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LAND USE CONSIDERATIONS FOR LARGE-SCALE SOLAR

Community-based Stormwater Strategies and Vegetation Management for Sustainable Solar PV Development

This SolSmart Issue Brief was written by the Electric Power Research Institute (EPRI) and edited by The Solar Foundation

Setting the Stage

Energy development is the largest driver of land-use and land-cover change in the United States.[1] Today, one of the leading forms of this new development is large-scale solar photovoltaic (PV) plants. These utility-scale solar farms are being installed around the world on a variety of terrestrial surfaces, including grasslands, deserts, farms, rooftops, and even bodies of water.

As with other forms of energy generation, land selection is a key aspect of the solar development process. It is guided by a number of considerations — for example, ownership and current use, constructability, grid access, and permitting — that will ultimately impact a project's design and economics. For municipalities and county governments, providing jurisdictional guidance to the solar development community can help influence associated land selection and use decisions in ways that offer local benefits and encourage environmental stewardship.

Land use considerations for ground-mounted solar projects include habitat degradation, biodiversity loss, water quality, and soil erosion. Another important consideration is public acceptance, since a project often hinges on converting prime farmland and natural areas to power production. Stormwater and vegetation management strategies can help address these issues and make large-scale solar projects a win-win for communities, solar developers, and the environment.

Expected Land Requirements for PV in the U.S.

Cumulative installed capacity for large-scale solar PV is expected to grow from 58 GW today to 144 GW by 2030.[2] Given the land requirements of typical large-scale PV systems — which range between 4.2 and 6.1 acres per MWac of installed capacity, depending on technology type — total land requirements for siting this anticipated capacity are expected to range between 604,800 and 878,400 acres (945 to 1372.5 mi^2), approximately the size of Rhode Island.[3]

The process of constructing large-scale PV plants often involves substantially modifying the native land above and below the surface, which can interrupt ecosystems and alter the dynamics of local hydrology and stormwater flow patterns. After solar facilities are installed, new vegetation can be costly to establish and maintain, particularly if sites must be frequently mowed. Stormwater runoff can damage local ecosystems and PV plant equipment, resulting in costly groundwork and repairs. Incorporating vegetation management strategies using appropriate regional native seed mixes can help restore ground cover and avoid soil erosion issues.*

This SolSmart issue brief is intended to educate local governments and community stakeholders interested in supporting solar development. Topics covered include:

1. Key challenges posed by stormwater runoff and mitigation measures that can be incorporated into project development processes.
2. Vegetation management concepts and their tactical application, including an Integrated Vegetation Management (IVM) strategy.

Together, these strategies can help communities and local governments develop policies and guidelines on large-scale solar that can realize both environmental and economic benefits.

Achieving SolSmart Designation for Large-Scale Solar

Solar facilities — and the lands they operate on — offer unique opportunities for communities to demonstrate environmental stewardship and realize economic benefits. Local governments can encourage solar development with effective guidance and policies governing solar land use decisions, including those concerning stormwater and vegetation management strategies. The national SolSmart program, funded by the U.S. Department of Energy Solar Energy Technologies Office, provides no-cost technical assistance to help local governments adopt best practices on solar development. These localities can join over 380 communities nationwide that have received SolSmart designation for making it faster, easier, and more affordable to go solar.

Any municipality or county in the United States is eligible to receive this no-cost technical assistance. Visit SolSmart.org for more information about how the SolSmart program can help communities meet their solar objectives, or contact us at info@solsmart.org to learn more.

Solar-Stormwater Management

As with other kinds of development, large-scale solar power projects can exacerbate soil and water quality issues by increasing the frequency and magnitude of peak flows during heavy precipitation events. Specifically, solar PV arrays and support structures, concrete inverter pads, paved or gravel access roads, compacted soil surfaces, and other infrastructure can contribute to increased overland water flow, decreased soil absorption, and concentration of runoff. If not properly managed, this runoff can lead to soil erosion and downstream sedimentation. Fortunately, however, there are many PV plant design alternatives and stormwater management practices that can be employed to mitigate these risks.

Stormwater management strategies for large solar projects typically focus on controlling sedimentation during and after construction and mitigating excess runoff. County-level soil and water conservation districts, which are part of USDA's Natural Resources Conservation Services, can provide developers with detailed soil survey maps for proposed solar project sites to help them identify and assess erosion and sedimentation risks. Once a project site is selected, understanding the soil type and other site characteristics can help guide selection of appropriate seed mixes to quickly re-establish robust vegetation ground cover.

