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Considerations for

“Grazing-Ready” Solar Facilities Planning for Integration of Sheep

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Considerations for "Grazing-Ready" Solar Facilities
Planning for Integration of Sheep

Prepared for:

New York State Energy Research and Development Authority

and

The New York State Agricultural Technical Working Group (A-TWG)

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Abstract

These considerations support integration of design and construction elements at the facility planning and design stage to help promote "grazing-ready" site conditions that enable integration of grazing at any point in the lifespan of a solar facility. The guide is intended to help to educate the solar development community, substantiate co-location of sheep grazing with solar, and encourage discussions among the farming and solar development communities to expand farmer involvement in agrivoltaics.

Keywords

Solar, agrivoltaics, agrophotovoltaics, agrisolar, solar sharing, PV agriculture, agri-PV, dual use, co-utilization, co-location, sheep grazing, solar design, agriculture, AgPV, AGV

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1. Background

The growth of renewable energy generation, and solar photovoltaics ("solar") in particular, is a significant component of New York State's need to comply with the Climate Leadership and Community Protection Act (Climate Act) mandate to achieve 70% renewable energy by 2030. New York State continues to identify opportunities to advance solar development in a manner that considers and supports the State's agricultural sector and communities. One potential avenue is through agrivoltaics, "a simultaneous use of land for solar photovoltaic power generation and agricultural production of 'crops, livestock, and livestock products' as that phrase is defined by Agriculture & Markets Law (AML) §301(2)" (NYSERDA 2023). To build on demonstrated successes of projects that integrate sheep grazing within solar facilities, the Agrivoltaics Specialist Committee of the Agricultural Technical Working Group (A-TWG), an independent advisory body to the State of New York convened by the New York State Energy Research and Development Authority (NYSERDA), recommended development and dissemination of grazing-ready solar facility design considerations to a broad group of stakeholders.

NYSERDA engaged Agrivoltaic Solutions, LLC and WSP USA to identify recognized design and construction practices that support safely and securely hosting grazing animals at solar energy facilities. Integration of these elements at the facility planning and design stage can help promote "grazing-ready" site conditions that enable integration of grazing at any point in the lifespan of a solar facility. NYSERDA hopes this guide will:

- Help to educate the solar development community and substantiate co-location of animal agriculture with solar
- Support solar developers seeking to implement livestock co-utilization strategies within the NYSERDA Smart Solar Siting Scorecard[1] included within NYSERDA's Large-Scale Renewable Tier 1 Program solicitations
- Encourage discussions among the farming and solar development communities, and expand farmer involvement in agrivoltaics.

This guide focuses on the planning and design phase of new solar facilities ranging from 1 to 20 megawatts of alternating current (MWac) electric energy generating capacity and ranging from 5 acres up to approximately 120 acres in project scale. **Content is limited to facility planning and design considerations for hosting small ruminants, specifically sheep, and does not cover management of all grazing livestock.** Future iterations of this document may expand consideration to other types of grazing livestock. Further information on the management of grazing animals can be found through Cornell University Extension and the American Solar Grazing Association, among others (section 11 Additional Resources). A grazing management plan, including site-specific standards for daily management and operations, is developed at a later project phase by the solar developer; engineering, procurement,

[1] NYSERDA RESRFP-1 Appendix 2. Smart Solar Siting Scorecard (page 14)

and construction (EPC) contractor; and operations and maintenance contractor, in collaboration with the farmer/flock manager servicing the solar facility. It will be important at that later phase for collaborators to clearly delineate where responsibilities lie for maintenance activities (e.g., maintenance of an installed well, vegetation management outside of grazing periods, etc.).

