which can aid adaptation when orders are placed. When substituting species, try to substitute with species that fulfill similar functions (growth habits, bloom period, or similar).

Section 7
Construction Planning and Site Preparation

WHAT'S IN THIS SECTION?

- Integrating Vegetation into Construction Planning
- Seed Procurement
- Planning Site Preparation
- Site Grading and Planting Schedules
- Pre- vs Post-Construction Seeding
- Financial Considerations
- Cost Comparisons
- Putting Planning into Practice

New Solar facility planning. © *Stock.adobe.com*

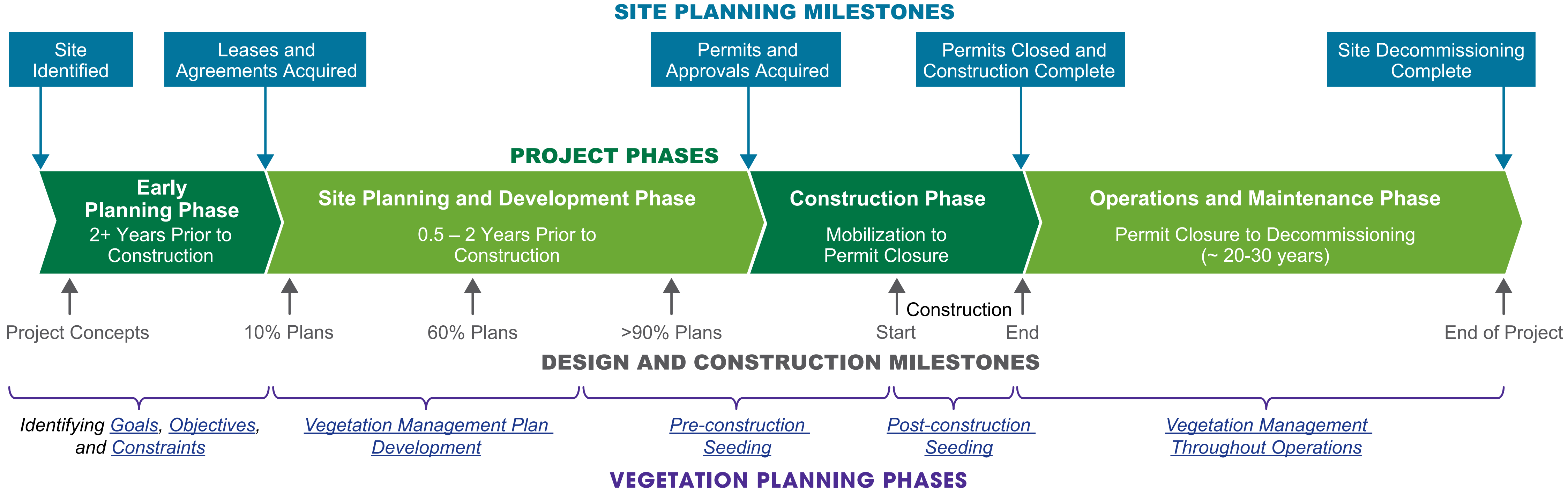
Integrating Vegetation into Construction Planning

Integrating vegetation into construction planning should begin as soon as a project schedule is identified (Figure 7.1). Information from Sections 4 through 6 can help delineate vegetation areas and develop preliminary seed mixes. When integrated early, a wider range of available seeding windows and options can be estimated. Knowing what, when, where, and why allows all suitable options to be considered earlier in the planning process. The purpose of this section is to help identify what steps need to occur before seeding and when they should occur on the project timeline.

Seed Procurement

Procuring seed mixes that comply with site goals and constraints can take time; sometimes weeks or months, depending on seed mix requirements. For large sites, market availability can directly impact the availability and cost of seed. Seed prices may fluctuate throughout the year based on availability and demand. Seed costs are generally less subject to market fluctuations when seed materials are identified and selected well in advance. Arrangements should be made to obtain the required seed at least 4-6 weeks prior to seeding.

Figure 7.1. *Timeline of pre-construction project sequence highlighting ideal times for vegetation plan development and seeding options.*



Planning Site Preparation

Proper site preparation supports the establishment of desired vegetation by creating conditions that promote initial seed germination and reduce competition from other undesirable plants. Good site preparation plans must recognize that each site is unique. Time and effort spent planning site preparation activities will have long-term benefits in improving the rate and success of vegetation establishment while simultaneously reducing long-term costs. In contrast, poor site preparation can prevent or slow seed establishment, result in higher or more persistent weed densities, and increased costs. The ideal conditions for seeding are generally bare, weed free, loose soil with moderate moisture content. Preparations needed to achieve these conditions on sites vary across regions and climates.

Factors to consider in site preparation include understanding prior herbicide use, prior crop and residue type, compaction, existing vegetation (invasive species threats, gaps in vegetation management), organization and site goals (organic methods), along with timing and sequencing.

Prior Herbicide Use

Some crops require the use of treatments that can impact the germination of seeds for months after application. The treatments used, residual effects, and mitigation strategies should be considered before determining seeding schedules. Early coordination can either mitigate the problem by planting alternate crops, using different products, or planning the seed installation after the effects have worn off. Table 7.1 presents common herbicides used on agricultural lands, their maximum recommended day to planting, and other considerations for persistence and planting (Lingenfelter and Curran 2017, Bosak and Davis 2013). With numerous herbicides available on the market, this table only provides a representative sample for a common crop planted across the U.S. (corn). Other crops may be managed with other herbicides not included in this table. Vegetation planners should evaluate the herbicides applied to planting areas during vegetation management planning.

Key Takeaways for Site Preparation

- Each project site is unique. Site preparation needs will vary from site to site, or even locations within a site.
- Plan for seeding in suitable seeding windows where possible, but plan for adaptation in case of less ideal timing.
- Verify contracts, funding, and scope aligns with planting schedules and needs.
- Care taken in site preparations will result in more successful vegetation establishment.

***Table 7.1.** Months to Plant Vegetation Following Corn Herbicide Applications Prior to Site Preparation (based on Lingenfelter and Curran 2017, Bosak and Davis 2013)*

Trade Name	Common Name	Months (Min-Max)	Other
2,4-D 4S	2,4-D	1-3	Amine formulations are more water soluble and can leach into seed zone
Accent 75DF/Steadfast75DF	nicosulfuron/ nicosulfuron+ rimsulfuron	4-18	More persistent in high pH soils (> 7)
Armezon/Impact 2.8SC	topramesone	3-18	
Atrazine 4L	atrazine	6-12	More persistent in high pH soils (> 7)
Callisto 4L (includes Acuron, Acuron Flexi, Halex GT, Harness Max, Instigate, Lexar, Lumax, Resicore, Revulin, Solstice, Zemax, etc.)	mesotrione	4-18	Sequential applications increase the potential for injury
Capreno 3.45SC	tembotrione + thiencarbazone	4-18	15 inches of cumulative precipitation required from application to planting rotation crops except wheat
Clarity/Banvel 4S (DiFlexx, Distinct, Engenia, Status, Xtendimax/Fexapan)	dicamba	0.5-4	Anything can be planted after 120 days with 24 fl oz/acre or less
Dual II Mag 7.62E/Cinch	metolachlor	4.5-12	
Glyphosate 4L	glyphosate	0-1	Glyphosate does not have soil activity at normal use rates
Harmony 50WDG	thifensulfuron	0-1.5	
Laudis 3.5SC (DiFlexx Duo)	tembotrione	4-18	Other crops may be seeded after a successful field bioassay
Liberty 2.34L	glufosinate	2.5-6	Glufosinate does not have soil activity at normal use rates
Outlook 6E (Armezon Pro)	dimethenamid	4-6	Nonfood/feed winter cover crops should be OK after corn harvest

***Table 7.1.** cont*

Trade Name	Common Name	Months (Min-Max)	Other
Prowl H2O 3.8CS	pendimethalin	0-12	
Python 80WDG (Hornet and SureStart)	flumetsulam	4-26	Cover crops and forage grasses are restricted for 9 months
Resolve 25DF (Resolve Q)	rimsulfuron	3-18	More persistent in drought conditions
Sharpen 2.85SC (Verdict)	saflufenacil	0-6	
Stinger 3S (Hornet, Resicore, SureStart)	clopyralid	0-18	
Zidua (Anthem)	pyroxasulfone	12	Nonfood/feed winter cover crops should be OK after corn harvest

Prior Crop and Residue Type

When projects are located on agricultural lands, different crops leave varying residues that must be considered in pre-construction planning. Crop residues consist of the leftover plant stems and stalks remaining on a field after harvest. As summarized in Table 7.2 on the right, additional site preparation methods vary depending on which crop residue is present. Timing of seeding should consider when these additional site preparation needs can be implemented. Work with project area landowners and tenant farmers to plan low residue crops in the growing season prior to seeding. Effective crop residue planning can save costs on seedbed preparation.

Pasture and arid areas may have existing vegetation that could be compatible with the operation of the facility. Identify the species present and evaluate their characteristics. Plants with incompatible characteristics should be treated prior to construction to prevent interference with operations.

Some residue reduction step can occur at or near the time of seeding, others must be done in advance. Identify the steps necessary for each area of a site and schedule them appropriately. Section 8 has additional information on residue.

***Table 7.2.** Prior Crop Residue Influences on Site Preparation*

Existing Conditions	Runoff Potential	Pre-seeding Site Preparation
Harvested soybean field	High	• None
Harvested small grain field	Low	• Reduce crop residue (e.g., bale straw) • Shallow disc soils before broadcast seeding • No discing of soils if drill seeding
Standing forage hay field	Low	• Final harvest to reduce biomass • Herbicide treatment forage to remove remaining cover • Shallow disc soils before broadcast seeding • No discing of soils if drill seeding
Harvested corn silage field	Moderate	• Shallow disc soils before broadcast seeding • No discing of soils if drill seeding
Harvested corn grain field	Moderate	• Mow/Bale corn residue • Disc soils
Arid rangeland or scrub	Moderate	• Verify compatibility • Treat incompatible or noxious species; maintain desirable cover
Post-construction bare ground within array	High	• Disc or plow to reduce soil compaction • Drag and smooth soils
Post-construction bare ground outside array	Low	• Disc or plow to reduce soil compaction • Drag and smooth soils
Post-construction noxious weeds within array	Moderate	• Treat weeds with appropriate herbicide • Disc or plow to reduce soil compaction • Drag and smooth soils

Decompacting Soils

During construction, soil often becomes compacted or rutted. These conditions can prevent seeded vegetation from establishing. Prior to permanent seed installation, soils may require additional soil preparation or decompaction to create a suitable seedbed.

Decompaction efforts can occur well before the scheduled seeding window and should be schedule to be complete when the seeding window opens. See Section 8 for additional information steps to decompact soils prior to seeding.

Existing Vegetation

Existing vegetation onsite (if desirable) can be preserved where possible to avoid the need for seeding. However, sometimes existing vegetation can also pose threats, especially where it contains invasive or noxious weeds, or where gaps in management may occur. Section 8 describes the steps to be taken to address existing vegetation. These steps should occur immediately prior to the target seeding window.

Timing and Sequencing

Identification of required preparation activities is necessary to determine the appropriate timing and sequence needed. Different activities will need different timing and sequencing. Ultimately compromises in site preparation sequencing and timing may be necessary. Understanding and planning for the consequences of such compromises in future management can minimize the impacts of less-than-optimal timing.