Stormwater Regulations & Permitting

Stormwater runoff is regulated by multiple government agencies at the federal, state, and local levels and requires coordination with multiple permitting agencies. Permitting requirements can vary significantly depending on the proposed project location and the authority having jurisdiction (AHJ).

At the federal level, stormwater is regulated through the U.S. Environmental Protection Agency's (EPA's) Clean Water Act under Section 402(p). This section provides a framework for regulating stormwater runoff during a project's construction phase by requiring a Construction General Permit under the National Pollution Discharge

*Native plants typically have deep root systems that reduce water runoff, decrease soil erosion, increase soil filtration, and make plants more draught tolerant than ground covers like turf grass. Native species also typically require less maintenance if established properly. Low-growing native species that do not require mowing are of particular interest for use at solar power plants.

Elimination System (NPDES) program, or through another EPA-authorized state program for all projects that disturb more than one acre of land. Coverage under all general permits, regardless of administering authority, is granted after several requirements are met, including the development and approval of a Stormwater Pollution Prevention Plan. Figure 1 depicts the major steps involved for states to issue a general permit under which developers can apply for coverage, as described above.

Figure 1. Steps to Obtain an NPDES Permit

Adapted from: Environmental Protection Agency

Major Steps to Develop & Issue an NPDES General Permit

1. Identify need and collect data
2. Develop Permit Fact Sheet
   - Effluent Limitations
   - Monitoring Requirements
   - Special Conditions
   - Standard Conditions
3. Public Notice & Review Comments
4. Complete EPA review of CWA Section 401 certification process
5. Prepare Administrative Record
6. Issue Final Permit

Under the statute, most states have received EPA authorization to administer all or portions of the federal NPDES program. Furthermore, those authorized states can delegate administration of NPDES to qualifying local governments that have a Municipal Separate Storm Sewer System (MS4) permit.[4] All local governments can enact stormwater control requirements, including post-construction stormwater quantity and quality. Qualified local programs can also implement the NPDES program. Normally, local post-construction standards are established through municipal planning and zoning boards, but other government entities, such as regional water control boards, can also implement new plant design, construction, and operation provisions to regulate stormwater discharge.

Even aside from any local requirements, stormwater management provisions vary considerably by state, depending on state-level regulations, legislation, and local government zoning codes and ordinances. In states that have undergone rapid solar growth in recent years, local government planning and development agencies typically have final approval authority for construction permits (i.e., condition use permits or special use permits), but some states require more robust environmental review for major projects than others.[5]

For example, California and New York each require environmental review processes for larger project sites (disturbing one acre or more of land) that closely resemble the terms of the federal National Energy Policy Act (NEPA), which imposes substantial consulting, engineering, and legal due diligence before construction permits are approved. Decision making authority for permits in most other states, including Arizona, North Carolina, and Texas, is largely delegated to local government agencies with minimal state-level requirements except for water and air quality permits required under the Clean Water Act and Clean Air Act.

Some notable differences across state jurisdictions include solar-specific provisions and the designation of solar panels as "impervious" or "pervious" surfaces. Many state definitions of impervious surfaces include phrases such as, "a surface composed of any material that significantly impedes or prevents natural infiltration of water into soil." (For a summary of state stormwater standards, see https://www3.epa.gov/npdes/pubs/sw_state_summary_standards.pdf.) Vegetated land beneath solar arrays can absorb stormwater, and some states, including California, Maryland, New Jersey, Virginia, and North Carolina, consider this area to be pervious.[6] Ground covers such as gravel, on the other hand, may impact the natural infiltration processes and therefore trigger additional stormwater mitigation requirements. Table 1 summarizes stormwater policies in 11 states.

Maryland, Minnesota, and North Carolina have each drafted stormwater management regulations and guidance documents that are specifically tailored to the construction of large-scale solar projects. Common design considerations include:

- Ensuring that there is an adequate permeable space between rows of solar panels so that runoff from the panels remains hydrologically disconnected.
- Selecting a construction site with a slope of less than 5%, or terracing the site to maintain sheet flow conditions.
- Minimizing site compaction during construction or tilling and amending soil following construction to maintain the natural infiltration capacity of the soils.
- Limiting the vertical distance between the ground and the panel drip edge to limit soil erosion.
- Establishing native groundcover that will help prevent erosion, promote infiltration, and support ecological function.

