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Forage as Vegetative Cover for Utility-Scale Solar in Ohio

Farm Energy Fact Sheet Series

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The Midwest has seen an increase in photovoltaic (PV) solar energy production over the past several years. Nowhere is this more evident than in Ohio. Traditional ground cover options for utility-scale solar projects includes stone, gravel, bare earth, and various types of turfgrass vegetation. However, as the buildout of utility-scale solar projects increases, many are exploring the feasibility of dual land-use strategies that incorporate agricultural and conservation practices with solar production. Popular examples include pairing solar production with specialty vegetable crop production, livestock grazing, and pollinator habitats. However, as the size of utility-scale projects in Ohio has evolved from 100- to 200-acre projects into projects that are 2,000 acres or more, widespread integration of these practices faces real, common challenges:

- Growing specialty crops is labor intensive, requiring access for many people within the utility-scale solar site.
- Raising livestock requires massive herds, frequent watering, and additional fencing to rotate the animals.
- Creating pollinator habitats requires expensive seed mixes and the control of noxious and invasive weeds.

This fact sheet provides developers and landowners information about alternative vegetative cover strategies—including forage crops—that prevent greenwashing opportunities while also offering legitimate benefits to the landowner and the solar developer over the project lifecycle. Topics include common vegetative cover strategies and how cool-season forage crops can provide the greatest environmental, social, and economic benefit. This fact sheet also summarizes the requirements of utility-scale solar vegetative cover, species selection, establishment, and site maintenance.

Solar Industry in Ohio

The Solar Market Insight Report 2020 Q2 estimates more than 80 gigawatts of utility-scale PV solar capacity additions are expected nationwide by 2025 (Wood Mackenzie 2020). Based on the average total direct land requirement for utility-scale PV solar project development of 7.9 acres per megawatt, it would take roughly 526,666 acres to develop

80 gigawatts (DC) of utility-scale PV solar across the United States. (Ong et al. 2013). The U.S. Office of Renewable Energy and Energy Efficiency defines utility-scale renewable energy projects as 10 megawatts or larger (USDOE 2020). However, this is not always an accurate definition, as there are now examples of projects larger than 10 MW that are installed behind the meter to serve individual business or industrial loads. This fact sheet defines a utility-scale solar project as a solar electric generation facility that is interconnected to the distribution or transmission grid, supplying an off-taker (usually a utility with a power purchase agreement) with the energy generation (Figure 1).

Figure 1: Utility-scale solar project under construction in northwest Ohio. *Photo: Eric Romich*

Over the past decade, Ohio has experienced considerable growth in PV solar development. In 2010, Ohio had 150 solar projects certified with the Public Utilities Commission of Ohio. Certifications grew to more than 2,895 projects in March 2021. Prior to 2020, most solar projects in Ohio were small projects located on homes, farms, and businesses. In fact, between 2010 and 2020, certified solar projects totaled 2,895 in Ohio, which yielded a combined installed capacity of 513 megawatts, or an average of 47 megawatts of capacity additions per year. While small scale behind-the-meter solar project development is expected to continue, significant growth is also projected for utility-scale solar projects. As of March 2021, there were 35 utility-scale PV solar projects submitted to the Ohio Power Siting Board, representing over 6,395 megawatts of potential electric generation capacity (Figure 2). Combined, these 35 utility-scale PV solar projects represent a footprint of over 60,000 acres of land to support the planned solar development in Ohio (Ohio Power Siting Board, 2021). Based on the amount of land leasing activity throughout the state, it is obvious that additional projects are currently under development and that more utility-scale solar projects will likely be submitted for review.

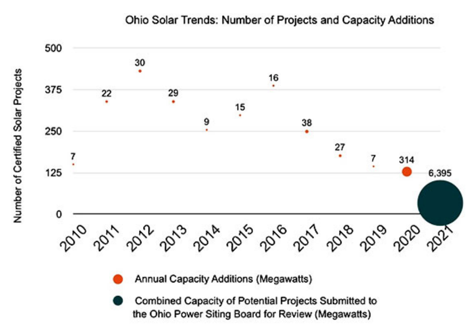

Figure 2: Ohio solar trends: number of projects and capacity additions.

Community Concerns

Although solar energy is green and renewable, it is not without conflict. When it’s compared to other energy sources, PV solar technology has a lower power density, which is defined as the amount of energy per unit volume. But power density can also be defined in other ways based on the technology application. According to Power Density Primer: Understanding the Spatial Dimension of the Unfolding Transition to Renewable Electricity Generation (Smil 2010), power density is the rate of transfer of energy per unit of horizontal surface area of land or water, expressed as a ratio of watt per square meter (W/m2). Due to the low power density of PV solar, utility-scale PV solar projects require large tracts of land, often involving thousands of acres. And while a utility-scale PV solar facility is often referred to as a temporary land-use conversion, they often include terms with an overall lifespan of 40 years or more. In addition, establishing a utility-scale PV solar facility may take an existing agricultural or forested land out of production and resuming such operations in the future will be a challenge (Coffey 2019). Due to the overall size and length of these projects, common concerns from landowners, neighbors, and community members are often related to impacts on the land, such as subsurface drainage, surface erosion, loss of wildlife habitats, and long-term soil health. The vegetative cover selected for a utility-scale PV solar development is a key component in solving these issues.

Characteristics of Utility-Scale Solar Vegetative Cover

Identifying a vegetation cover that minimizes the land use impacts can provide benefits to solar developers, project owners, landowners, and neighbors. For example, vegetative seed mix options can lower project installation and maintenance costs while providing wildlife and pollinator habitat, minimizing runoff, adding soil organic matter, and preventing the loss of soil carbon sequestration capacity. The challenge is identifying the seed mix that provides the desired benefits while meeting the performance needs of the solar developers. Solar developers are often contractually obligated to meet criteria outlined in a power purchase agreement with an entity that will buy the electrical generation from the project. As a result, developers are hesitant to adopt new vegetative cover practices that add liability and/or lower electricity production. For example, utility-scale solar developers are interested in seed mix options that are cost competitive, lower ongoing maintenance costs, and that control weed growth. It is essential that the seed mix cultivates low-height plants that will not exceed a height of 18 to 24 inches and that can thrive in low sunlight conditions underneath the PV solar modules. Utility-scale solar projects are industrial electric generation facilities with many tight spaces and obstructions. The vegetative cover must account for the limited ability to use large machinery to maintain the site.

Current Seeding Trends in the Midwest

Vegetative cover options typically used in the Midwest are turfgrass or pollinator plantings. These may include various types of plants including grasses (e.g., Kentucky bluegrass), legumes (e.g., clovers), and forbs (e.g., wildflowers) in various combinations. In Ohio, the most commonly utilized species are cool-season plants. Regardless of the vegetative cover chosen for the site, periodic maintenance to remove excessive growth is required. Turfgrass requires frequent mowing to maintain the appearance of a lawn. Pollinator mixes require mowing at the end of the growing season to self-seed and remove excess biomass. Depending on the goals of the developer, the design of the system, and the siting regulations, the cover that is best suited to the site could be a pure seeding of one plant species or a diverse mix of many.

Turfgrass plantings usually consist of pure grass species and provide excellent ground cover but do not fix nitrogen. A pure turfgrass stand does not provide food or habitat for pollinators such as bees and butterflies. Turfgrass varieties are not developed for animal consumption and should not be used as animal feed. In Ohio, it is best to use mixes that include cool-season grasses such as tall and fine fescues, perennial ryegrass, and Kentucky bluegrass (Sherratt, Street, and Gardner 2017). These mixes are low growing and tolerate frequent mowing. Mature tall fescue can reach heights between three to four feet, while mixes of fine fescue, perennial ryegrass, and Kentucky bluegrass reach two to three feet if left unmowed.

Pollinator mixes may provide adequate ground coverage and excellent benefits to pollinators but typically have more plant species per mix than other vegetative covers. These mixes also include a variety of annual and perennial species. Mixes typically include varieties of clover, coneflowers, milkweeds, various other wildflowers from the Aster family, and some grasses. To achieve maximum pollinator benefit and maintain season-long appeal, select a variety of species that flower at different times throughout the growing season (Ellsworth 2015). It is best practice to utilize mixes that include species native to the region. Maintenance height of these stands varies greatly depending on the selections. Warm-season grasses that thrive in Ohio's climate typically do not satisfy developers' height thresholds (Sulc, Barker, and Tilmon 2017) and therefore are not discussed in this fact sheet.

Figure 3: Unmowed cool-season pasture mix in early spring that includes tall fescue, orchardgrass, and reed canarygrass (April 10, 2019). *Photo: Christine Gelley*

The standard expectations for turfgrass systems are that they require frequent mowing and significant consumption of energy and investment to maintain an appealing aesthetic while providing limited benefit for the surrounding ecosystem. For pollinator plantings to successfully maintain long-term ecosystem benefits, mowing should be avoided until after the peak growing season when flowering has subsided. However, weed populations may thrive under the same conditions. In naturalized prairies the most effective method for biomass removal and weed control is prescribed fire (NRCS 2020; ODNR 2021). When fire is not feasible, spot spraying with herbicides is most effective. When neither are employable, hand pulling weeds is required as a last resort. Preventing the establishment of noxious and invasive weeds is critical for the site manager and surrounding landowners. Control of problematic weeds is a severe challenge in pollinator stands and is legally required to preserve environmental health (Hall 2018; Ohio Administrative Code 901:5-37-01; Ohio Revised Code § 731.51 to § 731.53).

Other options for vegetative cover also offer soil stabilization, carbon sequestration, pollinator value, and marketable products. Ohio and neighboring states are investigating cool-season pasture mixes as an option. Depending on the scale, panel height, alley spacing of the solar site, and local siting regulations, these plantings could either be intensively grazed by sheep or harvested for hay (American Solar Grazing Association 2019).

Cool-Season Pasture Mixes

Cool-season pasture mixes offer a mix of legume and grass varieties. Cool-season grasses and legumes can be utilized for their abundant ground cover, pollinator benefits, and livestock forage. Legumes also fix additional nitrogen for plant uptake. Cool-season pasture mixes grow in the spring when soil temperatures reach 45–50 degrees Fahrenheit, typically during April and May in Ohio. Cool-season grasses perform best when air temperatures are between 65–75°F and growth declines when summer temperatures rise over 80°F (Oregon State University 2021). In Ohio, this slump usually comes between June and August, but these grasses return with a second growth spike in the late-summer and early-fall when temperatures begin to decline again (Sulc, Barker, and Tilmon 2017). Normally, pasture mixes consist of perennials that enter dormancy during the winter months and continue growth in the spring. Therefore, a cool-season perennial mix can provide year-long ground coverage.

Figure 4: Unmowed pasture of tall fescue in late spring (May 31, 2019). *Photo: Christine Gelley*

Some cool-season grass species that typically perform well in Ohio include Kentucky bluegrass, tall fescue, meadow fescue, orchardgrass, perennial ryegrass, and meadow fescue. Some cool-season legumes include alfalfa, birdsfoot trefoil, and many species of clovers. Mixes with alfalfa, birdsfoot trefoil, perennial ryegrass, Kentucky bluegrass, and most clover varieties reach mature heights of around three feet, while mixes with orchardgrass and tall fescue can be up to five feet tall if left unharvested during late spring when plants produce seed heads (Sulc, Barker, and Tilmon 2017). As illustrated in Figure 3 through Figure 5, the selection of species variety and scheduled mowing throughout the growing season is important to maintain a desired grass height of 18 to 24 inches that keeps the vegetation below the front of the solar panels. Pasture mixes require two to four harvests per year to keep grass height below the solar panels, while also maintaining forage with nutritional value for livestock consumption.

Figure 5: Recently mowed cool-season pasture mix in early summer that includes tall fescue, orchardgrass, and reed canarygrass (June 4, 2019). *Photo: Christine Gelley*

Similarities and Differences Among Seed Mixes

Although the species names listed in forage mixes may be the same as listed for turfgrass seed or pollinator mixes, there are distinct differences among the varieties best suited for each purpose. Turf type seed is selected to be resistant to mowing and foot traffic. The most used turf type grass is KY 31 tall fescue, which contains a fungal endophyte that improves the stress tolerance of the plants, but also produces compounds that are toxic to grazing livestock in high concentrations. Therefore, turf type seed should not be used for forage fed to livestock. Pollinator seed is selected to provide nectar and pollen throughout the growing season. Forage type seed provides the best nutritional value for livestock and is easy to harvest. The cost of seed mixes varies greatly depending on the varieties included. Due to the increased labor and technology associated with creating and distributing mixed seed, the cost per pound increases when the diversity of the seed increases. Labor to maintain the site also increases due to variability between needs of each plant type. Each vegetative cover mix contributes benefits and challenges to providing soil cover in the solar field. The best cover option depends on the long-term maintenance plan and the priorities of the community where the site is located.

Cool-Season Pasture Species to Consider

When choosing the appropriate seed mix, site managers should consider the soil type, pH, prior crop history, and shading of the stand to select species that will thrive on location for the long term. The seed mix should provide uniform site coverage, be maintained below the height of the panels, and provide secondary benefits including improving soil health, carbon sequestration, and adding value to the community as a habitat for wildlife or as feed for livestock. All of the forages recommended in Tables 1 and 2 are perennial, cool-season forages with good to moderate shade tolerance.

Table 1: Ohio Perennial Cool-Season Grasses

Attributes	Max. Growth Height (ft.)	Tolerance to Acidic Soils	Seeding Rate (lb./ac.) & Depth (in.)	Environmental Stress	Frequent Defoliation Tolerance	Ease of Establishment
Kentucky bluegrass *Poa pratensis*						
Long-lived, short-growing, sod-forming grass	3.5 ft.	Medium	16 lb./ac. ¼–½ in.	Good	Good	Good
Meadow fescue *Schedonorus pratensis*						
No alkaloid problem from endophytic fungi	3.5 ft.	Medium	16 lb./ac. ¼-½ in.	Good	Good	Good
Festulolium *Festulolium Asch. X Graebn*						
Hybrid cross of four potential grasses, with varieties available for different growing conditions	3.5 ft.	Medium	25 lb./ac. ¼-½ in.	Fair	Good	Excellent
Perennial ryegrass *Lolium perenne*						
Best suited for the northern half of Ohio	3.5 ft.	Medium	24 lb./ac. ¼-½ in.	Fair	Excellent	Excellent
Orchardgrass *Dactylis glomerata*						
Choose late-maturing varieties to help manage	4 ft.	Medium	10 lb./ac. ¼-½ in.	Good	Fair	Excellent