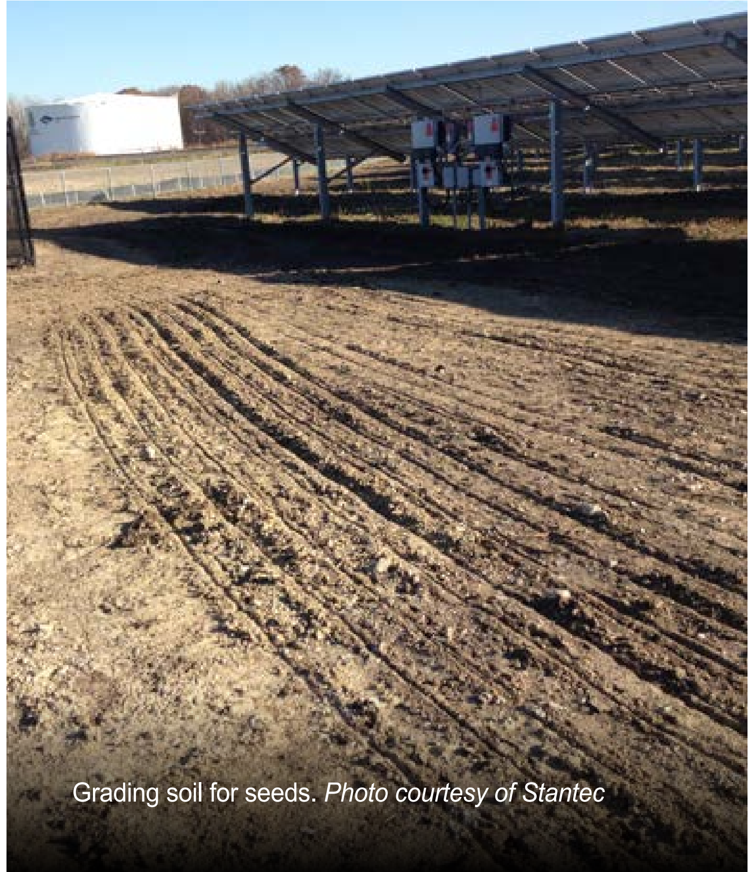
Arid regions likely require special timing considerations. Unlike temperate areas, arid areas can go many months without sufficient rainfall for seeded areas to germinate and establish. Planning for installation just before known or expected periods of precipitation is critical to timing establishment in these areas. Arid areas may also require an additional season or two for desired vegetation to fully establish. When planning for arid sites, additional temporary stabilization methods should be considered to remain compliant with permits if drier than expected conditions slow vegetation establishment.

Timing will be discussed in more detail in Section 8.

Site Grading and Planting Schedules

A common component of solar site preparation includes grading areas to level elevations compatible with the array infrastructure or stormwater features. Graded areas should be identified early and incorporated into the vegetation management plan. Short term stabilization with compatible perennial, annual, or erosion control products can maintain compliance until final seed installation occurs during the next available seeding window.

Construction schedules frequently change throughout a project development. Timing may be ultimately dictated by the construction schedule and requirements for stabilization compliance with stormwater permits. Pre-construction seeding may begin as soon as grading is complete, but before infrastructure is installed. Post-construction seeding occurs after the infrastructure is assembled.



Grading soil for seeds. *Photo courtesy of Stantec*

Pre- vs Post-Construction Seeding

Coordinating both infrastructure construction and vegetation installation during the construction phase can be challenging. Further, construction schedules change often. Deciding whether pre- or post-construction seeding is appropriate may depend on construction sequencing, cost analysis, and stabilization requirements (Table 7.3) on the next page.

Pre-construction Seed Installation

Pre-construction seed installation involves seeding areas that are at an acceptable grade with the final perennial mix before any built infrastructure is constructed. This approach allows for the use of agricultural-scale equipment, which reduces overall installation time and labor costs. Pre-construction seeding offers an early window for installation, which in turn yields an earlier establishment time. This can provide erosion control during the construction period and result in faster stormwater permit closures after construction is completed. Planning and funding mechanisms need to be in place early to leverage the potential benefits of pre-construction seeding.

Of course, construction activities are likely to disturb some of the pre-construction seeding areas. Disturbance can be minimized by allowing vegetation time to establish prior to mobilization. Limiting access by vehicles and equipment to portions of the site while vegetation is being established will also prevent unintentional disturbance. Regardless, construction disturbances will likely require some areas of pre-construction seeding to be repaired after the fact.

Despite this, pre-construction seeding can still present a more cost-effective option, even with the need to re-seed portions of the project area later.

Post-construction Seed Installation

Post-construction seeding reduces the need for follow up supplemental seedings compared to pre-construction seeding as vegetation is not being disturbed during construction activities. However, reseeding is still a common activity in these scenarios, as some areas of a site may experience inadequate germination and establishment of desired species due to multiple external and internal factors. Limitations of post-construction seeding include offering a short installation window contingent on construction completion and potentially requiring temporary stabilization for stormwater permit compliance.

Post-construction seeding may also restrict equipment size available for seed installation. Narrow row widths can make safe operation of tractors and seeding equipment between the solar arrays challenging and slow. End-of-row restrictions like cable housing, gearboxes, or drive shafts may prevent equipment from traversing from one end of a row to the other. Obstructions to vehicles and equipment like these can greatly impact the time and cost required for installation, establishment, and ongoing maintenance.

***Table 7.3.** Contrasts of considerations for pre- and post-construction seeding.*

Consideration	Pre-construction Seeding	Post-construction Seeding
Pre-construction Coordination	👎 Requires more upfront planning and preparation	👍 Less affected by pre-construction planning
Seeding Windows	👍 Large with multiple options	👎 Short and construction-defined
Equipment	👍 Any size equipment	👎 May be confined by row width and maneuverability
Establishment	👍 Begins prior to construction	✋ Begins after construction is complete
Cover crop	👍 Optional; can be incorporated as a nurse crop	✋ May be necessary to maintain compliance
Construction Impacts	✋ Moderately impacted by construction activities	👍 Minimally impacted by construction activities
Cost	👍 Lower initial installation cost	👎 Higher initial installation cost
Soil Preparation	👍 Minimal or unnecessary	👎 Moderate to intense; May require decompaction
Installation Time	👍 Short	👎 Long
Grading	👎 Highly influenced	✋ Less affected; May require decompaction

👍 Optimal ✋ Moderate 👎 Less Desirable

Financial Considerations

In the context of site planning, the vegetation establishment choices and ability to adapt should be supported by contracting mechanisms. Many vegetation contractors work as subcontractors to EPCs. If pre-seeding a site, providing time and arrangements needed for procurement and installation is a critical element of site preparation planning. Seed costs may need to be paid before they are procured and mixed. If necessary, consider making arrangements to contract vegetation services separately from the construction and design components. Additional contracting practices are suggested in Section 12.

Cost Comparison

With the range of potential seed mix, acreage, preparation activities needed, and planting windows, there can be multiple planning options for a single site. Consider comparing the costs associated with alternative approaches being considered. Determine which is most appropriate based on both the Captial Expense (CAPEX) and Operating Expense (OPEX) objectives for a project. It is important to include all the direct and indirect costs related to stabilization and permit compliance to achieve an accurate comparison.

Putting Planning into Practice

Owners, operators, developers, Engineering, Procurement, and Construction contractors (EPCs), and vegetation managers all have an important role on a project site. Maintaining communications and ensuring that vegetation goals are consistently considered throughout the lifetime of a project can produce more reliable and higher quality results.

Section 8
Seedbed Preparation and Installation


Blooming solar pollinator vegetation. © *Stock.adobe.com*

WHAT'S IN THIS SECTION?

- Seeding Conditions
- Seedbed Preparation *(Control and Removal of Existing Vegetation, Decompacting Soils, Crop Residue)*
- Seed Installation *(Timing, Methods for Seeding, Common Problems to Avoid During Seeding)*

Seeding Conditions

Section 7 (Construction Planning and Site Preparation) discussed site preparation, outlining how to determine the best approaches needed for successful germination and establishment of desired solar pollinator vegetation. Site preparations include alignment with the project schedule, evaluating favorable site conditions, and planning for installation. In contrast, this section focuses on seedbed preparation, creating the site-specific conditions required *at the time of seed installation* for successful germination and establishment of desired solar pollinator vegetation.

Successful seed germination and establishment requires a series of conditions be met on project sites. Seedbed preparation conditions should be met regardless of the seeding method and location. These conditions best for seed germination and establishment along with associated impacts and solutions are summarized in Table 8.1 on the following page.

Seedbed Preparation

Creating the ideal seedbed requires attention to details summarized in Table 8.1. Each site has unique pre-existing conditions that need to be considered to effectively support seed germination and establishment. This section discusses each of these conditions in more detail.

Removal or Control of Existing Vegetation

When establishing new vegetation onsite, reducing or eliminating competition from any existing vegetation is necessary. Existing vegetation competes for light, water, and nutrients that are necessary for the desired plant community. Established vegetation is resilient, giving it a competitive advantage over new seedlings. As a result, established vegetation can outcompete desired vegetation which has not yet matured or established successfully. Areas such as hayfields, pasture, or old fields, will require one or more herbicide treatments to eliminate preexisting, undesirable vegetation. Following treatments, the area should be assessed to determine the appropriate thatch removal technique.

Thatch that limits seed-soil contact may be removed by simply allowing enough time for decomposition to occur. If thatch is persistent, it may be removed by mowing or light discing, followed by cultipacking. If such techniques are unavailable or insufficient, cut material may be removed by baling or a prescribed burn.

Invasive and noxious weeds may be present in areas on or adjacent to the project area. Conducting onsite assessments can help identify and locate undesirable vegetation that may be aggressive under disturbed site conditions. If found within the project area, invasive and noxious weeds should be controlled to the extent practicable prior to seeding and construction. During construction, consider the use of practices such as cleaning equipment before mobilizing on or off the site to remove plant debris and soils from vehicles, which can help prevent the spread of seed or plant parts of invasive or noxious species. Documenting off-site invasive or noxious weeds prior to seeding and construction can help identify potential weed pressure risks within the project area. Invasive and noxious weeds growing in similar conditions can be a reference for potentially problematic species. Seeds from these species are easily spread by wildlife and wind, and can quickly overtake desirable vegetation.

Another risk of existing vegetation may occur after a site has been seeded. Some projects may transition vegetation contractors between seeding and establishment, or from establishment to maintenance. During these transition periods, undesirable vegetation in unmaintained areas can establish and spread within the site boundaries, disrupting desired vegetation establishment and overall site conditions. Maintaining continuity of treatments and ensuring consistency or smooth transitions from one vegetation contractor to another can avoid unnecessary setbacks.

Table 8.1. *Conditions, Impacts, and Solutions for Successful Seed Germination and Establishment*

Conditions	Impact and Severity	Potential Solutions
Seed Depth	Installing seeds too deep can inhibit germination and result in poor establishment.	Calibrate equipment and personnel to correct planting depth. Err seeding closer to the surface.
Seed-to-Soil Contact	Seed resting on an unprepared soil surface, crop residue, or hard dry soil can inhibit germination.	Install seed on clean, loose soil free from compaction.
Surface Soils Free of Compaction	Compacted soils can result in poor establishment as they may store less water, dry out faster, and resist root penetration.	Properly decompact and loosen seedbed soils prior to seeding.
Surface Soils Free of Compaction	Seedbeds with clumps, chunks, cracks, and ruts will bury seed too deep as the soil surface weathers.	Properly prepare the seedbed to be smooth, level, and firm.
Surface Soils Free of Compaction	NPDES post-construction monitoring Pollinator-friendly scorecards for established vegetation	Satisfy permit conditions Comply with conservation program participation Support company ESG reporting
Weed Free	Weeds grow favorably in unplanted seedbeds and compete with desired vegetation for nutrients, water, and light.	Install crops or treat with herbicide to control weeds prior to seedbed preparation. Seedbeds should be free of actively growing weeds.
Proper Soil Moisture	Seeding when soil is too wet or dry can reduce the accuracy of seeding equipment and inhibit seed germination and establishment.	Verify seed mixes are suitable for site conditions. Adjust seeding schedule or methods to improve conditions.
Even distribution	Seeds of varying sizes can impact even distribution resulting in patchy or inefficient establishment.	Calibrate equipment and personnel, verify even seed distribution and adapt methods in difficult areas.