Table 1. Summary of State-Level Stormwater Policies

State	State Level Stormwater Management Policy (Post Construction)	Solar PV Specific Stormwater Policy	Solar Panel Designation for Stormwater Design
Arizona			Not Specified
California	✓		Pervious
Florida	✓		Site Specific
Georgia	✓		Impervious
Massachusetts	✓		Site Specific
Maryland	✓	✓	Pervious
Minnesota	✓	✓	Impervious
New Jersey	✓	✓	Pervious
North Carolina	✓	✓	Pervious
Texas			Not Specified
Virginia	✓		Pervious

Guidelines and Ordinances for Pollinator-friendly Solar Development

In addition to enacting stormwater regulations and guidelines, Minnesota implemented voluntary pollinator-friendly development guidelines in 2013 that emphasize the use of native low-growth flowering plant species to support robust pollinator habitats that benefit nearby agricultural lands. In addition, the state found these site management practices could reduce stormwater runoff and erosion. In 2016, these beneficial habitat guidelines were formally enacted by the Minnesota state legislature for solar sites greater than 40 kW. The Minnesota Board of Water and Soil Resources created a one-page pollinator habitat assessment scorecard for solar companies and local governments seeking a pollinator-friendly designation. Illinois, Maryland, Michigan, Vermont, and other states now have similar pollinator-friendly solar scorecards, and several states, including Ohio and Virginia, have similar scorecards to support county-level ordinances and procurement.

Pollinator-friendly guidelines are also an option at the local level. Stearns County, Minnesota (SolSmart Silver) was the first county to require that all solar projects be certified as pollinator habitat. The county arrived at this decision through a stakeholder workgroup that was tasked with proposing changes to the county's 2010 solar ordinance in light of solar market dynamics, applicable regulations, and community member concerns. Pollinators are critical to Stearns Country's agricultural industry. The revised solar ordinance is intended to benefit local farms and ecosystems through establishment of native vegetation that provides pollinator habitat and enhanced stormwater protection.[7]

Best Management Practices (BMPs) for Stormwater Management

Many state environmental agencies have produced stormwater and erosion/sedimentation control guidelines and handbooks that describe best practices for complying with stormwater permitting regulations, as well as requirements for a variety of construction projects—including large solar facilities. BMPs that are applied during the construction phase of a project are designed to control the erosion and resulting sedimentation that can occur when natural land surfaces are disturbed. These BMPs include use of mats that are placed over exposed soil, silt fences, stone filters, and drainage swales, among other common methods. Each BMP reduces surface erosion and/or promotes the settlement of sediment particles that have been dislodged.

A Snapshot on Solar Permitting in New York, North Carolina, and Texas

New York – In New York State, standardized permitting programs and ordinances have been enacted to streamline the solar permitting process and reduce permitting costs. These activities are a response to moratoriums by nearly 90 towns and villages on large solar project development that were ratified in 2016. Each county and municipality has the authority to approve new construction projects under a so-called "home-rule state" structure that requires cooperation between state and local government on land use issues.[8] Large, ground-mounted projects that include stormwater management plans face more regulatory scrutiny under major site plan applications, due to the potentially high land disturbance and increased impervious surface. Such projects must comply with the State Environmental Quality Review Act (SEQRA) and may require heightened land use review by local government planning and zoning bodies.

For projects that involve a site plan application, or special use permit, the local planning board or zoning board of appeals can require project developers to submit an initial Environmental Assessment and also a full environmental impact statement (EIS) if a project will have a significant impact on the environment. The local legislative body may be involved if the project needs rezoning. It may also be involved if it has granted itself the authority to review particular applications. Pre-application negotiation meetings between local government staff and solar project developers are advised to address any problems that would require the completion of a full EIS under SEQRA. The lead agency carries the responsibility to determine the significance of any impacts to the SEQRA process.

Photo by Greg Johnstone, NREL, 000580_172630_517891_4578

In 2019, the New York State Department of Environmental Conservation amended SEQRA to exempt solar PV projects up to 25 acres that are built on certain types of sites — such as closed landfills, brownfield sites, inactive hazardous waste disposal sites, wastewater treatment facilities, and sites zoned for industrial use — from the full environmental review process.[9]

North Carolina – In addition to meeting relevant federal requirements, solar project developers in North Carolina must apply for a Certificate of Public Convenience and Necessity to the North Carolina Utilities Commission. The application then goes through an environmental review by the North Carolina State Clearinghouse, where regulatory agencies have an opportunity to comment on project proposals. Successful proposals are then reviewed by county/municipal government bodies for compliance with relevant local ordinances or zoning restrictions.[10]

After passing the state-level environmental review process, solar project developers must obtain special use permits (also called conditional use permits) that typically require a quasi-judicial hearing where the application must be found to meet several general standards and any special conditions. Most North Carolina jurisdictions use the following four general standards: 1) Does not materially endanger the public health or safety; 2) Meets all required conditions and specifications; 3) Would not substantially injure the value of adjoining property or be a public necessity; and 4) Will be in harmony with the area in which it is located and be in general conformity with the county or municipality comprehensive plan.[11]