aggressive spring growth						
Smooth bromegrass *Bromis inermis*						
Later maturing than orchardgrass	4 ft.	Medium	16 lb./ac. ½ in.	Good	Fair	Good
Timothy *Phleum pratense*						
Late maturing Best suited for the northern half of Ohio	4 ft.	Medium	8 lb./ac. ¼-½ in.	Poor	Fair	Good
Novel enophyte tall fescue (NE+) *Schedonorus arundinaceus*						
Novel endophyte tall fescue, has an endophytic fungus present that does not cause animal health issues and is ideal for animal feed use	4 ft.	High	15 lb./ac. 1/3-½ in.	Excellent	Excellent	Good

Table 2: Ohio Perennial Cool-Season Legumes

Perrenial Legume Forages for Consideration	**Max Growth Height (ft.)**	**Tolerance to Acidic Soils**	**Seeding Rate (lb./ac.) & Depth (in.)**	**Environmental Stress Tolerance**	**Frequent Defoliation Tolerance**	**Ease of Establisment**
White clover *Trifolium repens*	1 ft.	Medium	5 lb./ac. ¼-½ in.	Excellent	Excellent	Excellent
Red clover *Trifolium pratense*	3 ft.	Medium	11 lb./ac. ¼-½ in.	Good	Good	Excellent
Alfalfa *Medicago sativa*	3 ft.	Low	15 lb./ac. ¼-½ in.	Good	Good	Good
Birdsfoot trefoil *Lotus corniculatus*	3 ft.	High	9 lb./ac. ¼-½ in.	Excellent	Good	Poor
The information in tables 1 and 2 is referenced from: Sulc, Barker, and Tilmon 2017; Lacefield et al. 2000; and Van Sambeck et al. 2007.						

Site Preparation, Seed Establishment, and Maintenance

Follow recommendations for forage establishment as provided in the *Ohio Agronomy Guide*, Chapter 7 (Sulc, Barker, and Tilmon 2017). Complete all soil tests and adjustments prior to seed selection and planting. Choose seed that is adapted to the growing site; has a high percentage of pure live seed, good germination rate, and low weed seed content; and comes with the proper inoculant for legume crops. After construction is complete, the planting site should be prepared so it is smooth, firm, and free of weeds. If this cannot be accomplished by the preferred seeding date, delay planting until good conditions are attainable both for the site and for the seed and in the appropriate seeding time frame. Conventional tillage, reduced tillage, and no-till planting methods can all be successful for establishing forages. Calibrate the planting equipment to seed at the appropriate rate and depth depending on the composition of the seed mix (Duiker et al. 2013).

Seeding too deep and weed competition in the first six weeks after planting are common causes of stand establishment failures. Allow at least two months of growth before first harvest of the crop. Delaying defoliation allows time for critical root development. Properly planted and maintained cool-season grass-legume forage mixes should produce two to three hay harvests per growing season. Soil tests should be taken every three years and fertilizer applications should be performed according to *Tri-State Fertilizer Recommendations* (Culman et al. 2020) based on the laboratory tests. Monitor the stand for weed encroachment, disease, and harmful insects. Consultation on forage pest threats can be assessed through Ohio State University Extension and the Ohio Forages website (https://forages.osu.edu). Depending on environmental and managerial pressures, forage stands may require overseeding or reseeding to maintain the desired mixture from year to year.

Anticipated Challenges

Limited information is available to guide the successful establishment and management of vegetative cover in solar fields. The Ohio State University College of Food, Agriculture, and Environmental Sciences is currently conducting research that addresses the following uncertainties:

- how to adjust seeding rates
- how spacing between solar panels impacts growth rates and forage quality
- how soil type variations impact plant growth and persistence

A fundamental challenge to realizing the economic benefit of a cool-season forage system within a solar field is related to panel spacing limitations and system layout designs. The solar field’s design and panel spacing can prevent access and safe operation of the equipment required to rake, bale, and load out the harvested bales on trailers, or the safe and efficient operation of grazing livestock. Recognizing these challenges, simply establishing a cool-season forage ground cover and allowing the biomass to remain on site provides immediate environmental benefits and promotes long-term soil health. Additional research and ongoing communication between agricultural producers and solar developers must continue to aid in the development of technical advice on successful implementation of these practices in Ohio.

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