Severity indicators:

- Unfavorable, may inhibit germination or establishment.
- Prohibiting, will likely prevent germination or establishment.
- Solutions and ideal conditions for germination and establishment.

Key Takeaways for Site Preparation

- Each site has unique pre-existing conditions that need to be considered to support seed germination and establishment.
- Successful seed germination and establishment requires specific conditions be met on project sites.
- Inadequate seedbed preparation can prevent germination or result in poor establishment.

Soil tilled for seeding. © *Stock.adobe.com*

Comon milkweed is a favorite of the monarch butterfly.
Photo courtesy of Argonne National Laboratory

Decompacting Soils

In areas where grading or use of heavy equipment has occurred, soil decompaction may be necessary. Areas with wet or clayey soils are also prone to compaction and may require similar attention. The type of equipment used to decompact soil will vary based on the soil type, extent of compaction, and availability of equipment. Equipment should be capable of loosening the soil to a minimum depth of 4 inches to provide a smooth, evenly textured surface while maintaining as much of the existing soil structure as possible. Typical decompaction equipment includes discs and tillers. The purpose of soil decompaction is to reduce surface and near surface compaction that can inhibit germination and the ability of young roots to penetrate the soil.

Crop Residue

Many utility-scale solar facilities are developed in landscapes with a history of row crop agriculture. The type of annual crop grown prior to seeding, and subsequent crop residues, can have a significant influence on site preparation. Crop residue includes the leaves, stems, and stubble remaining on site after harvest.

Fields where soybeans, canola, or dry beans were previously grown will require the least amount of site preparation. Soils in these fields are typically firm enough to drill seed into without any additional tillage, and the amount of residue remaining does not require impact seed-to-soil contact necessary during broadcast seeding activities. Previously farmed soybean fields also have the advantage of increased soil nutrients; root nodules on soybeans fix nitrogen into the soil, which can be important source of nutrients for newly seeded plants and young vegetation. Selecting soybeans, canola, or dry beans as the last crop planting prior to seeding can save time and lower costs associated with site preparation.

By comparison, fields previously planted with crops like corn, sorghum, rice, or some small grains may require more intensive site preparation. These fields typically retain higher amounts of residue which can limit seed-to-soil contact. Several options are available to mitigate crop residues during seedbed preparation.

The selected methods and sequences used to remove or reduce residue will depend on local conditions and may include mowing, raking, baling, discing, or a combination of these activities. If baling removes enough residue leaving the majority of the ground bare, additional tillage may not be necessary. If baling is not used, residue should be worked into the soil through tilling, discing, raking, or a combination of the three. Several passes may be required to ensure residues are sufficiently incorporated into the soil. Once done, a final pass with a cultipacker, disc and harrow, or the equivalent soil conditioning attachment will be necessary for final seedbed preparation.

Seeding

Seeding is the planting or installation of seed mixes in project areas with a goal of establishing desired perennial solar pollinator vegetation. Seeding activities may also include the temporary installation of cover crops depending on the timing of site preparation and construction in the project sequence. Determining specific timing and methods for seeding activities is necessary to ensure successful vegetation germination and establishment.

Timing

As noted in Section 7, the timing of seeding during the calendar year has a significant influence on the success of germination, establishment, and long-term maintenance of the site. Soil temperature, seasonal air temperatures, and soil moisture availability are important factors to consider when planning and conducting seeding activities. Construction schedules may not always allow for optimal timing; requiring less-than-ideal conditions to stay compliant with permit conditions that may limit the number of days the ground can remain bare or exposed. Seeding may also occur at times less optimal so that permits can be closed out, the construction phase completed, and facility operation can begin. Where seeding cannot wait until optimal seeding windows, several approaches may be used.

- Use temporary cover crops and follow up with a permanent seeding during a more suitable time of year,
- install permanent seed mixes, but plan on follow up with supplemental seeding in areas of poor germination and establishment, or
- increase volume of permanent seed mixes applied to account for higher mortality rates.

Seasonal seeding windows vary greatly depending on site location. Seasonal summaries noted here are general guidelines that must be tailored to specific seasons, dates, and local conditions.

Spring

Lower air temperatures paired with higher precipitation and soil moisture make spring an ideal time for seeding. Flooding, wet soils, and areas with standing water for extended periods of time can present challenges to seeding in the spring. During the site preparation phase, identify areas where flooding or poorly drained soils are present. Avoid seeding those areas during wet periods or take advantage of dry conditions by expediting the seeding schedule. Monitoring seasonal conditions is important. If spring is trending warmer and drier (especially towards the end of the season), waiting until fall to seed may be beneficial to prevent loss due to inadequate root development under hot and dry summer conditions. Using temporary cover crops may be a better option to satisfy permit conditions until seeding desired vegetation is appropriate.

Spring seedings are more favorable to the establishment of grass species over many forb species. Seeds of some forbs require overwintering and cold stratification to germinate successfully. If seed mixes contain larger proportions of forbs, confer with a seed specialist to determine the ideal seeding window for your mix.

Summer

Seeding perennial species in the summer should be avoided whenever possible. In the United States, summers typically have higher air temperatures, drier conditions, and more variable precipitation patterns compared to other seasons. Like a late spring planting, warm season temporary cover crops may be a better option to maintain permit compliance until the next appropriate seeding window.

Fall

Fall is a common and often recommended time of year for seeding. Optimally, fall planting will occur soon after average temperatures cool and precipitation increases, allowing newly seeded plants time to grow before winter sets in. As the fall progresses the available growing time shortens; when temperatures are too low seeds will not germinate until spring. The distinction between germinating in the fall or spring can be important to establishment success. Cool season grasses and many forb species can germinate and survive winter and continue growing in the spring. Warm season grasses, however, need several months of growth prior to winter to survive. If a mix is heavily reliant on warm season grasses, it is better to postpone seeding to ensure there is no chance of germination before spring.

Winter

Seeding during winter when low temperatures will inhibit germination until spring is known as dormant seeding. Dormant seeding without snow can be similar to a spring or fall seeding –either by broadcast or drill seeding, depending on soil conditions. Dormant seeding over snow cover can be completed by broadcasting seed onto the snow surface. Care should be taken to avoid windy conditions both during and immediately following snow seedings. Sunny days where melting occurs allow seed suspended in snow to settle on the ground, and early spring freeze-thaw cycles will improve seed-soil contact. Generalized seeding periods and guidance based on seasons are shown in Table 8.2. It is important to understand the influence of latitude and seasonal precipitation trends when deciding to seed. Even within a given latitude, the seeding season may shift temporally depending on weather variations.

What Season is Best to Seed?

- Spring seeding is generally favorable for grass-based mixes.
- Seeding pollinator mixes in the fall allows for cold stratification, which may be required for germination of some species.
- When possible, seeding in summer should be avoided due to the high risks of seedling loss due to hot and dry conditions.
- Regional patterns and trends in temperature and precipitation play a key role in determining appropriate seeding periods.

Photo courtesy of Stantec

Table 8.2. *General seeding periods and guidance throughout the year.*

Season*	Seeding Period and Comments
Spring	• Soil temperatures must be at least 60°F for warm season grasses to germinate. • Cool season grasses may germinate in colder temperatures. • Optimal dates may vary by several weeks based on latitude (North: later; South: earlier). Plan to have all your seeding operations complete before the end of the cool, wet, period of spring.
Summer	• Not typically recommended due to hotter, drier conditions and variable precipitation. • Use cover crops if seeding is required to satisfy permit conditions. • Adjust the summer seed window earlier in southern latitudes. • Plan to monitor for and re-seed areas that do not germinate.
Fall	• In northern latitudes, seed when soil temperatures are consistently below 40°F to prevent early germination of warm season species. • Frozen soils may limit drill seeding capabilities. • In southern latitudes, seeding window extends through end of winter and may be preferred.
Winter	• In northern latitudes, broadcast seeding can be effective on frozen ground provided proper soil conditions. • In southern latitudes, seeding window extends through end of winter and may be preferred.

** Optimal dates and seasons may vary regionally. Refer to local guidance or experience for site-specific consideration.*

As described, there are many different factors that are necessary to consider before seeding solar pollinator vegetation on a utility-scale project including site preparation, season, and weather conditions. Figure 8.1 illustrates a decision-making process that may be used to navigate the various considerations needed prior to seeding.

What seeding method is best?

- Opinions vary on the best seeding method based on professional experience and site conditions.
- All methods have advantages and disadvantages that must be considered.
- Select the method that best aligns most with vegetation management goals, site conditions, and construction sequencing.

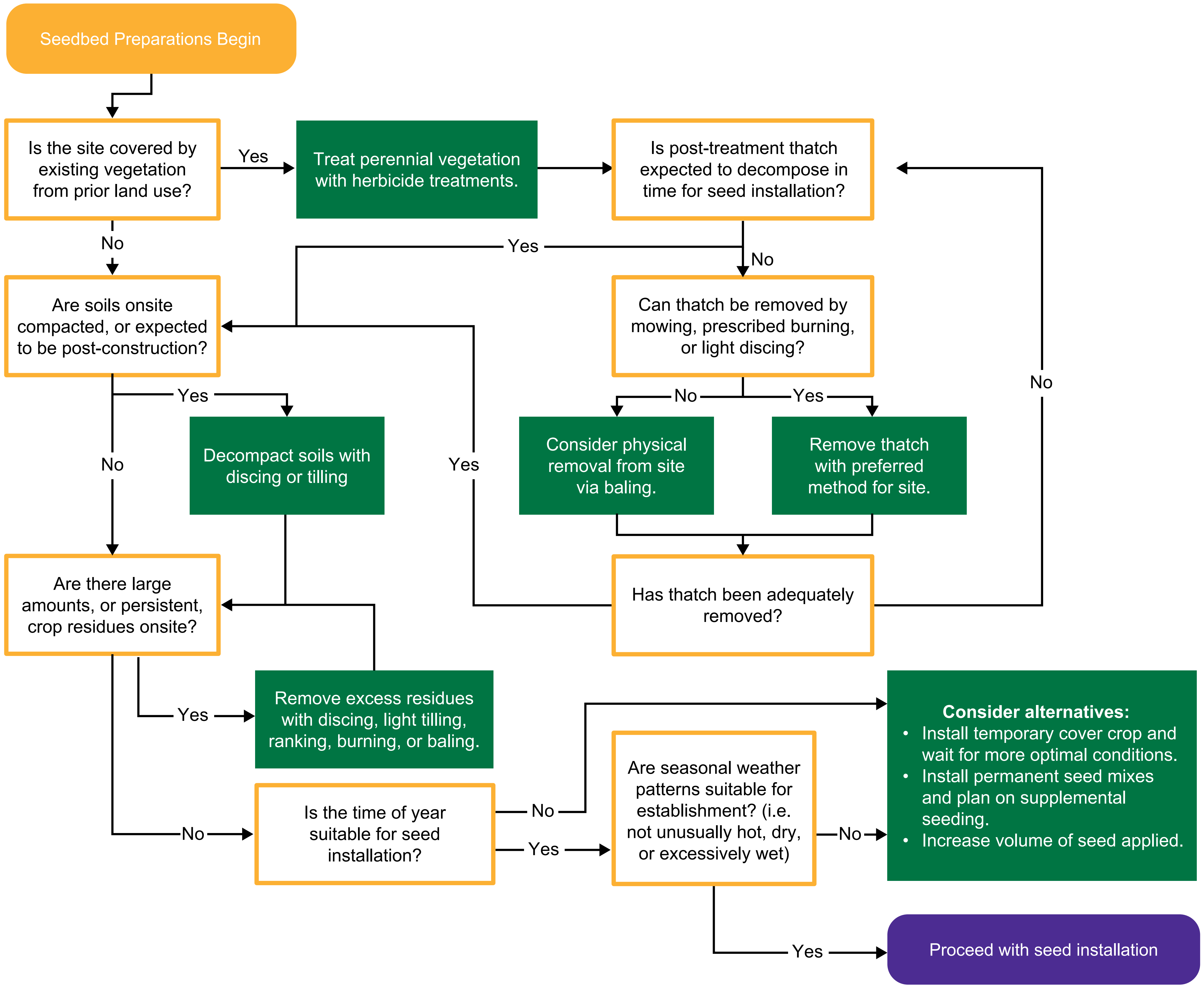
Methods for Seeding

Several methods are available for seeding, each with their own set of advantages and disadvantages (Table 8.5). Within the vegetation management industry, opinions may differ on which method is the best based on personal experience and environmental conditions. For solar facilities, a combination of techniques may be required due to variability in timing, site conditions, and construction sequencing.