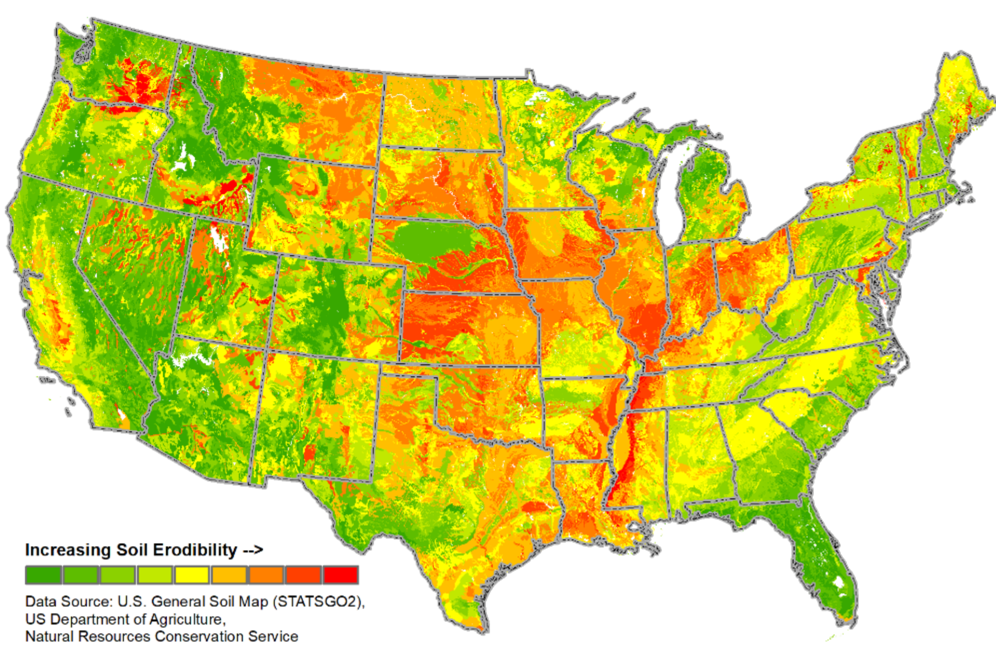
While each county and municipal government may adopt their own unique zoning and permitting ordinances, the North Carolina Sustainable Energy Association and North Carolina Clean Energy Technology Center have developed a model solar ordinance to standardize requirements for solar project developers. The model solar ordinance is a template designed to be adapted and then adopted by jurisdictions across the state, and to serve as the basis for local development ordinances that provide guidance and flexibility. It provides different levels of permitting requirements for three types of solar projects, such as ground-mounted systems no larger than 10 acres in commercial/business districts, and of any size in industrial districts. The North Carolina Department of Environmental Quality has facilitated this process by developing a Stormwater Permitting Interactive Map that illustrates the status of, and administering authority for, stormwater management at the local level.

Texas – At the state level, the Texas Commission on Environmental Quality (TCEQ) has jurisdiction over numerous aspects of a project's construction and operation including stormwater discharge permits for construction activities. Large-scale solar projects are typically not a category defined in local zoning regulations; therefore, the project developer must obtain a Conditional Use Permit (CUP). Depending on the local AHJ, strict zoning and ordinance requirements could make the cost of developing a project on the land prohibitively expensive for site consideration. In some cases, a project developer can initiate a process to re-zone the land with the AHJ. While counties have the authority to adopt zoning regulations for unincorporated areas, it is customary to obtain a letter from a county judge or attorney stating that there are no applicable zoning regulations. This provides transparency to developers about any zoning requirements and expectations from the county. Though Texas lacks local zoning regulations in its unincorporated areas, environmental studies can still be completed as part of legal and financial due diligence. Most utility-scale solar projects have not been built close enough to city limits to trigger municipal zoning or extra-territorial jurisdiction.

Requirements for post-construction stormwater management vary by location, but they typically include BMPs designed to reduce erosion, lessen off-site sediment transport, and mitigate any alteration of the natural volume and timing of runoff. These BMPs include site grading and terracing to reduce runoff flow velocity, soil stabilization through effective re-vegetation, constructed and natural depressions to promote stormwater infiltration, vegetated swales (with or without check dams), and retention ponds. Aligning re-vegetation activities with the growing season is encouraged to establish groundcover.