This guide is informed by Agrivoltaic Solutions' experience contracting managed sheep grazing within solar facilities in the Northeast, and input from the members of the A-TWG Agrivoltaics Specialist Committee, as well as external review by key stakeholders. Contributors and reviewers recognize that co-use strategies for simultaneous energy and agricultural production are still evolving, and that design considerations are subject to revision as best practices continue to emerge, and as the scope and species of grazing animals that are co-located with solar energy generation progress. The guide is limited to the perspective of accommodation to sheep grazing activities and, for purposes of informing solar development and design, should be reviewed in concert with additional engineering, design, and required site management practices.

2. Solar Project Design and Grazing

Operations and maintenance costs are an important financial consideration impacting the economics of running solar facilities (Walker et al. 2020). Design changes to accommodate agrivoltaics may bring financial and non-financial benefits but may also disproportionately impact project costs. Therefore, such considerations are best explored early in the development cycle to establish budgetary cost estimates that can be revisited at appropriate development milestones.

The use of grazing sheep has emerged across the United States as a cost-competitive alternative to solely mechanical and chemical control of vegetation under solar panels, as grazing sheep requires minimal changes to common ground-mount solar configurations. Animal grazing can be an attractive option for communities that host solar infrastructure because it supports continued agricultural land use, aligns with sustainability mandates, and—when managed with sound grazing practices—sheep can perform as well as mechanical mowing equipment in both cost and efficiency. Solar facility operators do not generally need to adjust panel heights and spacing to integrate sheep grazing within a solar facility but may need to make other modifications to facility layout, design, and infrastructure to successfully host a viable grazing operation.

Managed sheep grazing is an established U.S. Department of Agriculture Natural Resource Conservation Service conservation practice that is recognized as foundational to ecosystem restoration by the New York State Department of Environmental Conservation (NYSDEC):

> *Controlled grazing by domestic livestock is a sustainable alternative to herbicide or mowing for control of invasive plants in natural areas. The use of sheep or goats to graze invasive plants can not only help meet [NYSDEC] goals of pesticide reduction but can also improve plant biodiversity and soil health. Grazing can be an effective substitute for mowing (especially in areas too steep to mow safely), while also reducing fuel costs, and minimizing plant litter and thatch. In areas with sensitive wildlife populations, managed grazing can be much safer for wildlife than mowing (NYSDEC n.d.).*

Furthermore, the use of prescribed sheep grazing within solar facilities helps to develop perennial vegetation and contributes to soil health (Amsili et al. 2020; NYSAGM 2023). Grazing allows for diverse plant, insect, and pollinator habitats, while improving soil stability by nurturing vegetation that helps. In addition to improving environmental outcomes, grazing sheep flocks at solar facilities can help New York farmers to realize new economic benefits (Kochendoerfer et al. 2019). The practice may lower the barrier of entry for beginning and underserved farmers and allow new farm businesses to contribute to the economy while improving the viability of their overall farm operation (Kochendoerfer and Thonney 2021).

3. New York State Considerations for "Grazing-Ready" Solar Facilities

These recommendations relate to ground-mount solar facilities in New York State ranging from 1 MWac to 20 MWac generating capacity and from 5 acres to approximately 120 acres. Facilities at the larger end of this range may, in general terms, accommodate flocks of between 300 to 400 sheep in the Northeast United States depending on forage growth conditions. Stocking rate, or the total number of sheep per acre over a year, is commonly between two and four sheep per acre at a solar facility in New York. Stocking density, or the number of sheep per acre at any given timepoint, can be many times this, depending on the management regime or grazing paddock size within a solar facility. It is recommended that a grazing plan which outlines the number and size of grazing paddocks, predicted stocking rates and rotation schedules is prepared and communicated between facility owners and grazing managers. While topics included herein are relevant to larger sites—and many of the considerations will still apply—solar facilities and sites larger than 20 MW and over 120 acres will require distinct design considerations for logistics and animal management that are largely not explored within this document (e.g., water delivery and associated labor will vary with larger flock sizes).

Size and stature of sheep varies and is dependent on breed and sex. There are approximately 60 breeds of domestic sheep common in U.S. production systems (Schoenian n.d.). These breeds stand between 37 to 54 inches at the top of the head and 31 to 47 inches tall at the shoulder. Sheep can duck under the lowest leading edge of tilted panels at solar facilities with panel edges as low as 24 inches from the ground.

3.1 Fencing

The facility perimeter fence (also referred to as the security fence) may be the most significant piece of facility infrastructure to a managed solar grazing system. In this case, recommendations for the design of solar perimeter fences are based on the planned co-location of an animal agriculture enterprise with renewable energy production. Fencing is foremost stipulated to contain and protect livestock (sheep) on the solar facility (NYSAGM 2020).

A secure, competently installed perimeter fence is the best first defense for a flock of sheep against natural and domestic predators (ASI 2021). If a facility fence is inadequate for grazing activities or has improper specifications, significant losses from predators may occur. Decisions related to fencing should involve the developer, EPC contractor, and sheep farmer/manager to ensure fences will best serve the intended grazers while meeting any additional standards and requirements.

Height

- The perimeter fence does not need to be higher than 7 feet to contain sheep.
- State and municipal regulations and codes should be reviewed to identify requirements related to fence height.

Common Fence Types

- "Fixed knot," agricultural woven wire, minimum 12.5-gauge thickness
- Chain link

Tensioning

- Woven wire fencing with fixed knots tying vertical and horizontal wires together to maintain the integrity of patterned openings from movement.
- Properly installed, high tensile woven wire fence should have sufficient tension to prevent animals pushing underneath the bottom edge to gain entry.
- Chain link fence may be installed with the twisted, wire-tied portion at the bottom to act as a predator deterrent (Figure 1). Additionally, it should have a bottom tensioning wire to achieve sufficient tension.

Figure 1.Chain Link Fence with Bottom Tensioning Wire and Additional High-Tensile Barbed Predator Wire

Source: Ely Valdez South Texas Curbing LLC, Solar Farm Services. Used with permission.

Bottom of Fence

- The gap between bottom of fence and grade should be as small as possible. The target should be a maximum 1.5-inch gap underneath the fence. Care should be taken to follow the ground contour as closely as possible.
- In areas where high predator pressure is known to exist, slightly burying the bottom of the facility fence below grade may be considered. Alternately, predator aprons or predator wraps may be used. Aprons are short sections of fence material installed laterally outward at the bottom of the fence to prevent predators digging underneath.
- As predator aprons present an additional project cost, project developers may wish to consult with a regional wildlife biologist and/or review predator studies to determine the need.
- The addition of one to two strands of 15.5-gauge barbed predator wire (with barbs at 5-inch intervals), may be installed to fill gaps at the bottom of the facility fence as a low-cost deterrent to predators.
- Use of livestock guardian dogs (LGDs) to help minimize predator risk may also be an effective mitigation strategy; however, employing LGDs in solar facilities is still relatively new, and requires additional planning and management considerations. Consultation with livestock and O&M experts is recommended if considering this approach.

Other Openings

Gaps in the perimeter fence such as culverts, ditch crossings, etc., should be patched with temporary fence material or steel “hog panel” type material in a manner not to interfere with the intended function of a culvert or ditch.

“Wildlife Friendly Fencing”

This type of fencing has an intentional 6-inch to 8-inch gap remaining between the bottom of the fence and the soil/grade or 8-inch openings within the vertical perimeter fence at intervals around the solar facility for wildlife passage. It is generally incompatible with sheep grazing securely. Given the opportunity, predators will use these openings to access the flock and harm the livestock.

- Tensioned, fixed knot woven wire fencing with 4-inch squares at the bottom, closest to the ground, will allow passage of small mammals, amphibians, and other fauna through the facility, while keeping larger predators out.
- Proper installation of a woven wire fence with smaller openings at the bottom and larger at the top is essential when planning for the protection of grazers (Figure 2).

Figure 2.Perimeter Fencing to Grade and Appropriate for Containing Sheep

Source: Agrivoltaic Solutions, LLC. Used with permission.

3.2 Exterior Gates

Exterior gates enable both facility access and passage for grazing animals between the fenced arrays. As flock size increases, gateway width becomes more important for the safety of animals and personnel.

Gateway Width & Style

- Gate style –should be double gates that are either swinging or rolling to open.
- 20 feet minimum opening. 24 feet is preferable.
- Gates sections should be installed with a 4-inch maximum tolerance between closed gates.

Grading

- Large gaps between the shoulder of the roadbed and the corners of the gateways should be avoided by grading the roadbed as squarely as possible as it passes through gateways.

Alignment Considerations

- Gates between separate fenced segments of the facility should be lined up, facing one another, when possible, to accommodate smooth movement of grazing animals from one fenced area to the next.
- Swinging gates should swing freely in both directions.
- Rolling gates should roll away from the center point in line with the perimeter of the fence line.
- The EPC contractor and quality engineer should verify the functionality of exterior gates before signing off as a completed project.
- The Developer/EPC contractor should verify gates are within locations that are part of the leased project area.

4. Facility Access

Grazed solar arrays require regular access for truck and livestock trailer traffic and deliveries of water and supplies. Overall roadway integrity, visibility, and room to turn and maneuver are key considerations. In most circumstances, the access roads of ground-mount solar facilities authorized by the permitting authority that are consistent with the applicable State and federal codes guiding access to electrical infrastructure are suitable for trucks pulling livestock trailers.

Facility Road

- Facility driveway should be at least 12 feet wide plus shoulder.
- The driveway should be constructed of compacted material and should not become unstable or soft during periods of wet weather.
- The driveway should provide the ability to turn a 40-foot truck and trailer, either with a cul-de-sac style turning area in the facility, a hammer head, or with a spur area branching off to the side.
- A trailer must have the ability to turn around without needing to back out into the public roadway to exit the facility.

5. Wiring

Competent wire and cable management is of paramount importance to the safety and long-term operation of a solar facility, particularly when hosting sheep within it (Figures 3 and 4). Poor wire management can lead to sheep entanglement, fatalities, equipment damage, among others. The wires and cables to focus on as it pertains to planning for sheep to be grazing within the array are those which are above ground and generally not sleeved in a fully enclosed conduit. Common examples of this are the wires connecting one solar panel to another, the wires/cables which connect a series of modules into a string/homeruns, bundles of homerun cables, among others.

Wire Control

- Wiring should be neatly tucked and secured, with no large loops or dangling members.
- Wires and cables that are less than 36 inches from the ground should be secured using the appropriate type of cable tie, clip, clamp, hanger and/or sleeve in accordance with the manufacturer's installation guide.

Raised Cabling

- Above-ground cable management systems on grazed solar facilities installed with 24 to 32 inches of clearance allows sheep to easily pass underneath without interference (Figure 5).
- With less than 24 inches of clearance, sheep may rub or push on the exposed wires/cables in the above-ground cable management system as they pass underneath.
- Consider options for heavier gauge CAB support cabling and hanger brackets in the long term to avoid issues from prolonged interaction with low-hanging cabling.
- When practical, appropriately burying cables is the most compatible strategy for wire control within solar facilities intended for grazing animals.
- When burying wire/cables, attention should be given to segregating topsoil from subsoil to preserve the topsoil needed to reestablish pastures; therefore, chain trenchers should not be employed. Additional guidance can be found within New York State Department of Agriculture and Markets Guidelines for Solar Energy Projects - Construction Mitigation for Agricultural Lands (NYSAGM 2019).

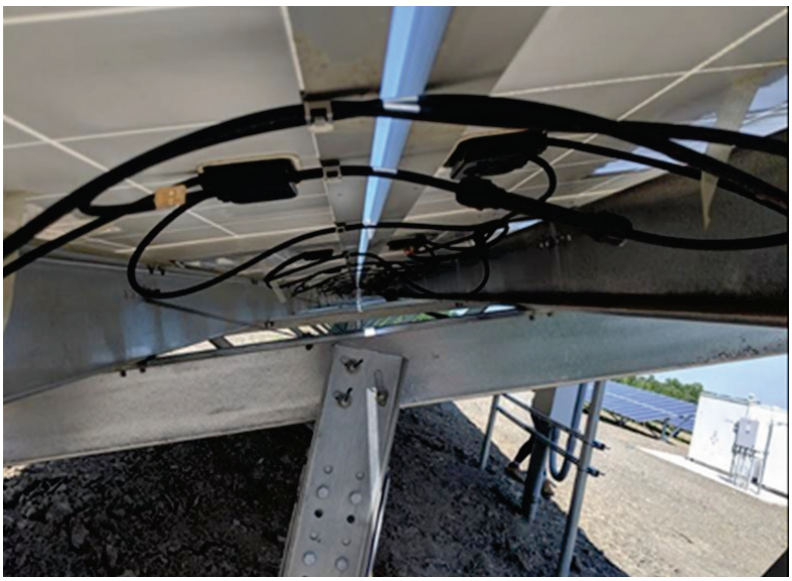
Electrical Access:

- Access to auxiliary 110-volt or 220-volt power for the servicing farmer/flock manager is helpful for powering fence chargers and tools.

Figure 3.Sheep Passing under Cable Management Systems

Source: Agrivoltaic Solutions, LLC. Used with permission.

Figure 4.Good Wire Management on Module-to-Module Connectors



Source: Agrivoltaic Solutions, LLC. Used with permission.

6. Racking

Sheep do not typically climb on equipment or chew on wires. At times they may rub against the racking. However, this generally has little impact on equipment. Racking should be reviewed to confirm that there will be no accessible sharp edges that could result in sheep injuries.

General Sheep Behavior around Racking

- Sheep can move under a low leading edge of panel, but as with cabling and wires, a leading edge of 24 inches or higher is preferred, particularly with fixed tilt racking (Figure 5).

Figure 5.Sheep Grazing a Fixed Panel System with Leading Edge >18 Inches

Source: C. Stovall, Hidden Mountain Farm. Used with permission.

7. Water

Sheep water consumption fluctuates with environmental conditions, but they require access to fresh drinking water at all times. They are selective about water quality and will avoid dirty or brackish water. It is critical that water access, location of troughs, and availability is considered during project planning and design. For this guide, it is assumed that sheep flocks are removed from the solar facility to another location during winter months when freezing and snowy conditions are prevalent.

Water Consumption

- Water requirements are seasonal and highly weather dependent. Peak consumption will be in the range of 5 to 10% of body weight for mature, open ewes and feeder lambs and more generally 1 to 3 gallons per sheep per day for mature animals (Meehan et al. 2021).
- Water can be delivered throughout the facility using above-ground flexible 0.75-inch to 1-inch poly water line.
- Water lines are best laid out along facility roadways or along fence lines and are easily drained to avoid freezing in winter. Water lines should be fitted with spigots at regular intervals to allow water tanks to be moved from paddock to paddock as the sheep move through the facility.
- Water can also be delivered to and around the facility in trailer-mounted tanks that move with the flock, which is a common and economical practice on smaller solar sites. Access to a high-volume water filling station is recommended for this approach.
- If feasible, a permanent on-site water source is preferable to trucking water to the site. This can be from an existing or new well, municipal hookup, farm pond, or spring development. Note, that there may be restrictions to installing waterline laterals in locally adopted, New York State certified Agricultural Districts, as well as implications for decommissioning. Consultation with NYSAGM will be required regarding new infrastructure installation subject to an Agricultural District Notice of Intent of Executive Law 94-c submissions.
- Solar-powered pressurized water systems can be practical and effective solutions for pumping water from remote areas of a solar facility.

Water Quality

- Facility retention ponds may be an acceptable pumping source in some circumstances, but it is important to note that sheep water needs are highest during dry periods, and this is often when pond levels are low and water quality deteriorated.

- Sheep should be fenced from having free access to ponds and other surface waters to avoid contamination. It is best when this is done with a permanent fence of the same material as the perimeter fence installed during the project construction phase.
- Temporary panels or portable exclusion fencing may be used post-construction by the servicing farmer/flock manager when surface waters are not protected by a permanent fence.

8. Other Exclusion Areas

Sheep are naturally curious, and while they do not pose a risk of damage to facility equipment pads, they often find them attractive places to gather and sleep. This can lead to manure accumulation on the pads and nuisance to service personnel.

Equipment Pads

- Equipment pads should be protected with permanent fence installed by the asset owner/solar developer.
- When a permanent fence is not already in place, simple exclusion fences of rigid, livestock panel, woven wire or mesh fencing placed around them with gates for technician access may be employed (Figure 6).
- Height and material can be 36 inches to 48 inches, as with other interior paddock fencing, or simple metal livestock panels may be set up to create an exclusion area.

Figure 6.Simple Exclusion Fence of Rigid Wire Panels and Metal T Post

Source: Agrivoltaic Solutions, LLC. Used with permission.

9. Handling Systems

Periodically corralling sheep and penning them into a small holding area is a fundamental part of good shepherding and critical to sheep health and welfare. Flock management tasks like vaccinations or health checks can easily be performed with a handling system.

Typically, handling systems consist of portable panels and chutes, which are temporarily installed in open areas within the solar array or in an adjacent open space outside the array as needed (Figure 7). It is also possible to allow for a more permanent dedicated area for installation of temporary structures to be provided at solar facilities. These areas should not interfere with the racking or other aspects of facility infrastructure and can be located off to the side in an otherwise unused area. Former laydown areas are sometimes appropriate for this application.

Figure 7.Mobile Handling System

Source: United Agrivoltaics. Used with permission.

10. Seeding

It is important to consider requirements for seeding and revegetation of the solar facility during the project planning and design stage. Plant species must satisfy the conditions of the Storm Water Pollution Prevention Plan, while the anticipated height of mature vegetation must be gauged in relation to maintenance of solar infrastructure and to prevent shading the panels. Finally, nutrition and potential toxicity must be accounted for when selecting plants that grazers are intended to feed from at the location.

Solar arrays are constructed on a wide range of soils and topography with mixed historical land uses. The goal of seeding a solar array with future grazing in mind is to create a nutritious and palatable blend of plant species that satisfies not only the needs for soil stabilization and storm water quality of the project, but is also productive and palatable to sheep. A diverse species mix will offer resiliency to varied weather conditions while maintaining compliance with vegetative cover requirements.

Forage species mixes should be comprised of a blend of grasses, legumes, and forbs. Some species that may be appropriate for storm water control, such as fescue (Festuca Poaceae) and ryegrass (Lolium perenne L), should be avoided as they are less palatable to sheep and may contain endophytes, which can be toxic. When fescue and ryegrass are to be used, they must be confirmed endophyte-free varieties. Further, the use of native and naturalized plant seed mixes and pollinator-friendly plants may be a conservation measure or a permit requirement. For all these reasons, it is recommended to work with land management professionals such as ecologists and established seed providers in order to carefully select and mix regional, native, and site-specific seed combinations to meet both stabilizing vegetation and grazing objectives.

11. Additional Resources

- Cornell Cooperative Extension, Agriculture & Food Systems
- The American Solar Grazing Association
- Small Ruminant Q & A
- The Nature Conservancy, Principals of Low-Impact Solar-Siting and Design (pages 4-5)
- Agricultural Best Management Practice Systems Catalogue, NYS Soil and Water Conservation Committee, February 2024

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