Drill Seeding

Seed can be installed directly into the soil using a drill seeder. Drill seeders contains one or more seed boxes where seed flows through equipment evenly and is then drilled slightly below the ground surface. Drills provide accurate seed placement and perform best in large open spaces. There are a variety of drill types available and selecting the right drill type depends on seedbed conditions and the species being seeded.

Figure 8.1. *Process for navigating seedbed preparation*



Conventional drills are appropriate for seedbeds that have been tilled and packed. A no-till drill has specialized cutters that can create a trench through existing vegetation and thatch. The advantages of a no-till drill are that there is less effort spent preparing the seedbed and the existing thatch can provide moisture retention and act as a weed barrier.

Many species of pollinator vegetation are extremely sensitive to the depth at which they are seeded. Installing seed too deep is one of the most common causes for seed failure or. Using equipment that can adjust and consistently provide the appropriate depth is necessary.

For solar facilities, drill seeding during the pre-construction phase may be a preferred option as it allows easier equipment access and for the use of larger equipment. Drill seeding in the post-construction phase may not be suitable, as infrastructure will limit equipment size to what can fit between panels and will always require a second seeding method to deliver seed under and around panels and infrastructure.

Drill seeders must be calibrated to install a seed mix at a specified rate. Failure to properly calibrate the drill could result in too little or too much seed being installed over a given area, which has both financial and performance implications. Equipment manufacturers provide calibration procedures specific to their equipment. Many regional vegetation manuals available from NRCS, state natural resources departments, and local non-profits may also provide calibration procedures.

Drills are manufactured with a variety of row widths. The row width for typical pollinator seed mixes should be no greater than eight inches. Some small cool season grasses with high pounds per acre seeding rates may not be appropriate for drill seeding.

Broadcast Seeding

Broadcast seeding spreads seed from a hopper mounted to a vehicle or equipment. Seed lands on the soil surface and then is pressed by a cultipacker or roller to improve seed-soil contact. Broadcast seeding is appropriate for seedbeds that have been tilled and then firmed.

The advantage of broadcast seeding for solar facilities is that seed can be delivered under and around panels and other infrastructure more efficiently than using a drill seeder in the post-construction phase. Other advantages of broadcast seeding include versatility in different seasons. Broadcast seeding is not limited by frozen ground or wet conditions, and less likely to install seed too deep. Adequate preparation is required before installation. Cultipacking or rolling is preferred as a follow up step to improve seed-soil contact.

Like drill seeding, calibration of the equipment to the specific seed mix is important to install the seed mix at the appropriate rate. The equipment manufacturer's instructions along with support from other regional vegetation guides should be used when calibrating the equipment. Distribution is another critical factor for some types of broadcast seeders. Spinner type broadcast seeders using a rotating disk to distribute the seeds can throw large, heavy seeds several times farther than small, light seeds. These seeders should be calibrated with the distribution width of the smallest seeds to ensure even coverage.

Hydroseeding and Hydromulching

Hydroseeding delivers a slurry of water and seed through a hose onto the soil surface. Hydromulching delivers a slurry of water, hydraulic erosion control product, and binder agent to the soil surface. Seed can be directly applied to the soil before hydromulch is applied or mixed in with the erosion control product. Hydroseeding and hydromulching are commonly used to re-vegetate sites following land disturbing activities. The advantage of hydro-applications is that like broadcast seeding, it is efficient at delivering seed to hard-to-reach areas, such as under and around panels. Applying seed with the mulch can be effective in many situations but can also reduce the seed contact with the soil leading to reduced germination under dry or arid conditions. It is important to evaluate site and local weather conditions to determine if hydro-applications are appropriate for the specific project and seeding window.

Table 8.3. *Comparison of common seeding methods*

Method	Advantages	Disadvantages
Drill Seeding	• No-till drilling does not require additional steps following seed installation. • Specialized equipment designed for seed types (small seed, fluffy seed).	• Limited access under and around panels. • Risk of installing seed too deep. • Use should be avoided in wet, soft, and frozen soils.
Broadcast Seeding	• Installs seed under and around panels. • Can be used in all seeding seasons. • Can be used in both pre-construction and post-construction phases. • Less likely to install seed too deep.	• May require more seed. • Requires proper seedbed preparation through tillage or vegetation removal. • Requires follow up packing or pressing to improve seed-soil contact. • Mulching may be required to provide erosion control and water retention.
Hydro-seeding and Hydro-mulching	• Installs seed under and around panels. • Can install seed and temporary erosion control products in one application.	• Requires large volumes of water. • Not recommended during extended hot and dry periods. • Not available in harsh winter conditions. • Expensive for larger projects. • Requires proper seedbed preparation

Other Resources Available

Many regional or state-specific resources are available to help inform local considerations described here for seedbed preparation and installation. Check out local guidance that may be available for your area such as:

- State or region-specific guidelines for solar pollinator vegetation installation
- Native seed vendor catalogs and installation recommendations
- NRCS conservation practices job sheets available in Field Office Technical Guides (FOTGs)

Section 9
Establishment and Maintenance

WHAT'S IN THIS SECTION?

- Establishment
- Maintenance
- Establishment and Maintenance Risks
- Common Establishment and Maintenance Tools
- Communicating Expectations
- Site Establishment Checklist


Beautiful day at the solar facility. © *Stock.adobe.com*

Key Takeaways for Establishment and Maintenance

- Proper establishment is critical to cost effective use of solar pollinator vegetation.
- If established well, the maintenance phase may require less intensive vegetation management implemented on a prescriptive schedule.
- Communication between project designers and contractors is necessary for successful establishment and maintenance to adapt to changing conditions or timing.

Establishment

Establishment is a transitional time for vegetation management. Focus turns from site preparation and seed installation considerations to supporting germination and seedling growth. This largely entails weed management and supplemental seeding where original germination targets were not achieved. Establishment often requires multiple years to achieve the desired vegetation originally envisioned. In this phase, solar pollinator vegetation needs intensive and active management to encourage the establishment of desirable and compatible vegetation across the site. Management will typically include activities such as mowing, applying herbicide, and supplemental seeding. The establishment phase is often a multi-year period, often taking between 2 to 5 years to reach target conditions. Some projects may end the establishment phase when desirable perennial vegetation has reached the required cover target specified in erosion and sedimentation control permits. This target may or may not be synonymous with the targeted plant community. Understanding both the desired cover and composition of species is important to evaluating establishment success.

Vegetation establishment timing, coverage, and species composition can vary across the site. Selection of management actions in this phase are best targeted to vegetation conditions, rather than a prescriptive schedule or routine.

Consulting a vegetation specialist for repeated site assessments in the establishment phase can help advise on management actions and timing.

Defining Terms

Establishment – The phase between seed or plant installation until when plants have achieved the desired amount of cover. Typically, when permit conditions have been satisfied or management responsibility is transferred from developer to site owner.

Maintenance – The phase following establishment, when cover of desired perennial vegetation is maintained until the end of the project lifespan.

Maintenance

After desirable vegetation has been established, it then transitions into the maintenance phase. Unless there are major vegetation disturbances or setbacks, the maintenance phase will be sustained for the lifespan of the project. The transition to the maintenance phase can also be a time of contractual transition.

If establishment was successful, vegetation management should be less intensive during the maintenance phase, although still needed. Guidelines for maintenance should be included in the site's vegetation management plan. Vegetation management plans should be tailored to the types of vegetation designed for the site. These typically include different strategies for native versus non-native vegetation, forb-dominated vs grass-dominated vegetation, or by primary management tools intended.

Project teams may wish to update the vegetation management plan as the project enters the maintenance phase. The timing of the original vegetation management plan, construction modifications, and establishment success can change aspects of vegetation establishment. Changes or alterations may have occurred since the original plan. Updating plans for changed conditions can help protect the upfront investments made in vegetation establishment and avoid costly mistakes in vegetation management.

Establishment and Maintenance Risks

Knowing what risks to avoid can help build vigilant and resilient site management. Table 9.1 summarizes some of the common risks encountered when establishing solar pollinator vegetation. Avoiding these scenarios will put site vegetation on a path to success.

***Table 9.1** Common Establishment and Maintenance Risks*

Trade Name	Potential Outcomes to Avoid	Warning Signs	Corrective Actions
Establishment Phase			
Seed selection	Applying a seed mix unsuited for site conditions.	Poor germination and establishment; Lack of seeded species present after multiple growing seasons.	Develop or verify seed mixes with a vegetation specialist knowledgeable of the project site and species planned.
Seed supply unavailable	Suitable species unavailable at the time needed for installation schedules.	Lack of preferred species available when securing seed orders.	Order seed supplies as early as possible to retain preferred species. Consider growing contracts with preferred seed vendors. Identify suitable substitutions with a vegetation specialist knowledgeable of the project site and species planned.
Installation timing	Installing seed at times of year unlikely to achieve successful establishment.	Changes in project scheduling or construction sequencing.	Work with the project team to determine adaptation to seeding during preferred seeding times of year.
Changed site conditions	Planned seedbed conditions are not within tolerances seed mixes were designed for.	Pre-seeding site conditions are more compacted, stripped of topsoil, or altered hydrology from original plans.	If caught early, work with the project team to address concerns and improve conditions. If not practicable, consider adapting seed mixes to the altered conditions.
Early weed pressure	Establishment of aggressive weeds that outcompete desired vegetation.	Identification of individual plants or small populations of invasive or noxious weed species.	Early detection and a rapid treatment response. Eradicate small populations of invasive or noxious species. Information on common weed species can be found at https://www.naisn.org/species/
Unplanned site disturbance	Unplanned disturbance damages seeded areas.	Visible or reported ground disturbance in an area where seeds are being established.	Evaluate the extent of disturbance and conduct supplemental seeding as needed.
Maintenance Phase			
Transition from capital to maintenance teams	Establishment actions incomplete or unsatisfactory.	Vegetation not established to specifications, or lack of communication during transition of responsibilities.	Conduct an onsite meeting to evaluate conditions and communicate needs and expectations among all parties.
Delayed or poor establishment	Delays in establishment postpone transition to maintenance team.	Lack of establishment of seeded species; Extent of bare ground, invasive, or noxious weed cover.	Coordinate schedules and supplemental actions between capital construction and establishment teams and maintenance teams to resolve remaining needs.
Established weed pressure	Established vegetation contains extensive weed pressure.	Well-established areas of invasive or noxious weed species identified as problematic to vegetation objectives.	Evaluate plant physiology and effective treatment options available. Conduct targeted treatments to control or eradicate weed species.
Unplanned site disturbance	Unplanned disturbance damages seeded areas.	Visible or reported ground disturbance in an area where seeds are being established.	Evaluate the extent of disturbance and conduct supplemental seeding as needed.
Vegetation management plans not followed	Divergence from vegetation management plan may result in undesirable vegetation conditions.	Evidence of vegetation management plan recommendations not followed, or poorly adhered executed.	Discuss concerns with appropriate site supervisor(s). Confirm if divergence is an intended adaptation or an unplanned management concern. Determine the appropriate follow up actions based on findings.
Maintenance crews unavailable	Lack of resources or personnel necessary to address maintenance needs.	Personnel or contractors unavailable at times when time-sensitive maintenance needs such as mowing or weed controls are required.	Discuss concerns with appropriate site supervisor(s). Confirm availability of resources or alternative solutions to deliver resources necessary for maintenance needs.