Perhaps the most effective approach for minimizing adverse stormwater impacts is to prevent stormwater concentration from occurring in the first place, which can lead to reduced construction, operation, and maintenance expenses. This can be accomplished by selecting project sites with low potential for stormwater damage. Communities can encourage developers to analyze a range of environmental variables that can be used to estimate potential stormwater volume. Mean annual precipitation and soil erodibility are two examples of datasets that can be used to inform site selection decisions during the planning and design phase of project development. Local government planning and zoning bodies can also require that specific metrics be met through special use permits or other mechanisms to deter development in areas prone to erosion. Choosing a site with low annual precipitation and/or low soil erodibility minimizes the potential for adverse stormwater impacts. Figure 2 provides a broad view of the likelihood of soil erodibility across the continental U.S., though there are variations in stormwater risk among potential solar sites at the local level.

Figure 2. Soil Erodibility in the Contiguous U.S.



Stormwater Management Guidance for Communities

A growing number of municipal governments are adopting "model solar ordinances" designed to streamline the permitting approval process for residential and small commercial projects. However, utility-scale solar projects carry substantial land use requirements that may require zoning changes and non-trivial mitigation measures for stormwater management and other environmental impacts. The level of support for zoning and permitting at the local level often dictates the development of large-scale solar projects.

Communities can consider becoming engaged in stormwater control both to the extent they are interested and have the ability to participate. For large-scale solar projects that encompass one or more acres, engagement can range from implementing the NPDES program, to developing local ordinances or zoning restrictions that address large-scale PV-specific stormwater requirements, to revising existing zoning codes that may (intentionally or unintentionally) restrict solar development in low stormwater-risk areas, to cross-training inspection and permitting staff on how to identify potential stormwater issues.

Several ways that communities can minimize stormwater risk through ordinances or zoning for new large-scale solar facilities and BMPs include:

- *Site selection.* Local government planning and zoning bodies can require that specific metrics be met through special use permits or other mechanisms to deter development in areas prone to erosion. Selecting land with existing stormwater management systems in place minimizes ground disturbance and is a best practice for solar project development. The lead agency typically conducts a pre-application negotiation meeting with project developers to identify and, if possible, remove any significant environmental impacts that would otherwise trigger further environmental compliance requirements — for example, the completion of a full EIS in New York under SEQRA.
- *Plant design.* Local stormwater management regulations can be crafted to include design requirements that reduce erosion risk, such as array spacing and height, site topography, soil infiltration capacity, and groundcover.
- *Permitting process.* Local governments can work with state AHJs to standardize stormwater requirements for large-scale solar project development, which helps to streamline the permitting process. It also enables greater transparency for community members and solar installers about stormwater risks. Further, they can cross-train inspection and permitting staff on solar PV and how to identify potential stormwater issues.
- *Best management practices.* Local governments can work with state AHJs to identify and promote BMPs that enable responsible and informed PV project development and operation. For very large solar sites that may have substantial runoff, this may include the use of mats, stone filters, and drainage swales to avoid or contain runoff and native vegetation to improve soil absorption.

Vegetation Management at Solar Development Sites

Vegetation management comprises a set of activities that aim to control the growth of undesirable flora around power plants. The general goal of vegetation management is to prevent vegetation from negatively impacting the technical performance, operational safety, and regulatory compliance of these assets. Typical ground covers used at ground-mounted PV facilities include bare earth, rock or sand, and various types of vegetation, such as grasses and grass-like species including forbs and sedges. If left

Photo by Lucia Bourgeois, NREL, 000304_169550_514286_4578 unmanaged, other plants such as shrubs and trees can take root. Informed vegetation selection and management practices can avoid costly stormwater and maintenance expenses throughout a solar project's lifetime, while providing benefits to local ecosystems and the surrounding community, such as pollinator habitat (see sidebar, *Guidelines and Ordinances for Pollinator-friendly Solar Development (p4)*).

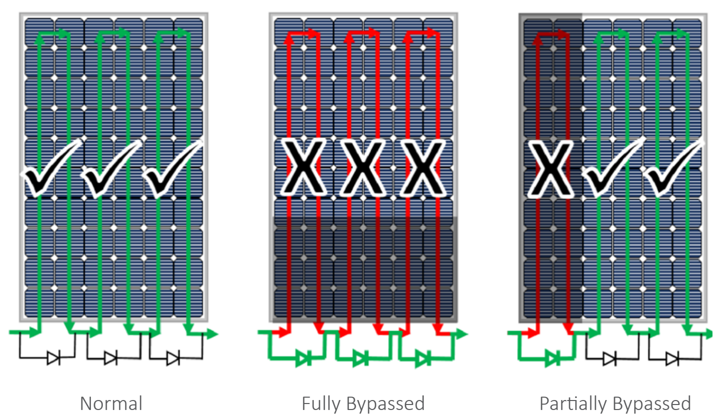
Maintenance Considerations

Over time, live and decayed vegetation can build up within and around a PV plant. As a result, safe access and egress around critical work areas can be impeded, system performance can be reduced, and risk of fire damage can be increased. Generally, it is in the interest of the project owner or operator to ensure accessibility for maintenance and avoid performance and safety issues. However, it is good practice for local governments to periodically revise local permitting requirements to include the most up-to-date codes. In some cases, if solar facilities are not being properly maintained or have high risk of fire, the AHJ could use a special use permit to enforce proper vegetation management or implement other safety measures.

- *Accessibility.* Personnel safety is the most important factor when conducting maintenance work at a solar facility. Unmanaged vegetation can limit maintenance technician access and egress to combiner boxes, string inverters, electrical switches, and other electrical enclosures. Solar developers must take care to maintain working clearances specified in Article 110 of the National Electric Code.
- *PV System Performance.* Shading of PV modules poses both performance and safety risks. Bypass diodes are designed to protect modules from overheating when shaded and minimize the impact of the shaded module(s) on overall array performance (see Figure 3). Shading one cell of a single PV module can activate a bypass diode and reduce the power output of the module by approximately 30%. When multiple PV modules are wired together in series, shading just 20% of a single PV module can reduce the power output of the string by the full power rating of the partially shaded module.[12] At large-scale PV plants, PV modules are often installed in a portrait orientation such that when vegetation grows tall enough to cause irregular shading across the entire bottom edge, all bypass diodes are activated, potentially reducing the power output of the array to nearly zero. Over time, failed bypass diodes can lead to hot spots, which pose safety concerns.

  Additionally, vegetation can interfere with single-axis tracking structures which incorporate mechanical components such as motors, drive arms, and pulley systems to change the orientation of the PV array and follow the sun throughout the day. Power and control equipment to support the trackers is typically installed under the PV arrays throughout the plant. Vegetation should be managed so that leaves and stems do not become entangled within the system and cause premature failures or dislocation of components.
- *Fire Risk.* Overgrown vegetation around equipment and surrounding areas can increase risk of fire in the event of an arc flash incident and increase the risk of equipment damage in the event of a fire.† Removing dry vegetation below arrays can both help prevent fire events entirely and minimize fire-related damage.

Figure 3. Current Flows of Normal, Fully Bypassed, and Partially Bypassed PV Modules



Regionality

Regional climate, local weather, equipment design and configuration, and vegetation type affect vegetation growth and maintenance strategies. In regions with high levels of rainfall and sunlight, frequent mowing and continual monitoring and control may be required.‡

PV facilities in arid regions receiving less than 10 inches of rainfall each year often utilize a "zero-vegetation" approach. Ground cover is composed of existing sand,

† An arc flash is a rapid release of light and heat from a high-power electrical system that is produced as part of an electrical explosion or discharge known as an arc fault. It is caused by such events as unintentional shorting or equipment malfunction.

‡ PV facility managers across the Southeastern U.S. have noted the need for as many as 12 annual mowing events for vegetated solar facilities in their region, while facility managers in northern states, with similar precipitation levels, have reported as few as three mowing events per year.

gravel, or other construction aggregates, and vegetation growth is often sporadic and scattered. In these areas, herbicides are often preferred over mowing or trimming to prevent projectiles from damaging equipment and personnel. No-growth strategies have been justified at some PV plants to protect workers from venomous snakes and terrain undulations, which can limit line of sight to potential hazards. Allowances for use of herbicides in these locations can be considered by local AHJs and addressed in local ordinances and permitting requirements. The lack of vegetation coupled with heavy rains during the Southwest monsoon season (July-August) can cause major stormwater and erosion control challenges.

Solar equipment designs and plant configurations can impact the propensity of vegetation growth and the ability to manage it. For facilities with low-angle, fixed-tilt racking structures, the spacing between rows of PV modules can be as little as 6-8 feet, creating access challenges for mowing equipment and increasing the risk of equipment damage. Some single-axis trackers have mechanical components that are installed perpendicular to the rows of PV modules, preventing mowing equipment from making a single pass down the row and requiring the equipment operator to "reverse out" before accessing the next row. Cable trays, above-ground conduits, and wire management solutions that span across rows create similar access issues that reduce mowing efficiency. Meanwhile, increasing deployment of transparent bifacial PV modules is poised to introduce vegetation management challenges caused by more light passing through the modules to the area beneath the array. Local communities can encourage use of hardware and plant configurations that support vegetation management goals through local ordinances and special use permits if desired.

Vegetation management strategies also depend on vegetation type. Engineering drawings submitted for construction permits typically specify a site's vegetation. To reduce upfront costs, the civil design of PV plants, including seed mix and seeding rate specifications, are often based on temporary and permanent ground cover recommendations provided by state or federal agencies that issue stormwater management permits. But these seeding recommendations do not tend to consider the type of land use or equipment configuration of a PV plant, and can lead to the selection of tall-growing plants that require long-term mowing maintenance. State agencies, such as the North Carolina Department of Environmental Quality, offer guidelines with minimum requirements for revegetating construction sites of all types. Local AHJs could pursue local ordinances to require seeding plans specific to solar facilities to reduce fire risk or address other vegetation management concerns.

Photo by Merrill Smith, NREL, 000077_153180_492606_4578

Vegetation Control Methods

There are several methods for controlling vegetation at PV plants. Common approaches include physical controls such as mechanical mowing or manual trimming, chemical controls in the form of selective and non-selective herbicide applications, and biological controls such as livestock grazing and weed seed predation — a method that introduces birds, insects, or rodents to consume or damage the seeds of unwanted weeds.

Determining the appropriate timing of vegetation management activities is an important consideration for solar developers. Time-based vegetation management plans are common, but these plans may unintentionally promote over- or under-management of vegetation that can lead to additional maintenance costs or lost power generation, respectively. As the pressure to reduce operating costs at solar facilities grows, active monitoring of vegetation — routine inspection of areas within a solar plant where vegetation is managed using repeatable methods to detect the presence of weeds, their quantity, and damage to plant equipment — is increasing in importance.[13] Active monitoring assesses the need for action by first identifying problematic vegetation, then determining the likelihood of negative impacts, and finally developing the best management strategy for the site.[14]

Local governments can require timelines for establishing specified vegetation measures to address stormwater and erosion risks and restore habitat, while considering seasonal or other constraints. For example, it may not be possible to establish groundcover during winter months in northern climates. The timing of maintenance could also be addressed through requirements at the local level to support habitat development. For example, mowing while vegetation is in bloom could negatively impact pollinator species.

An Integrated Vegetation Management (IVM) strategy for solar facilities implements science-based, species-specific management and combines multiple practices to increase the effectiveness of undesirable vegetation suppression. IVM principles, which have evolved since the 1990s, are based on well-established Integrated Pest Management (IPM) practices developed for the agricultural industry.[§]

In IVM strategies for solar facilities, the pests are weeds and undesirable vegetation. IVM programs aim to implement strategies that deliver exceptional technical and economic performance, improve environmental sustainability and biodiversity conservation, and support positive community perceptions of clean solar power generation facilities. Vegetation establishment is addressed in stormwater and erosion control permits, which typically require roughly 80% groundcover. In some cases, local agencies are involved in managing the permit and inspection process for such permits. While not common, submission of an IVM or IPM plan could be a permitting requirement.

IVM makes use of a wide variety of control methods and promotes limiting the use of broad-spectrum herbicides by first employing other control methods and using selective herbicides in a targeted manner.[15] An IVM strategy may involve controls, such as seeding with low mature-height vegetation, and modifying soil inputs and PV array spacing. It may also include using certified seed mixes, intentionally removing undesirable vegetation from the site, and aligning planting of permanent seed mixes with favorable weather.

To encourage sustainable vegetation management practices at local solar plants, communities may consider promoting the use of IVM strategies by solar project owners. This could potentially be achieved through a special use permit or other local ordinance. Table 2 lists key features of successful solar IVM programs.

Co-Located Solar and Agriculture

Solar development is sometimes viewed as competing with agriculture and conservation, creating potential conflicts over land use. However, opportunities are emerging to develop solar facilities that co-locate solar energy and agriculture, including integration of pollinators (e.g., beekeeping), livestock grazing, or crops. While still a relatively new area, "agrivoltaics" can potentially mitigate land competition by providing business opportunities to small local producers. Such sites may also support conservation goals, such as protection of habitat,

Table 2. Key IVM Program Components

Program Feature	Components
Planning	• Specification of ideal vegetation in engineering phase • Assessment of current site conditions and creation of site-specific plans • Involvement of experienced vegetation subject matter experts • Clear understanding of which vegetation is supposed to be established
Sustained Monitoring	• Implementation of remote monitoring or imaging to identify when management and control is needed • Plan for documenting vegetation establishment successes and failures
Incorporation of Appropriate Tools & Techniques	• Avoidance of broad-spectrum herbicides when possible • Employment of cultural, biological, and physical controls
Periodic Adjustment of Vegetation Management Plan	• Expected modification of plans based on monitored failures and successes • Creation of knowledge feedback loop to inform design/engineering phase

§ IPM is the practice of preventing or suppressing ecologically and economically damaging pest populations using a strategy that combines multiple control tactics. The goal of IPM is to implement science-based pest management that considers pest biology, environmental data, and technology to suppress damaging pest populations in a way that minimizes costs as well as risks to people, the environment, and property.

biodiversity, water quality, and soil erosion. Community zoning ordinances can help to encourage developers to pursue solar projects that incorporate agriculture.