Common Establishment and Maintenance Tools

Although regional and vegetation types may differ, the vegetation management toolbox consistently includes several common tools.

Mowing

Mowing is a primary method for preventing and controlling weedy noxious and invasive species. Mowing schedules should be carefully managed throughout the year. Mowing too frequently or too low can negatively impact the establishment of desired vegetation and encourage growth of tall-growing annual weeds. Mowing timing should be adjusted according to weather conditions and vegetation growth. Targeted mowing carefully considers the vigor, percent cover, and growth of both desirable and weedy vegetation. If undesirable species are highly concentrated in a location, mowing in those select areas may require more frequent mowing to deter flowering and reproduction of the target weeds. In contrast, areas that are relatively weed-free may benefit from less frequent mowing so that desirable vegetation can reproduce and spread.

Mower height typically adjusts through the establishment phase. Mower heights may start lower early on, then gradually adjust higher as seedlings germinate and grow. Preferred mowing height will also vary depending on the seed mix selected for permanent vegetation.

Table 9.2 presents an example mowing strategy on a solar site during the establishment phase. This example can be used as a template with appropriate modifications depending on site-specific constraints and conditions.

During the maintenance phase, mowing acts as a disturbance needed to maintain vegetation in an early-successional state. Mowing prevents encroachment or natural succession resulting in woody plant establishment. Frequency of mowing in the maintenance phase is often reduced as compared to the establishment phase, unless panel heights require limiting vegetation growth, frequency can decrease from two or three times annually, to once every year or longer.

Mowing portions of site, rather than the entire site at once, on a rotating basis can be an effective way to both mimic a natural disturbance regime and maintain continuous pollinator habitat. Adopting a rotational mowing system during the maintenance phase may also help reduce annual budgets.

***Table 9.2** Example mowing guidance on a solar site during the establishment phase*

Mowing Period	Initial Mowing	Mower Height	Mowing Triggers
May through November, typically two events per growing season	Late spring or early summer, when vegetation reaches a height of 12 to 18 inches	• **Year 1**: 4 to 6 inches • **Year 2**: 4 to 6 inches • **Year 3**: 8 to 12 inches	Flowering undesirable vegetation, or dense undesirable vegetation with a height of 12 to 18 inches

For demonstration purposes - Mowing guidance should be tailored by vegetation specialists based on the specific site location, target plant communities, and contractual requirements.

Grazing

Grazing is another tool used as an alternative to mowing for pre-seeding site preparation or maintenance during operations. The use of livestock (primarily sheep) for grazing in solar arrays is considered another form of agrivoltaic land use. Use of grazing onsite requires careful planning, cooperative farming agreements or specialized grazing contractors, and additional infrastructure to protect and manage flocks. Sites planning on grazing as a frequent management tool should have a grazing plan established for the site that maps grazing areas, as well as infrastructure like fences, water tanks, paddocks, signage, and access. Plans should note the planned grazing timeframes for the site and the type and number of animals planned. More information on grazing in solar arrays can be found online at the American Solar Grazing Association website.

Herbicide

Herbicide applications are another tool used to prevent or control invasive and noxious weed species. During the establishment phase, using targeted methods like spot foliar treatments can avoid negative impacts to desirable vegetation. Herbicide treatments can be mapped to evaluate effectiveness of treatments in different areas of the site over time. Specific herbicide formulations with little or no residual effects on perennial seed germination or persistence should be used as they could negatively impact establishment of desired vegetation.

Herbicide applications should be timed for when undesirable vegetation is actively growing and not before significant rainfall to avoid non-target effects to plants and ecosystems outside of the site. Seasonal timing can also be adjusted based on the growth stage of target species to increase effectiveness. As with all herbicide applications, licensed applicators should review product labels for specific concentrations and application methods allowed for the product being applied.

Herbicide application during the maintenance phase is like establishment. Depending on weed pressure and establishment success, herbicide applications may be needed less frequently.

Supplemental Seeding

Supplemental seeding may be necessary where desired solar pollinator vegetation has not reached required coverage, where site disturbance has occurred, or when other management actions have results in “resetting” vegetation areas onsite. Monitoring efforts (covered in Section 12) can help determine when and where supplemental seeding should occur on the site. Supplemental seeding should follow the same guidelines for seeding practices outlined in Section 8. Areas that receive supplemental seed should be mapped and tracked during the establishment phase. If these areas need multiple years of supplemental seeding, this may indicate that a change in seed mix or management is necessary for successful vegetation establishment.

Supplemental seeding during maintenance is similar to the establishment phase. The need for supplemental seeding is often less frequent in maintenance, as desired solar pollinator vegetation should be established across the site.

Woody Vegetation Removal

Maintaining solar pollinator vegetation sometimes requires hand removal of woody vegetation. In most cases, mowing will prevent the establishment of woody vegetation. However, mowing accessibility may be limited in some areas, like around fences, structures, or pilings. Hand tools may be used to remove woody vegetation. If mowing or hand trimming is not successful, foliar, basal bark, or cut stump application of herbicides may be used with care to avoid any off-target effects.

Communicating Expectations

Communicating expectations is one of the greatest challenges of the establishment and maintenance phases for solar pollinator vegetation. Motivated by images of flower-covered fields, bees buzzing, and butterflies mid-air, many land managers expect to see these results in the first growing season. Perennial solar pollinator vegetation takes time to establish. As discussed in this section, establishment can take years to achieve. Once established, attentive maintenance is important to keeping a company's solar pollinator vegetation investment.

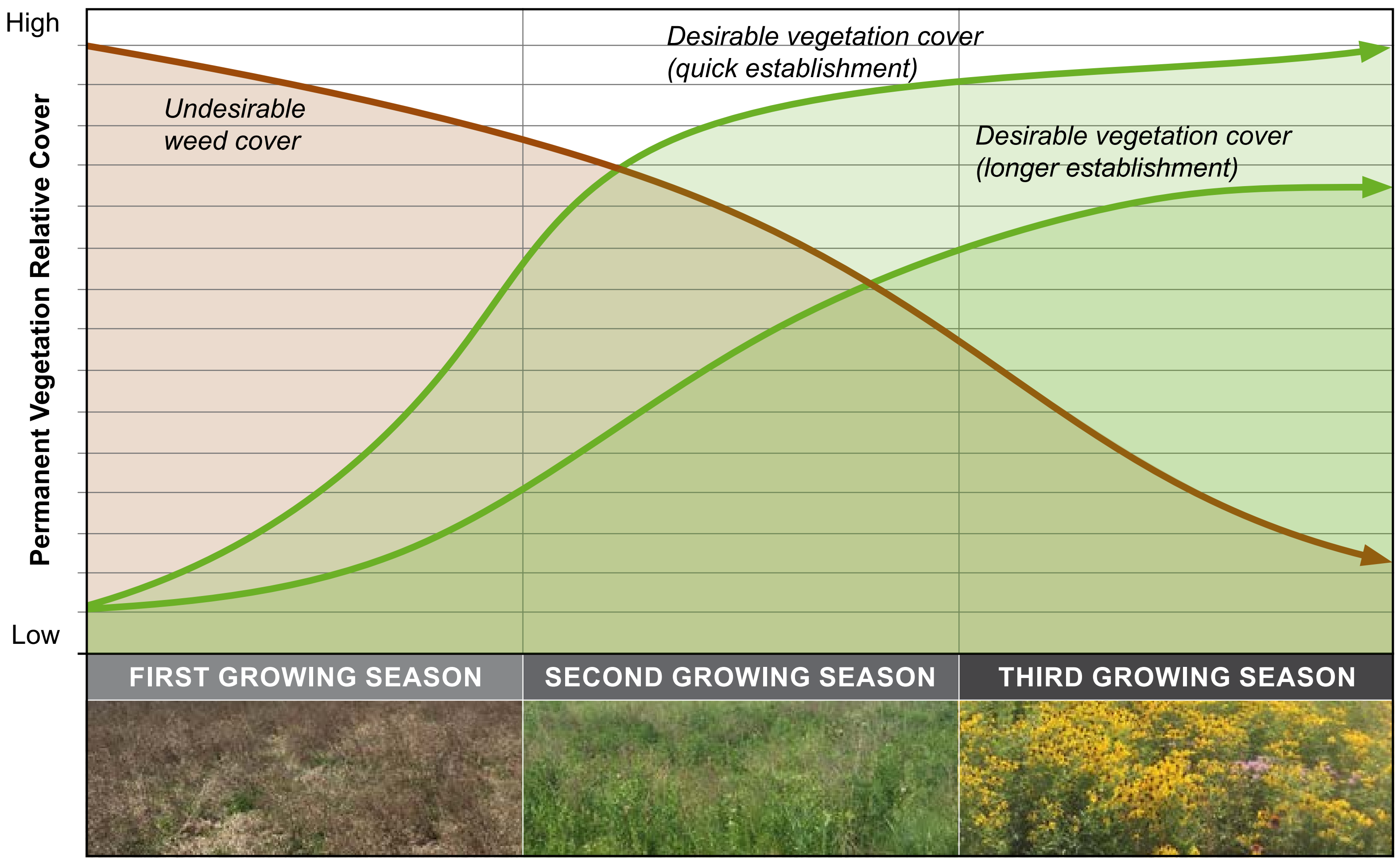
Figure 9.1 is a conceptual diagram of solar pollinator vegetation establishment on a site. As indicated by the red line, early stages of establishing vegetation are dominated by weeds and undesirable plant cover. As time moves into the second and third growing season, the cover of desirable species that were planted begins to increase and become dominant onsite.

The rate of establishment varies (as indicated by the two green lines) depending on site conditions, species included in seed mixes, and amount of weed pressure present.

Site Establishment and Maintenance Checklist

- ☐ Verify that planned vegetation management is appropriate to sustain the desired plant communities.
- ☐ Verify that vegetation management tools are described in the site's vegetation management plan.
- ☐ Verify establishment and maintenance actions included in the vegetation management plan are still appropriate based on as-built site conditions. Revise if needed.
- ☐ Secure personnel or contractors with knowledge, skills, and abilities suitable to conduct required establishment and maintenance actions.
- ☐ Communicate establishment and maintenance expectations to the project team, site owners, and contractors clearly and frequently.

Figure 9.1. *Conceptual graph displaying relative vegetative cover during establishment of solar pollinator vegetation.*



Weedy mix of fast tall-growing annual weed species. Seed mixes early in establishment.

Mixed weeds may still be dominant in planted area while seed mixes are establishing.

Weed species cover is reduced. Seed mixes become more established and dominant.

Maintaing grounds at solar facility. *Photo courtesy of Stantec*

Section 10
Site Decommissioning


Solar panel site to be decommissioned. © *Stock.adobe.com*

WHAT'S IN THIS SECTION?

- Decommissioning Provisions
- Site Closure Risks and Uncertainties
- Decommissioning Planning Checklist

Key Takeaways for Site Decommissioning

- Site decommissioning provisions related to pollinator solar vegetation should be considered early in project planning.
- Agreements with landowners and relevant permitting authorities is an important component when establishing plans for decommissioning.
- Identify areas of risk early on, and revisit periodically over the project duration, to address decommissioning concerns.

Decommissioning Provisions

Utility-scale solar developments may include provisions for site decommissioning within landowner agreements or in decommissioning plans created for project approvals.

Provisions for site decommissioning vary from site to site, and sometimes landowner to landowner. Thus, special attention should be given to the specific provisions made for each project.

When site closure involves removal of built infrastructure, it can involve the removal, disposal, or recycling of panels, pilings, racking, roads, wires, inverters, and fences (ACP 2021). Alternatives to site closure and removals exist. One primary alternative is that use of the site as a solar facility may be continued through reuse, refurbishment, or repowering (CFRA 2022).

Vegetation may or may not be specified in decommissioning plans or agreements. When vegetation is included, typical provisions may include:

- Lands will be restored to their preconstruction condition and land use,
- Lands will be restored as required by the landowner commitments, or that
- Restoration will occur as directed by other federal, state, and local regulations in effect at the time of decommissioning.

Site Closure Risks and Uncertainties

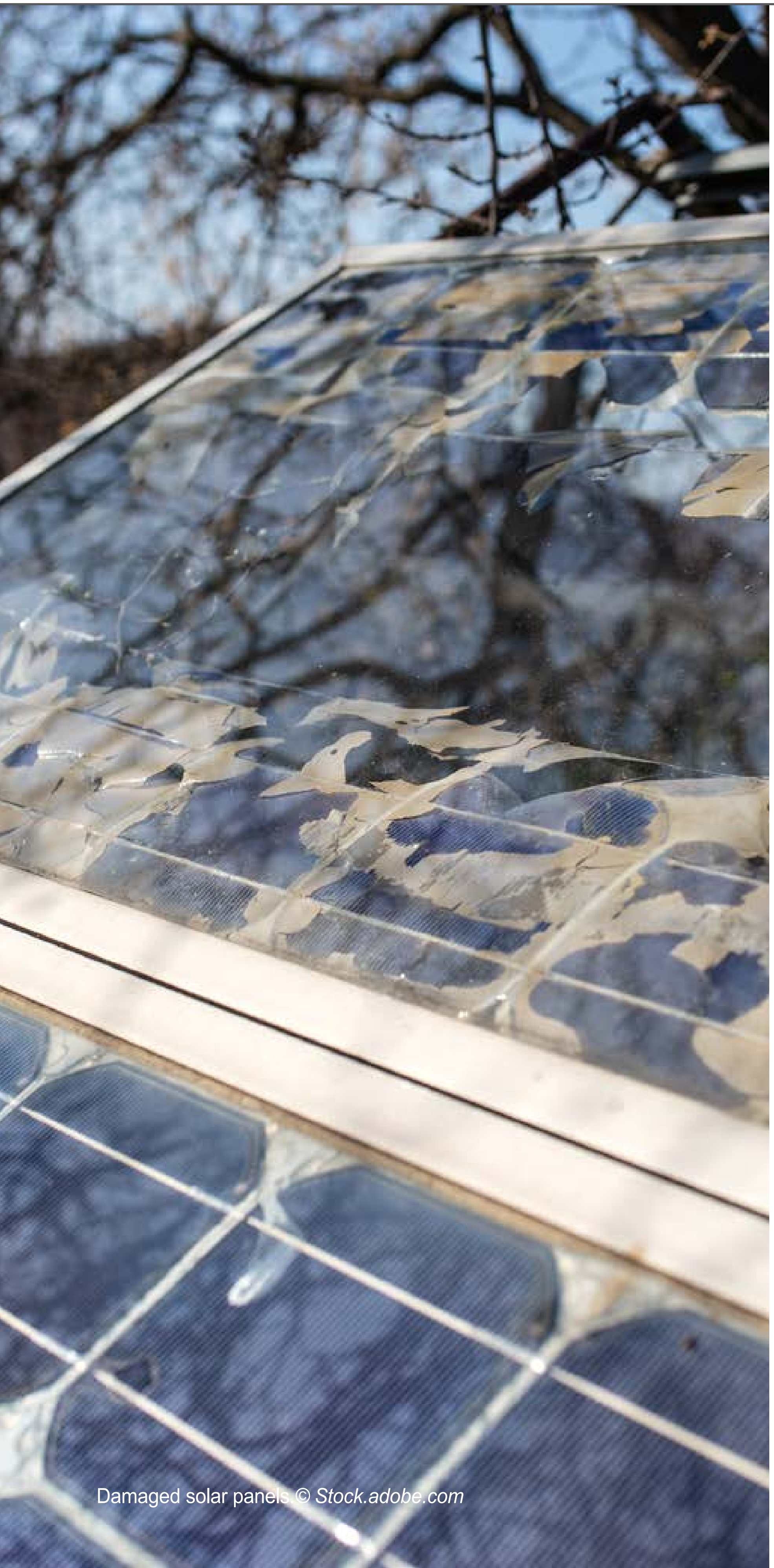
With a planned operating lifespan of 20 to 30 years for most utility-scale solar facilities, many facilities built today will not require decommissioning considerations for many years. As with many other aspects of pollinator vegetation on utility-scale solar facilities, decisions made early in project planning can have lasting implications. While it is impossible to envision all conditions that will be present in two or three decades, project teams may want to evaluate risk mitigation measures for areas of known uncertainties.

With any evaluation of risks, it is important to consider both the impact and the likelihood of the risk materializing. Project teams and counsels may maintain their own risk assessments of individual projects that involve comprehensive analysis of risks. To the extent practicable, project teams should attempt to quantify the severity and probability of risks through accepted analyses, industry records, past projects, or expert feedback.

For utility-scale solar sites, decommissioning may pose several areas of risk or uncertainty that project teams may want to consider in planning, establishing, and maintaining solar pollinator vegetation. Several known areas of concern are identified here, along with potential risk mitigation strategies that can be used to address these uncertainties while still using solar pollinator vegetation.

Endangered Species

As of January 2023, over 30 species of insect pollinators, including bees, butterflies, moths, and beetles, were listed under the Endangered Species Act (NatureServe 2023). Listed insect pollinators are varied in their distribution and habitat requirements. Some, like the rusty-patched bumble bee (*Bombus affinis*, Federal Endangered) have more general habitat requirements encompassing a diversity of floral resources for nectar and pollen foraging (USFWS 2021). Other species, like the Dakota skipper (*Hesperia dacotae*, Federal Threatened) have specific plant species associated that may be unique or unlikely to occur on some utility-scale solar sites (USFWS 2015).



Damaged solar panels © *Stock.adobe.com*

Site owners and landowners may be concerned that creating pollinator habitat may attract existing or future endangered species over the course of a project. Presence of an endangered species can result in additional requirements for avoiding or minimizing 'take' of listed species, which often include timing restrictions, limitations on types of activities that can be conducted in potential habitats, or other considerations.

Potential risk mitigation strategies include:

- **Consider potential regulatory concerns during project siting and planning.** Many companies already include review of endangered species as part of critical issues analyses conducted early in siting. The findings of these desktop reviews and any subsequent field assessments can inform the likelihood of listed species in the project vicinity. Understanding the specific species and their habitat requirements is an important first step to evaluating potential risks.
- **Provide pollinator habitat to prevent declines of at-risk species.** Species at-risk of being candidates for future listings can be helped prior to regulatory intervention. Providing habitat needs of at-risk but not-listed pollinators in the vicinity of project sites can provide needed habitat resilience for these species. Preventing future listings is the most cost-effective solution for companies and agencies alike.
- **Participation in formal conservation agreements with Federal and State agencies.** Species listed on the Endangered Species Act may recover more quickly with habitat restoration and conservation practices. Existing regulatory tools like habitat conservation plans, conservation benefit agreements (also known as Candidate Conservation Agreements with Assurances or Safe Harbor Agreements), Section 7 consultations (for Federal agencies), and other enhancement of survival permitting can be used to leverage conservation benefits for specific species, while offering regulatory protections and cost savings to projects and landowners.

Soil Erosion and Sedimentation Control

Project teams building utility-scale solar projects are subject to the Clean Water Act's National Pollutant Discharge Elimination System (NPDES), which requires permits for "construction activities for one or more acres of land". The U.S. Environmental Protection Agency defines "construction activity" as including "earth-disturbing activities such as clearing, grading, and excavating land and other construction-related activities that could generate pollutants." "Construction activity" does not include routine earth disturbing activities that are part of state or federal reclamation programs to return an abandoned facility property to an agricultural or open land use (USEPA 2023). States or local municipalities may also enforce other regulations or ordinances that may dictate compliance requirements with vegetation removal on utility-scale solar sites.

Potential risk mitigation strategies include:

- **Consider potential vegetation removal regulations several years prior to decommissioning.** The regulatory landscape changes over time to accommodate new information, changing land uses, or public concerns. Erosion and sedimentation permitting requirements at the time of decommissioning may differ from those in place at project implementation. Project teams should evaluate regulatory compliance requirements associated with site decommissioning when it involves removal of vegetation. Doing so several years prior to decommissioning allows time for coordination with regulatory agencies and addressing any permitting that may be required.
- **Evaluate options for avoiding vegetation removal during decommissioning.** Removal of vegetation may or may not be a requirement of decommissioning plans or landowner agreements. Avoiding removal of vegetation in consideration of post-decommissioning uses, such as for transitioning to solar reuse, other land uses, or per landowner request, can limit potential regulations associated with vegetation removal or ground-disturbing activities that may be applicable to the project otherwise

Potential for Future Noxious Weeds or Undesirable Species

Climate change threatens changes to the underlying conditions current plant communities are adapted to. Although it is recognized that the weed pressure associated with climate change is a significant threat, the current knowledge of this effect is limited. Changes in increased temperatures, rainfall shift, and elevated CO_2 levels, can alter species ranges, population dynamics, and individual species traits. As a result, weed problems can change or be aggravated under changing conditions requiring new strategies in preventing the spread of undesirable species (Runyon et al. 2012, Ramesh et al. 2017). Thus, at the time of decommissioning, weed pressures may be different than during project planning and implementation.

Potential risk mitigation strategies include:

- **Adopt a robust weed prevention and control strategy.** Adopting site maintenance and vegetation management practices that identify and control undesirable weed species early on can prevent noxious weeds or other undesirable species that may affect site decommissioning requirements.
- **Use native species where appropriate.** Use of native species in vegetation onsite can provide resilience against a changing climate, which may resist future weed invasions. Increased species and functional group diversity in established plant communities can also increase weed resistance.
- **Site reconnaissance.** Conducting systematic, regular reconnaissance efforts on solar sites can help develop a clearer understanding of ongoing vegetation issues, threats which may ultimately lead to more efficient and lower cost management decisions.

Vegetation-related Ecological or Economic Commitments

As discussed in Section 3, there may be co-benefitting reasons for using solar pollinator vegetation on utility-scale solar sites. To the extent that these co-benefits have been valued by the owning company, landowners, or communities, there may be a desire to transition decommissioned use into another land use that maintains the ecological or economic benefits created by solar pollinator vegetation. For example, improvements in soil health, reduction in water runoff, or increases in carbon sequestration may require decades to achieve the optimum benefits expected. Commitments made towards these co-benefits may require additional communication or consideration as site decommissioning is considered.

Potential risk mitigation strategies include:

- **Communicate expectations for long-term co-benefits early and often.** Communicating expectations for any long-term co-benefits early in project planning will be important to avoiding miscommunications or future conflict. Highlight realistic expectations and areas of uncertainty being considered. As projects move into operations and maintenance, it is important to maintain continuity in communicating the long-term expectations for solar pollinator vegetation as personnel and stakeholders change over the duration of a project.
- **Document commitments made where appropriate.** Documenting expectations and commitments through project documentation, memorandums of understanding, or similar methods can help avoid confusion, miscommunications, or conflicts. Review commitments and considerations made during project planning and vegetation establishment and verify that appropriate documentation is maintained in project records.

Decommissioning Planning Checklist

The checklist provided below can provide a planning support tool for teams considering decommissioning risks and uncertainties on projects.