Vegetation Management Guidance for Communities

Local government planning and zoning bodies can pursue local ordinances or special use permits to specify vegetation management approaches and practices; however, this is not common practice today. For municipally-owned plants, local governments can take a more active role in dictating vegetation management approaches that recognize climate and weather patterns, local vegetation types, PV plant configurations, and the tradeoffs of time-based maintenance versus active monitoring activities. Moreover, physical, chemical, and biological controls can be designated that balance upfront and ongoing investments with hard and soft benefits. Communities can encourage sensible vegetation management practices in several ways:

- *Revised permitting requirements.* With each electric code change, permitting requirements should be updated to support compliance with the latest safety requirements.
- *Plant design.* While not common, in some instances it may be appropriate to require or encourage use of equipment and plant configurations that support local vegetation management and safety goals. For example, the array height or wire management method could be specified during project development to reduce wildfire risk.
- *Vegetation type.* Local governments can require appropriate regional native seed mixes that help restore ground cover and avoid soil erosion issues. Native vegetation also provides pollinator habitat and other ecosystem services. State voluntary scorecards are the most common method for encouraging use of native seed mixes.
- *Agrivoltaics.* While a relatively new concept, agrivoltaic plants that incorporate crops, livestock grazing, or pollinators can be encouraged through zoning modifications.
- *Integrated Vegetation Management.* While not common, communities could require use of IVM or IPM at solar plants to specify vegetation control methods. Region- and site-specific circumstances should be given consideration. For example, it may not be practical in arid climates to establish vegetation or there may be risks to site personnel.

Realizing Opportunities through Integrated Vegetation Management at Solar Sites

A properly implemented solar IVM program can furnish communities (and plant owners) with several economic and environmental benefits that bolster the approach's attractiveness. To wit:

- Appropriately selected and established native wildflower seed mixes can improve a site's visual aesthetics, provide critical habitat — including pollinators — for vital insects and foraging animals, and provide ecosystem services like crop pollination in areas surrounding the solar facility.
- Applying IVM techniques can reduce the overall cost of electricity generation through enhanced plant performance and avoidance of unnecessary maintenance for stormwater management and mowing. It can also reduce fire risk, improve safety for site workers, and minimize damage to equipment.
- IVM concepts can promote rich educational opportunities at the nexus of technology and the environment. Combining agriculture within solar facilities can offer additional revenue streams that help offset operating costs while increasing the economic productivity of the land.[16]

Recommended Resources

- **[Solmart, *Solar Energy: SolSmart's Toolkit for Local Governments*]**

  SolSmart has published a comprehensive online roadmap for local governments seeking to expand solar development. It includes sections on stakeholder engagement; planning, zoning, and development; codes, permitting and inspection; and much more.

- **SolSmart webinar, "Planning and Zoning Best Practices for Large-Scale Solar"**

  This recorded webinar covers ways to provide maximum siting options for ground mount solar projects while preserving your community's character and historic resources. Learn about the development standards that can be used to ensure large-scale development creates agricultural, vegetative, environmental, and water quality co-benefits.

- **SolSmart webinar, "Best Practices in Solar Planning and Zoning"**

  This recorded webinar addresses best practices for including solar in land use plans and your community's zoning ordinance.

- **Megan Day, "Are You Solar Ready? Seven steps to successfully manage large-scale solar development," *Planning*, March 2020**

  An overview of how local governments can lay the groundwork for large-scale solar development, including how communities can integrate solar energy into their planning and zoning processes; lay out a path forward for solar PV projects; and respond to public concerns.

- **National Renewable Energy Laboratory (NREL), PV-SMaRT Project**

  The Department of Energy-supported Photovoltaic Stormwater Management Research and Testing (PV-SMaRT) project, led by NREL, is developing and disseminating research-based, PV-specific resources and best practices for stormwater management and water quality at ground-mounted PV sites. This ground-breaking research could reduce solar costs by avoiding unnecessary installation of stormwater infrastructure where appropriate and provide a scientific foundation for applying vegetative cover as green infrastructure to help communities and states meet water quality goals.

Notes

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