- ☐ Does the project site contain documented decommissioning requirements in any of the following?
  - ☐ Site decommissioning plans
  - ☐ Landowner agreements
  - ☐ Permit authorizations
  - ☐ Other _______________
- ☐ Do decommissioning requirements include provisions specifically for vegetation removal?
- ☐ Are any of the following areas of risk or uncertainty identified as a concern for the project area?
  - ☐ Endangered species
  - ☐ Soil erosion and sedimentation control
  - ☐ Potential for noxious weeds or undesirable species
  - ☐ Vegetation-related ecological or economic commitments
  - ☐ Other _______________
- ☐ For any areas of risk or uncertainty identified, have potential risks been evaluated?
- ☐ For any areas of risk or uncertainty evaluated and determined to warrant risk mitigation, have strategies been selected to avoid, minimize, or mitigate potential risks?
- ☐ Are risk mitigation strategies being implemented and/or documented to project files for future reference?

Dakota skipper *(Hesperia dacotae, Federal Threatened). © Stock.adobe.com*

Section 11
Assessment and Monitoring

Assessing solar facility and vegetation. © *Stock.adobe.com*

WHAT'S IN THIS SECTION?

- Assessment and Monitoring Checklist
- What is Monitoring?
- Determine the Type of Monitoring Needed
- Evaluate Tools Available for Monitoring
- Prepare for Monitoring
- Documenting and Communicating

Key Takeaways for Assessment and Monitoring

- Monitoring can be an important and effective tool for tracking the progress of solar pollinator vegetation and habitat objectives over time.
- Monitoring efforts should be tailored to requirements, information needs, and effort available. Needs may change over the project duration.
- Understanding how monitoring will be documented, used, and communicated can ensure monitoring efforts provide useful information for the project.

Assessment & Monitoring Checklist

- ☐ Determine the type of monitoring needed, if applicable.
- ☐ Evaluate tools available for monitoring.
- ☐ Prepare for monitoring.
- ☐ Document and communicate findings.

What is Monitoring?

Monitoring is the repeated assessment or evaluation of a project site. Monitoring is used to collect data, track progress, and inform decision making. Monitoring is a tool and process used across many fields. It can be employed in tracking construction progress, permit compliance, or ecological performance, among others.

For vegetation managers on utility-scale solar projects, monitoring can be important to track the progress of solar pollinator vegetation establishment. Data collected through monitoring can help evaluate the success of activities like seedbed preparation or seeding. It can also track permit compliance or changes needed in vegetation management plans.

Depending on the project status, goals, and objectives, different types and frequencies of monitoring may be required.

Defining Monitoring Terms

Assessment – Typically a low-effort act of gauging quality, value, or condition. Assessments often document conditions based on a series of observable metrics, indicators, or abilities.

Evaluation – Systematic review of indicators as measured against a goal, objective, or target. The examination of indicators determines the effectiveness or impact of activities relative to specified objectives or targets.

Monitoring – Involves collection of data or information over time to identify issues or aid in evaluations. Repeated assessments or evaluations can provide data used to track progress of ongoing activities.

Determine the Type of Monitoring Needed

Defining if and why monitoring is needed is critical into developing and implementing a successful monitoring plan. Monitoring requirements are determined by a mix of operational, voluntary, or required purposes. Refer to Section 3 (Why add pollinator vegetation to solar projects?) and 4 (Identifying Site Considerations) for additional considerations for vegetation purposes and goals.

The need for monitoring will change over the lifespan of the project, with different purposes in the establishment phase compared to the maintenance phase. In the establishment phase, managers may use monitoring for:

- Erosion control practices evaluation,
- Seed establishment trends,
- Undesirable vegetation cover changes,
- Triggers for vegetation management (height or woody plant encroachment),
- Evaluation of vegetation management efficacy,
- Use as a communication tool, or
- Permit compliance.

In the maintenance phase, monitoring is often less intensive, but still may be useful to collect information on management activity triggers. Table 11.1 outlines common reasons for monitoring on utility-scale projects with solar pollinator vegetation. It is worth noting that not all projects will be able to to accommodate the same level of monitoring, if any, due to financial and other resource constraints. Managers and operators will need to assess site specific goals and requirements and choose a monitoring plan that is most appropriate.

Table 11.1. *Common purposes for monitoring solar pollinator vegetation.*

Purpose	Users	Examples	Decisions Informed
Operational	Internal operations	• Vegetation height assessment • Vegetation health and condition assessments • Company-specific monitoring protocols	• Success of vegetation establishment • Triggers for adaptive management • Approaches to vegetation management • Solar pollinator vegetation management efficacy
Voluntary	Internal operations External stakeholders	• Rapid habitat assessments • Plant species inventories • Pollinator observations or inventories	• Quantify the ecological or social benefits derived from solar pollinator vegetation • Communicate company sustainability commitments, and on-site environmental benefits
Required	Internal operations Regulating agencies	• NPDES post-construction monitoring • Pollinator-friendly scorecards for established vegetation	• Satisfy permit conditions • Comply with conservation program participation • Support company ESG reporting

Evaluate Tools Available for Monitoring

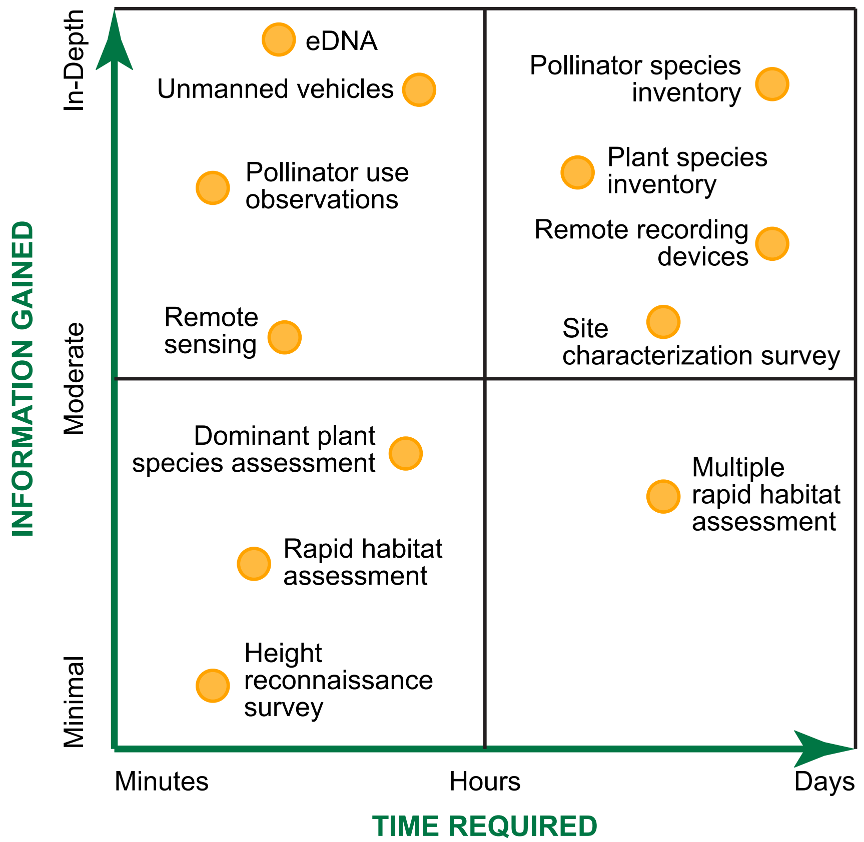
Determining which monitoring tools are most appropriate for your project will help provide the best quality data for the time and money invested. When evaluating monitoring tools available, consider what tools may be most effective in delivering the information needed for the project. Table 11.2, on the right, summarizes some of the common methods and tools used on utility-scale solar projects.

Table 11.2. *Overview of the solar pollinator vegetation monitoring and potential uses.*

Monitoring Method	Tools Available	Potential Uses
Height reconnaissance survey	Visual assessment; Maintenance specifications.	Informing mowing timing and techniques
Rapid habitat assessment	Scorecards and field assessment methodologies.	Summarizing a brief or high-level assessment of habitat conditions
Multiple rapid habitat assessment	Scorecards and field assessment methodologies.	Summarizing changes, trends, or consistency over time or locations
Dominant plant species assessment	Field assessment methodologies; plant identification resources and apps	Verification of desirable plant community and species; identification or confirmation of invasive or noxious weeds
Site characterization surveys	Field assessment methodologies; site information notes	Confirmation of vegetation conditions
Plant species inventory	Qualified botanists; plant identification resources and apps	Verifying seed mix establishment; characterizing plant communities; early detection or confirmation of invasive or noxious weeds
Pollinator use observations	Qualified botanists; plant and insect identification resources and apps	Confirming pollinator associations; communicating pollinator benefits
Pollinator species inventory	Qualified botanists or entomologists; plant and insect identification resources, tools, and apps	Documenting relative abundance of insects onsite; contribute to research or studies; confirming pollinator associations; communicating pollinator benefits
Unmanned vehicle technologies	Aerial or ground-based powered vehicles that do not carry a human operator.	Aerial imagery collection, video or photo documentation, or other data with incorporation of additional sensors.
eDNA	Environmental DNA capture methods vary depending on sampling targets	Characterization of biological communities and diversity for insect pollinators, soil biota, or other wildlife use
Remote recording devices	Acoustic recorders, remote cameras	Audio or visual documentation of wildlife use onsite
Remote sensing	Aerial imagery or data collection via aircraft, UAV, or satellites.	Aerial imagery collection, photo documentation, or time-lapsed image series

Different tools for effective monitoring require varying levels of time and effort to produce relevant, high-quality, and useful information. Figure 11.1 illustrates a comparison of time and effort between different forms of solar pollinator vegetation monitoring conducted on sites. Vegetation managers should consider the tradeoffs of time, effort, and information gained by monitoring when selecting the appropriate tools and methods that yield the best information to inform their site goals and vegetation targets.

Figure 11.1 *Relative time and effort tradeoff between common solar pollinator vegetation monitoring methods.*



Resources for monitoring may be obtained from industry groups, conservation organizations, and federal, state, or local agencies. Examples include:

- Rights-of-Way as Habitat Working Group Pollinator Habitat Scorecard
- Virginia's Pollinator-Smart Monitoring Plan
- Xerces Society's Pollinator Habitat Monitoring Form and Habitat Assessment Guides

It is worth noting that these assessments, and other examples like them, can vary greatly in the data collected, how that data is collected and evaluated, and how they were developed (EPRI 2021). Their use is appropriate for information gathering and not intended as a tool for regulatory criteria.

Prepare for Monitoring

Preparing for monitoring will require the dedication of resources, selection of appropriate tools, and engaging personnel with the appropriate qualifications. Qualified personnel can include vegetation managers, operators, and those with specialized experience (internal or external) in the environment, ecology, construction, or land management. Identifying a team of personnel that will be responsible for conducting monitoring early on can help ensure the right correct and high-quality information is acquired and integrated into vegetation management.

Vegetation management plans may include identify monitoring protocols and identify tools. If not included in vegetation management plans, project teams may wish to create an accompanying monitoring plan to outline the purposes, methods, the review or analysis expected, and communication of results to appropriate project personnel.

Documenting and Communicating

Documenting observations and findings is important to preserve useful information to identify long-term trends. Documenting observations also provides a means of institutional knowledge that can be passed on to future vegetation managers on other utility-scale solar projects.

What to document, in what format, and when to document it, are all considerations that may vary between company, site, or operations portfolio. Vegetation managers should verify requirements with project teams and encourage documentation of monitoring conducted. Requirements should also be verified with requirements in the different evaluation methods used on the project.

Capenter bee *(Xylocopa sp.)* on swamp milkweed *(Asclepias incarnata)*, *© Stock.adobe.com*

Section 12
Vegetation Contracting Suggested Practices

WHAT'S IN THIS SECTION?

- Successful Outcomes through Contracting
- Common Pitfalls in Solar Vegetation Contracting
- Suggested Practices for Vegetation Contracting

Recently mowed section of solar facility. *Photo courtesy of Stantec*

Successful Outcomes through Contracting

Many solar developers and owners rely on contracting for aspects of pollinator vegetation management. Unlike conventional vegetation management, which may be limited to a single tool (often mowing) across a single vegetation type like turfgrass, use of solar pollinator vegetation requires specialized knowledge and experience to be successful. Benefits of contracting vegetation specialists include:

- **Achieving results.** The vision and commitments produced in project planning require contractors to build and achieve. Successful contracting adds knowledge depth and practical support that can yield the desired results.
- **Supplying the right skills for the job.** Vegetation management professionals have acquired a set of knowledge, skills, and abilities unique to their profession. Successful contracting recognizes specialized qualifications and selects the support needed to deliver the results desired.
- **Avoiding pitfalls.** Knowledge and experience of contractors can be leveraged to avoid making mistakes in planning or establishment of vegetation.
- **Avoided risks.** Experienced contractors can often identify areas of risks that may save developers or operators from project impacts. Vegetation contractors can help identify and avoid establishment risks like poor site preparation, suboptimal seeding conditions, and weed pressure. Having vegetation managers onsite can also provide additional "eyes on-the-ground" that have the ability of identifying health, safety, or security risks.
- **Reduced long-term costs.** While contracting costs are an expense on projects, avoiding pitfalls or risks can yield more stable and lower costs over a project lifespan.
- **Adaptability.** Use of contractors can provide adaptability as project schedules and scope change.

Key Takeaways for Vegetation Contracting

- Many solar developers and owners rely on contracting for aspects of pollinator vegetation management.
- Contracting is subject to pitfalls that can have serious implications for a project's success.
- The best of contracting results in vegetation contractors becoming an extension of the project team by providing specialized and trusted support.
- Suggested practices can be used to improve vegetation contracting on solar projects to ensure success.

Common Pitfalls in Solar Vegetation Contracting

Like any other aspect of large project or construction management, contracting is subject to its own set of pitfalls that can have serious implications for a project's success:

- **Lack of clarity in site roles and responsibilities.** Contractors are often hired for a discrete series of tasks. While this can provide a straightforward scope for some tasks, different contractors for site preparation, seeding, establishment, and maintenance can lead to a lack of management continuity. By dividing vegetation roles and responsibilities, project teams or contractors may assume certain roles or tasks are being fulfilled by other parties. This can result in issues that go unnoticed or unaddressed, as well as spatial or temporal gaps in vegetation management.

- **Inadequate scoping for adaptation.** Vegetation includes a mix of species that are part of nature. They are influenced through various factors and may respond differently to management techniques or timing. Vegetation management scopes however, are often prescriptive in nature - assuming a certain number or types of treatments regardless of growing conditions or vegetation health. Prescriptive scoping inhibits adaptation, as a result, vegetation issues such as weed establishment, drought stress, or erosion can be exacerbated.
- **Insufficient timing.** Vegetation contracting often occurs shortly before a project goes to construction. Contracting within days or weeks of construction beginning can create unnecessary strains on contractors and project timelines. Materials such as specialized seed mixes may be difficult or impossible to acquire within such short time frames. In turn, this can negatively affect installation approaches and construction sequencing relative to vegetation establishment.
- **Insufficient contract modifications.** As noted, prescriptive scoping inhibits adaptation. This is true for contract modifications as well. Early detection and rapid response is often the most cost-effective way of addressing vegetation concerns such as new weed specie introductions, plant stress, or fire and other safety risks. Too often, the process required to process adaptive contract modifications can lead to issues remaining unaddressed or being treated during less optimal times.
- **Cost-based selection.** Developers and engineering, procurement, and construction (EPC) contractors are often under pressure to deliver projects for the lowest cost possible. The desire to deliver the project at the lowest cost possible results in vegetation contractors being selected solely based on cost without consideration for experience or desired end results. As a result, low-cost bids may result in hidden costs that may affect projects for years to come.
- **Cost based selections often negate the opportunity to consider adaptation.** Per acre or unit pricing may allow for some accounting for scale, but often don't allow for adaptive considerations for site preparations and establishment. By reducing the vegetation scope to one or more series of line items, procurement teams may often miss hidden elements of the scope that may or may not be expressed by different contractors.
- **Unrealistic expectations.** Some vegetation contracts contain performance standards or warranties that detail unrealistic expectations. Standards requiring unnaturally high degrees of establishment cover or scope of work criteria that are misaligned with desired project outcomes can create conflicts between procurement and contractors. Similarly, unrealistic expectations for this establishment and maintenance (e.g. less than 5% cover of invasive weed species across the site) may either prevent experienced contractors from bidding altogether, or result in unnecessary conflicts later on in contract management.

Solar facility pollinator vegetation making an impact. *Photo courtesy of Argonne National Laboratory*

Suggested Practices for Vegetation Contracting

Addressing common pitfalls with successful contracting does not have to be complicated. The best of contracting results in vegetation contractors becoming an extension of the project team by providing specialized and trusted support. Consultation with vegetation contractors working in the utility- scale solar industry identified a series of suggested practices to improve vegetation contracting:

Take time to scope vegetation contracting according to project needs. Taking time up front to tailor vegetation contracting requests according to project-specific conditions and needs. Avoid recycling scopes of work from project-to-project without changes or updates. Added time upfront can result in more thoughtful requests for proposals that avoid the common pitfalls identified. Doing so can reduce project risks and avoid setting up project teams for failure or conflict.

Give sufficient lead timing for procurement and staging. Securing contracts 3-6 months prior to the planned seed installation date will provide vegetation contractors with ample time for securing seed mixes, scheduling resources, and mobilizing equipment and materials. Completing contract procurements months in advance also provides some contingency time in the event of setbacks or delays in contract execution.

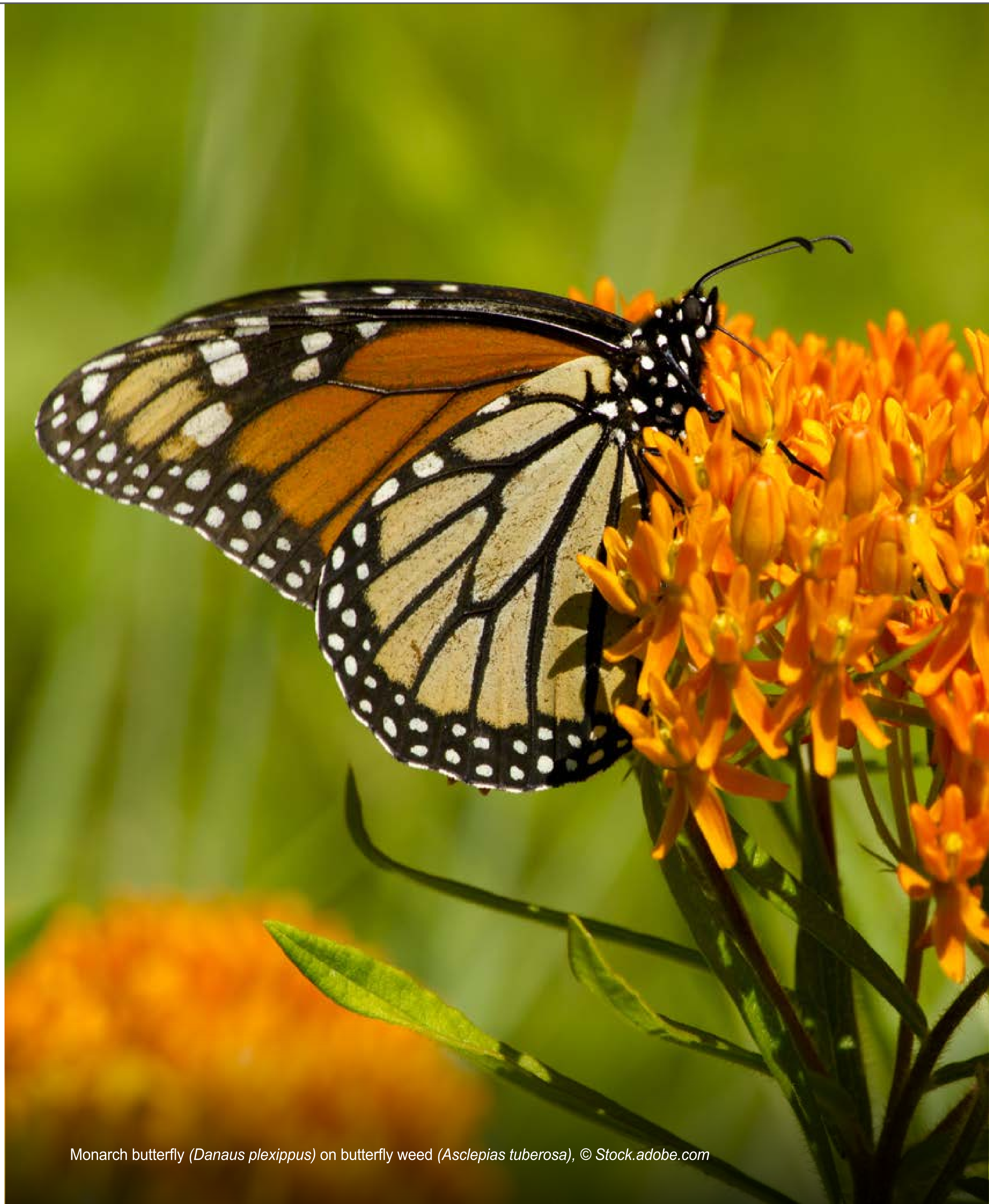
Use qualifications-based, not cost-based, procurement methods. Performance-based contracting selects contractors first on their performance or qualifications exclusive of costs. Primary selection criterion is often based on personnel qualifications and experience, firm experience with similar projects, knowledge of approach, resource capacity, or statement of work proposed. Once a preliminary selection has been made, costs can be negotiated with the contractor determined to be best fit for the project needs.

Use performance-based, not prescription-based, scoping. Performance-based scoping relies on contractors to define the tasks needed to achieve a desired outcome rather than specifying a set number of prescriptions. Performance-based scoping often requires having a clear set of goals and objectives to find for vegetation planned onsite. By clearly stating the desired outcomes, procurement can rely on vegetation contractors to propose the scope of work approaches that they believe will provide the most-cost effective and successful solutions for a site.

Include vegetation monitoring and reporting as part of the vegetation contractor annual scope. Vegetation monitoring and reporting are an important aspect of both integrated vegetation management and adaptive management. By including monitoring and reporting and vegetation contractor scopes of work, project teams can obtain regular feedback on vegetation conditions, trends, and emerging needs. Results of monitoring and reporting can be used to inform vegetation management scopes of work for the upcoming year - allowing for better adaptation over time. Monitoring and reporting may also save costs by identifying concerns early and avoiding costly mistakes.

Include triggers or thresholds for contract modification adaptive management. Identifying management triggers or thresholds can be a mechanism by which adaptive management can be more easily incorporated into contracts. Triggers and thresholds can be informed by annual monitoring and reporting or based on past experience. Contracts can include contingency provisions that are only enacted in the event that an expected trigger or threshold has been exceeded. Such provisions may include a maximum limit on invasive or noxious weed cover tolerated, a maximum allowable unvegetated area, or specific plant composition conditions desired.

Include clear performance standards in requests for proposals and contracts. Contracting EPCs, vegetation contractors, or other support specialists is a critical link in communicating expectations about vegetation conditions and desired outcomes. By including requirements associated with review and use of site vegetation management plans, adherence to site vegetation targets, or related performance standards, developers and site owners can safeguard their time and costs invested in vegetation.



Monarch butterfly *(Danaus plexippus)* on butterfly weed *(Asclepias tuberosa)*, © *Stock.adobe.com*

Appendix A
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Viceroy butterfly *(Limenitis archippus)*
Photo Courtesy of Argonne National Laboratory

Figures & Tables

Research and manual development conducted by: