Catalyst Energy Wolf Hills Solar – Agricultural Integration Plan

Cat Reedy Solar, LLC

Washington County, Virginia

Prepared for:

Cat Reedy Solar, LLC

Prepared by:

Agrivoltaic Solutions, LLC
1827 Leicester Whiting Rd
Whiting, VT 05778
(802) 349-6597
https://agrivoltaicsolutions.com/

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Introduction

Catalyst *Energy Wolf Hills Solar, LLC has enlisted Agrivoltaic Solutions, LLC (AVS) to develop a plan for agricultural integration at the Wolf Hills Solar project (project), a solar facility to be constructed on approximately 1,575 fenced and grazeable acres in Washington County, Virginia.*

The mission of AVS is to further the solar grazing industry in the United States by facilitating grazing opportunities for local farmers, and consulting on agricultural integration planning for solar developers. AVS endeavors to continually drive innovation in on-site management practices. AVS has consulted on dual use on over 6 GW of projects in the U.S., and currently has 860 acres under management with a total flock of ~2,100 locally owned sheep deployed in 2024 (Figure 1):

Figure 1. Agrivoltaic Solutions, LLC Katahdin sheep flock grazing in Geneva, New York.

This report introduces and outlines planned agricultural integration measures to be taken at the Wolf Hills Solar Project, with a focus on managed sheep grazing. According to the recently released solar grazing census conducted by the American Solar Grazing Association (ASGA) [1], solar grazing in the U.S. is now being practiced on roughly 100,000 acres and employs in the range of 1.5% of the nation's sheep. This growth has been extremely rapid, and managed grazing on solar arrays has been the most widely adopted form of agricultural colocation by a wide margin. There are some key advantages held by sheep grazing that makes it stand out:

Ease of integration. Sheep grazing can be easily integrated into "conventionally designed" solar facilities, without major modifications to racking dimensions, row spacing, DC collection lines, etc. Many of the solar sites that are currently being grazed were not necessarily designed with grazing in mind. Of course, with a utility scale solar array, planning and civil design considerations must be undertaken to create a site that can be effectively and efficiently grazed, but these will not be changes that will significantly alter the site plans. With small stature and docile behavior, sheep lend themselves to being able to work unobtrusively in the array and do not pose risk of damage to the site equipment or injury to themselves.

Production benefits from the site environment. Solar arrays provide an excellent environment for raising sheep. [2] [3] The abundant shade provided by the solar modules moderates the temperature during the hottest parts of the grazing season. [4] Predation, which is normally one of the leading areas of loss for a sheep producer, can be nearly eliminated with a secure perimeter fence. Finally, a well-chosen seed mix can provide an opportunity to tailor the forage production in the facility to meet the needs of the animals. It is fair to say that in a correctly designed solar site there is no production loss for a grazed sheep flock. On the contrary, there is the potential to have increased production compared to a traditional pasture setting.

Synergy with site operations. A managed solar grazing program performs an essential part of the Operations and Management (O+M) scope at a solar facility and is successful at managing on-site vegetation to avoid panel shading.[5] In this case, the goals of the partner farmer are aligned with those of the site owner/operator. This sets grazing apart as a form of agricultural co-location and means that it can work in concert with the rest of the site operations, rather than needing them to work around it. Grazing can perform

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[1] American Solar Grazing Association (ASGA). 2024. How Big is Solar Grazing in the U.S.? ASGA, preliminary results.

[2] Andrew, A. C., C. W. Higgins, M. A. Smallman, M. Graham, and S. Ates. 2021. Herbage Yield, Lamb Growth and Foraging Behavior in Agrivoltaic Production System. Frontiers in Sustainable Food Systems 5 (Original Research). https://www.doi.org/10.3389/fsufs.2021.659175

[3] Kampherbeek, E. W., L. E. Webb, B. J. Reynolds, S. A. Sistla, M. R. Horney, R. Ripoll-Bosch, J. P. Dubowsky, and Z. D. McFarlane. 2023. A preliminary investigation of the effect of solar panels and rotation frequency on the grazing behavior of sheep (Ovis aries) grazing dormant pasture. Applied Animal Behaviour Science 258:105799. https://doi.org/10.1016/j.applanim.2022.105799

[4] Williams, H. J., K. Hashad, H. Wang, and K. Max Zhang. 2023. The potential for agrivoltaics to enhance solar farm cooling. Applied Energy 332:120478. https://doi.org/10.1016/j.apenergy.2022.120478

[5] Kochendoerfer, N., C. E. McMillan, M. A. Zaman, S. H. Morris, and A. DiTommaso. 2022. Effect of Stocking Rate on Forage Yield and Vegetation Management Success in Ground Mounted Solar Arrays Grazed by Sheep Cornell Nutrition Conference No. 84. Cornell University Syracuse, NY. https://ecommons.cornell.edu/handle/1813/112173

vegetation management at competitive cost to conventional mowing [6], while also directing this income stream into the local agricultural economy. [7]

This plan for agricultural integration is built around a managed rotational grazing system outlined by a Prescribed Grazing Plan (PGP) tailored to the Project. The PGP is a blueprint for managed grazing advocated by the United States Department of Agriculture (USDA) through its Natural Resource Conservation Service (NRCS) Conservation Standard Practice Code 528 (Code 528-CPS). [8] The PGP is a master guidance document used to facilitate management of the site that achieves targets for vegetation control, animal production, and soil health. The potential stocking rate in this plan would be aimed at performing more than 90% of vegetation maintenance with a smaller amount of mechanical trimming to be performed by the farmer/contract holder on an as-needed basis.

The following expectations of facility design and grazing planning will be met to allow for sheep grazing as part of agricultural integration of the project:

- The grazeable acreage of the project will be prepared with seed mixes and planted vegetation that is compatible with animal grazing, optimizes forage recovery periods, the soil hydrologic cycle, and takes wildlife into consideration.
- A water distribution plan for sheep on the site using municipal water, water wells, and/or trucking water with portable tanks as needed will be developed based on the water resources available.
- Appropriate signage at facility entrances with contact information for the servicing grazing manager and which alerts visitors that sheep are on site.
- Annual sheep stocking rates and grazing rotations will be based on forage availability, time of year, weather conditions, animal characteristics, and producer requirements, and the managed grazing system will include rest periods for pasture recovery after grazing periods.
- Temporary, portable fencing will help to facilitate the managed grazing system and help to rotate sheep flocks according to a grazing plan.

The PGP utilizes the 1,575 fenced, grazeable acres of the Wolf Hills Solar project and regards them as five grazing management area based on the layout of the solar panels. The project grazing management areas consists of individually fenced arrays and will each have a planned number of sheep. Each array will be further subdivided into smaller units (grazing paddocks) at the discretion of a grazing manager to facilitate a rotational grazing system. It is intended that each management area will be serviced by a separate flock of

[6] McCall, J., J. Macdonald, R. Burton, and J. Macknick. 2023. Vegetation Management Cost and Maintenance Implications of Different Ground Covers at Utility-Scale Solar Sites. Sustainability 15(7):5895. https://doi.org/10.3390/su15075895
[7] Kochendoerfer, N., Thonney, M.L. 2021. Grazing Sheep on Solar Sites in New York State: Opportunities and Challenges. Cornell University Atkinson Center for a Sustainable Future. Ithaca, NY. https://solargrazing.org/wp-content/uploads/2021/02/Solar-Site-Sheep-Grazing-in-NY.pdf
[8] USDA/NRCS Prescribed grazing (Ac.) (528) Conservation Practice Standard. https://www.nrcs.usda.gov/sites/default/files/2022-09/Prescribed_Grazing_528_CPS.pdf

sheep that will rotate within the management area. A sheep farmer or grazing manager will be able to read and understand the materials presented in the PGP and use it as a planning tool for their grazing operations.

Background

Solar grazing is the practice of grazing livestock in solar power plants for vegetation management - a job which sheep are uniquely adapted to. Sheep are an ideal agricultural co-location strategy on energy producing solar power plants, because they fulfill a clear purpose (vegetation management) and require basic infrastructure to ensure animal safety and well-being. They have been proven to be successful at vegetation management in solar sites, with roughly 100,000 acres grazed in the US in 2024. [9] [10]

Grazing sheep in solar facilities is a cost competitive strategy [11] to maintain vegetation and offers an ideal grazing environment for the working flocks. Solar facilities offer nutritious pasture and beneficial conditions. [12] [13] Carefully planned grazing rotations will allow both the asset owner and servicing farmer to maximize synergy and work together to ensure a mutually beneficial relationship.

Site operators work within a budget to maintain a project over its operational lifetime, which includes maintenance of electrical systems, fence, access roads and/or panels, and vegetation management. The practice of contracting with sheep farmers is increasingly common for solar site operators; it is an attractive alternative to mechanical mowing because it supports agricultural land use, aligns with sustainability mandates, and when managed with good grazing practices, sheep can perform commensurate to mechanical mowing equipment in both cost and efficiency.

Site operators do not generally need to adjust panel heights to accommodate sheep on site. Sheep can negotiate module cabling and panel drive systems between array rows better than mowing machinery, but other site modifications to facilitate grazing may be necessary, such as adjusting the alignment of gates and corridors to promote the easy flow of livestock, ensuring perimeter fencing will keep out predators, and supplying on-site water.

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[9] Andrew, A. C., C. W. Higgins, M. A. Smallman, M. Graham, and S. Ates. 2021. Herbage Yield, Lamb Growth and Foraging Behavior in Agrivoltaic Production System. Frontiers in Sustainable Food Systems 5 (Original Research). https://www.doi.org/10.3389/fsufs.2021.659175
[10] American Solar Grazing Association (ASGA), membership data.
[11] McCall, J., J. Macdonald, R. Burton, and J. Macknick. 2023. Vegetation Management Cost and Maintenance Implications of Different Ground Covers at Utility-Scale Solar Sites. Sustainability 15(7):5895. https://doi.org/10.3390/su15075895
[12] Kampherbeek, E. W., L. E. Webb, B. J. Reynolds, S. A. Sistla, M. R. Horney, R. Ripoll-Bosch, J. P. Dubowsky, and Z. D. McFarlane. 2023. A preliminary investigation of the effect of solar panels and rotation frequency on the grazing behavior of sheep (Ovis aries) grazing dormant pasture. Applied Animal Behaviour Science 258:105799. https://doi.org/10.1016/j.applanim.2022.105799
[13] Kochendoerfer, N., C. E. McMillan, M. A. Zaman, S. H. Morris, and A. DiTommaso. 2022. Effect of Stocking Rate on Forage Yield and Vegetation Management Success in Ground Mounted Solar Arrays Grazed by Sheep Cornell Nutrition Conference No. 84. Cornell University Syracuse, NY. https://ecommons.cornell.edu/handle/1813/112173

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Benefits for Farmers

Grazing sheep flocks in solar facilities helps farmers to reap economic benefits [14] and enhances environmental outcomes. [15] It has potential to lower the barriers of entry for young, beginning, diverse, and underserved farmers, and allow new farm businesses to contribute to the local economy as well as increase sheep farmers and flock owners' financial viability. [16] Additionally, prescribed sheep grazing facilitates development of perennial vegetation and contributes to soil health. [17] [18] Grazing allows for diverse plant, insect, and pollinator habitats, and improves soil stability by nurturing vegetation to help prevent erosion by wind and water.[19]

In addition to marketing wool, leather, and meat products, solar-grazing farmers can also benefit from access to specialty markets for sheep products. Solar grazed lamb can be offered at gourmet outlets, farm-to-table restaurants, and through specialty online sales while generating premium prices and regional market distinction. [20] [21]

Further, new research shows that photovoltaic installations maintain physiochemical and biological processes occurring within the ecosystem, (ecosystem function), and that managed grassland water cycling is only minimally impacted by array construction. [22] Research from Oregon shows that panels may increase vegetation in shaded areas underneath panels due to water retention, offering opportunities for the grazing manager to grow the flock size over time. [23]

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[14] Mount Morris Agrivoltaic Study, Lamb Demand in Northeastern US, 2021, Julie Stepanek Shiflett, Juniper Economic Consulting. https://solargrazing.org/wp-content/uploads/2022/01/MountMorris-AgrivoltaicReport-FINAL_PRINT_ready.pdf

[15] Kochendoerfer, N., A. Hain, and M. Thonney. 2019. The agricultural, economic and environmental potential of co-locating utility scale solar with grazing sheep, Atkinson Center for a Sustainable Future, Cornell University Ithaca, NY. https://bpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/c/9310/files/2020/12/Atkinson-Center-report-2018_Final-22l3c5n.pdf

[16] Kochendoerfer, N., and M. L. Thonney. 2021. Grazing Sheep on Solar Sites in New York State: Opportunities and Challenges. Scope and scaling-up of the NYS sheep industry to graze ground-mounted photovoltaic arrays for vegetation management., Cornell University Atkinson Center for a Sustainable Future, Ithaca, NY. https://bpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/c/9310/files/2021/03/Solar-Site-Sheep-Grazing-in-NY-v2.1.pdf

[17] Amsili, J.P., H.M. van Es, R.R. Schindelbeck, K.S.M. Kurtz, and D.W. Wolfe, G. Barshad. 2020. Characterization of Soil Health in New York State: Summary. New York Soil Health Initiative. Cornell University, Ithaca, NY. https://bpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/6/7573/files/2018/04/Characterization-of-Soil-Health-in-New-York-State-Summary-Report.pdf

[18] New York State Department of Agriculture and Markets. 2023. Agricultural Environmental Management Planning Resources. Tier 2: Pasture Management Worksheet. https://agriculture.ny.gov/system/files/documents/2022/07/aem_tier2_pasture-management.pdf

[19] Thompson, L., Rowntree, J., Windisch, W, Waters, S., Shalloo, L., and Manzano, P., 2023. Ecosystem management using livestock: embracing diversity and respecting ecological principles, Animal Frontiers. https://doi.org/10.1093/af/vfac094

[20] Rentrow, G. 2006. Consumer and Producer Guide to Organic and Natural Meats. University of Kentucky Cooperative Extension Service. http://www2.ca.uky.edu/agcomm/pubs/asc/asc170/asc170.pdf

[21] Hutchens, T., G. Rentrow. 2011. Marketing Lamb and Goat Meat to Hispanic Retail Outlets. University of Kentucky Cooperative Extension. http://www2.ca.uky.edu/agcomm/pubs/asc/asc182/asc182.pdf

[22] Kannenberg, S. A., M. A. Sturchio, M. D. Venturas, and A. K. Knapp. 2023. Grassland carbon-water cycling is minimally impacted by a photovoltaic array. Communications Earth & Environment 4(1):238. https://doi.org/10.1038/s43247-023-00904-4

[23] Hassanpour Adeh, E., J. S. Selker, and C. W. Higgins. 2018. Remarkable agrivoltaic influence on soil moisture, micrometeorology and water-use efficiency. PLOS ONE 13(11):e0203256. https://doi.org/10.1371/journal.pone.0203256

Site Characteristics

The project is in Washington County, Virginia, an agricultural county with 170,000 acres of farmland and an average farm size of 125 acres as of 2022 USDA NASS data. Washington County has a high percentage of land in pasture production (79,000 acres), and 90% of the share of sales are livestock, poultry and products. The cropland is intensively managed and there is adoption of progressive techniques such as 8% no-till, 4% reduced or no-till, and 4% cover crops. [24]

The project is located adjacent to Interstate 81. Via Interstate 81, access is provided to urban centers along the east coast, as well as to the Midwest. This ensures opportunity to market lambs, as well as to secure the flock base to graze the project.

Weather and Climate

Washington County is located at 2,400 ft elevation. Monthly precipitation is on average between 4.7 inches (February) and 3.3 inches (September) in the forage growing season, with average temperatures between 25 F (low, January) and 82 F (high, July). [25] Conditions are ideal for forage growth.

Soil

The buildable area within the Wolf Hills Solar project area is on former pasture, hay ground, woodland areas, and crop land (corn and hay), as well as on cleared brush and successional shrubland. Most of the project (~60%) is built on Farmland of Statewide Importance, the balance of the of the project is planned on land classified as Not prime, with ~1% built on Prime farmland. Dominant soils in the project are Frederick silt loam, Hagerstown silt loam, Timberville-Marbie complex, and Wyrick-Marbie complex. [26] Dominant soils in the project site are rated to have mostly medium susceptibility for compaction (~ 70% of the project), with a smaller portion medium to high susceptibility (~ 10% of the project), and high susceptibility (~20% of the project). Soils ranked with medium susceptibility have a significant risk of compaction, leading to possible restrictions in growth rates of seedlings after equipment passes. However, after the initial equipment pass and resulting compaction, soils may be able to support subsequent equipment passes without a further increase in compaction.

Because of these soil characteristics, some compaction is to be expected during construction activities, yet even in high traffic areas that are repeatedly used, compaction may stay at a lower level, and allow for seedling growth. This is beneficial for pasture seed mixes, as a relatively fast establishment can be assumed.

[24] United States Department of Agriculture, National Agricultural Statistics Service, 2022 Census of Agriculture, U.S. Summary and State Data, Washington County, Virginia, https://www.nass.usda.gov/Publications/AgCensus/2022/Online_Resources/County_Profiles/Virginia/cp51191.pdf
[25] National Oceanic and Atmospheric Administration. National Centers for Environmental Information. https://www.ncei.noaa.gov/
[26] United States Department of Agriculture, Natural Resource and Conservation Service, Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Seed Mixes and Site Preparation

The project is built on former woodlands, pasture, hay ground, and tilled cropland. These project areas will have to be prepared and seeded with a grazing appropriate seed mix. The site preparation strategy, quality of work, as well as chosen plant seed mixes will impact expected forage growth following construction and into site operations. Sheep will graze successfully on a diverse array of grass, legume and forb species. An ideal seed mix will contain regionally adapted pasture grasses, legumes, and forbs. Ideally a pasture plant distribution should be 70% grass, 20% legumes, and 10% forbs, for optimal nutritional content and palatability for a sheep flock, as well as sod-formation and bare-ground avoidance for wind and water erosion prevention. Any species of Fescue or Ryegrass in the chosen mix will be of an *endophyte free* or *novel endophyte* variety to avoid issues with palatability and endophyte toxicity.

In addition to the planted seed mix it is expected that due to presence of existing pasture plant species, the site species composition will change and stabilize over time due to existing seeds present in the soil "seed bank." Cool season grasses which require temperatures between 40° F and 75° F, like Orchard Grass (*Dactylis glomerata*), Virginia Bluegrass (*Poa pratensis*), and Perennial Ryegrass (*Lolium perenne*) as well as legumes which require temperatures between 70° F and 90° F like White clover (*Trifolium repens*), Red clover (*Trifolium pratense*), and Alfalfa (*Medicago sativa*) will be present at the location under optimal growth conditions.

Forage Production Potential

AVS used the United States Department of Agriculture (USDA) National Resource and Conservation Service (NRCS) Web Soil Survey to estimate site specific forage production potential. [27] Forage production is expressed in Animal Unit Months (AUM). Under the given soil and climate, assuming a high level of management and current conditions (2024) of a well-established stand of mixed pasture grasses, 6.8 Animal Unit Months (AUM) are the expected annual pasture yield.[28] This corresponds to an annual stocking rate of 1.9 sheep per acre year-round after the successful establishment of seed mixes. AVS estimates that in the first years of seed mix establishment the full potential of AUM will not be reached and only 60 – 90% is realized. To prevent overgrazing and facilitate sod development, an annual stocking rate of 1.4 sheep per acre should not be exceeded in the first years of grazing and during stand establishment. It is advised to utilize supplemental mechanical mowing on these areas of the project to avoid overgrazing.

After seed mix establishment, and the start of sheep grazing, it is advisable to take a representative set of forage samples each year prior to the start of grazing and to submit the samples to a forage laboratory to determine quantity and quality (nutritional content) of the vegetation. These results can then further inform the PGP and (if samples are taken continuously throughout the grazing season) define stocking rates more conclusively, and confirm the assumptions made in the PGP.

[27] United States Department of Agriculture, Natural Resource and Conservation Service, Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
[28] United States Department of Agriculture, Natural Resource and Conservation Service, Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

The acreage planned to be built on cropland can be expected that ecosystem biodiversity and soil organic carbon will increase over time. [29] Grazing can greatly improve the biodiversity of land. [30] This will ensure that agricultural lands, especially those that are prime farmland or farmland of local importance remain in production and keep or improve their quality. Overall, soil quality (mainly sequestered soil carbon) is high in pastures. [31]

Sheep Flock Requirements

Sheep Flock Details

The health needs of sheep flocks vary during periods of their development and require modified grazing management strategies, especially for internal parasite prevention, often making it a disadvantage to graze different aged production groups together. Sheep flocks are best divided by different stages of production for grazing solar sites; groups of growing lambs, yearling ewes, dry (non-lactating) ewes, open (non-pregnant) ewes, or rams and neutered males (wethers) may be grazed together. The most adaptable management groups are growing lambs, yearlings, and dry (and breeding) ewes.

The daily feed intake and level of management responsibility of a given grazing flock is defined by the production stage of the flock and body weights of the animals. This also informs the land base/acres that are annually needed to support different management groups. Grazing groups of uniform production stage are generally able to integrate into a solar operation and help to ensure successful vegetation management more optimally. This also allows for more uniform forage intake, the mowing result, land use planning, and calculations.

If the decision is made to graze lamb groups, lambs should be at least 60 lbs. or 50% of their mature body weight (BW) to help them thrive on pasture. If growing feeder lambs for a fall market are being grazed, they should either be of the same sex, or the males should be castrated (wethered), to avoid uncontrolled breeding on site.

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[29] Amsili, J.P., H.M. van Es, R.R. Schindelbeck, K.S.M. Kurtz, and D.W. Wolfe, G. Barshad. 2020. Characterization of Soil Health in New York State: Summary. New York Soil Health Initiative. Cornell University, Ithaca, NY. https://bpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/6/7573/files/2018/04/Characterization-of-Soil-Health-in-New-York-State-Summary-Report.pdf

[30] Schrama, M., C. W. Quist, G. Arjen de Groot, E. Cieraad, D. Ashworth, I. Laros, L. H. Hansen, J. Leff, N. Fierer, and R. D. Bardgett. 2023. Cessation of grazing causes biodiversity loss and homogenization of soil food webs. Proceedings of the Royal Society B: Biological Sciences 290(2011):20231345. doi: https://10.1098/rspb.2023.1345

[31] Amsili, J.P., H.M. van Es, R.R. Schindelbeck, K.S.M. Kurtz, and D.W. Wolfe, G. Barshad. 2020. Characterization of Soil Health in New York State: Summary. New York Soil Health Initiative. Cornell University, Ithaca, NY. https://bpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/6/7573/files/2018/04/Characterization-of-Soil-Health-in-New-York-State-Summary-Report.pdf

Typical commercial scale sheep breeds in the U.S. are the Katahdin and Dorper hair sheep, and wooled breeds including the Polypay composite, Dorset, and Texel sheep. All are adapted to grazing and all have different mature body weights, and with that different nutritional requirements.

<u>Nutritional and Water Requirements</u>

Sheep nutritional and water intake requirements change depending on the animal body weights. All available US sheep breeds are adapted to grazing. Further, different grazing breeds develop different mature body weights, determining their level of daily feed intake. Feed intake in ruminant nutrition is given in weights of dry matter (DM). Dry matter of forages is the dry weight of the plant material (after water is extracted by drying) and is typically between 18 and 35% in forages across the grazing season, with lower DM concentration in Spring and Fall, and highest values in the hot and sunny summer months of July and August.

Table 1. below gives an overview of levels of intake (in %BW) [32]:

Table 1. National Research Council (NRC) estimates of nutritional requirements (levels of intake, %BW):

Breed	Stage of production	Body weight, lbs	Feed intake, DM %BW	Feed intake, lbs DM
Katahdin hair sheep	Growing lamb, 50% mature BW	65	2.5	1.6
	Yearling	110	3.0	3.3
	Open, dry ewe	130	3.5	4.6
Polypay composite	Growing lamb, 50% mature BW	80	2.5	2.0
	Yearling	130	3.0	3.9
	Open, dry ewe	160	3.5	5.6
Texel	Growing lamb, 50% mature BW	90	2.5	2.3
	Yearling	150	3.0	4.5
	Open, dry ewe	180	3.5	6.3

Sheep flocks of any stage of production must always have water available free choice. The water must be fresh and offered in clean troughs/ waterers. Typically, and depending on climate, dry matter percentage of the available feed, and stage of production (growing, lactating, or dry animals), a sheep will consume in the range of 5 – 15% of their body weight in water, daily. Water requirements in solar sites are much lower than in pastures without shade. Due to the sheep spending much of their time in the shade under the panels in the hot summer months, with grazing concentrated to dawn and dusk, sun exposure is minimized, and water intake decreases. New agrivoltaics research show a significant cooling effect of panels, temperatures in shaded areas under panels may be 10 C lower compared to temperature surrounding the panel [33]. No

[32] NRC. 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids. The National Academies Press, Washington, DC. https://nap.nationalacademies.org/catalog/11654/nutrient-requirements-of-small-ruminants-sheep-goats-cervids-and-new

[33] Williams, H. J., K. Hashad, H. Wang, and K. Max Zhang. 2023. The potential for agrivoltaics to enhance solar farm cooling. Applied Energy 332:120478. https://doi.org/10.1016/j.apenergy.2022.120478

specific research is known to identify how much water intake under panels is impacted by the shaded, cooled environment, but experience from grazing managers in the field shows less water is consumed by sheep in solar.

Table 2. below gives an overview of water intake in comparable climate:

Table 2. Water requirements. [34]

Stage of production	Weight range, lb	Water requirements, Gal per day [a]	Average water use, Gal per day [b]
Growing lamb	60 – 110	1.0 – 1.4	1.2
Gestating ewe, ram	175	1.1 – 1.7	1.4
Lactating ewe, unweaned lambs	175+	2.4 – 2.8	2.6

[a] Result of the animals' environment and management.

[b] Typical daily water consumption across one year under average conditions in Ontario, Canada.

Further, to satisfy mineral and salt requirements of the grazing flock, a formulated mineral mix, for example Cargill Lamb and Sheep Mineral Mix [35] should be offered ad libitum on site throughout the entire grazing season.

Parasite Management and *Evasive Grazing*

Internal parasites are one of the greatest challenges to successful grazing flocks in the United States. Internal parasite infection can have devastating effects on grazing flocks with significant losses in production and increased, high mortality rates. To avoid increasing contamination of pasture with parasite larvae and their intermediate hosts, pastures must be rested in between grazing intervals, and continuous grazing (without deferment) must be avoided. [36] Pastures should be rotationally grazed, allowing for rest periods in between services – an "evasive grazing" strategy in which animals are moved before they may be reinfected by parasites, can be a successful means of mitigating parasite infection risk.[37] Consecutive grazing days in paddocks should be kept to a minimum, and rest periods should be maximized. The guidelines for evasive grazing are that grazing days do not exceed 4 consecutive days per pasture, with rest periods of 28-40 days in between grazing visits. Due to solar site paddock layout, these targets are sometimes hard to achieve, with panel rows influencing paddock sizes, yet the goal should be to establish rest periods of 28 days or more. Sheep flocks must be kept in a parasite management protocol that uses diagnostic and preventative tools like:

[34] Ontario Ministry of Agriculture, Food & Rural Affairs, http://www.omafra.gov.on.ca/english/engineer/facts/07-023.htm#5

[35] Cargill Lamb and Sheep mineral Mix. https://blogs.cornell.edu/newsheep/management/feeding/agway-sheep-mineral-mix/

[36] Hepworth, K., M. Neary, T. Hutchens. Managing Internal Parasitism in Sheep and Goats. Purdue Extension & University of Kentucky College of Agriculture. https://afs.ca.uky.edu/sites/afs.ca.uky.edu/files/as573w.pdf

[37] Eysker, M., N. Bakker, F. N. J. Kooyman, and H. W. Ploeger. 2005. The possibilities and limitations of evasive grazing as a control measure for parasitic gastroenteritis in small ruminants in temperate climates. Veterinary parasitology 129(1):95-104. https://doi.org/10.1016/j.vetpar.2004.12.022

1.) Body condition scoring (BCS) [38], a process in which the animals are regularly assessed (either visually by experienced sheep flock managers, or physically in a working chute) based on their visual appearance using uniform conditions and weight as a measurement.

2.) FAMACHA® scoring,[39] A second form of uniform visual assessments used for accurate judgement of *haemonchus contortus* (Barberpole worm) infection by scoring parasite induced anemia (blood pigment) in eyelids of animals and thus allow for treatment plans.

3.) The 5-point check[40], evaluating animals based on 5 indicators caused by various internal parasites, including anemia (FAMACHA®), nasal discharge, bottle jaw, body condition (BCS), and diarrhea (scours).

Animal Welfare and Predation

It is the Shepherd's responsibility to check flocks frequently to assure the health and welfare of the animals, water and mineral supply, and forage availability to the captive flock. Certain flock management tasks must be performed before the sheep move on site. Hooves must be trimmed, the flock must be checked for parasites, animals must be tagged and recorded, and wool sheep must be shorn, or a shearing date must be scheduled. Sheep flocks originating out of state must have certificates of veterinary inspection[41] that are completed for the entire flock and are within the valid timeframe of 30 days when the flock is deployed to the solar site.

A cornerstone of solar site design for sheep grazing are the exterior fences. Fences and gates must be flush to the ground with any gaps or holes avoided that would allow for predators (mainly coyotes and stray/wild dogs) to enter the site and cause damage to the grazing flock. Prior to moving the flock on site, the perimeter fence should be checked, and any gaps and holes should be amended before introducing a flock. Depending on contracts and agreements with the Operations and Management or Asset Management teams of the site, guardian dogs may be deployed to help in securing the flock at the site. Solar sites provide shade and shelter to guardian dogs that, like the sheep, find ideal living conditions under panels. Feed and water must be provided to the guardian animals on a schedule, they must be registered with the town, tagged, and collared, and a contact number must be provided to the dog owner/grazing manager in case of emergency or in the event the dog leaves the facility location.

[38] Ely, D. G., D. K., Aaron. 2017. Body Condition Scoring Ewes. University of Kentucky Cooperative Extension Service. http://www2.ca.uky.edu/agcomm/pubs/ASC/ASC228/ASC228.pdf

[39] Wyk, J. A. V., and G. F. Bath. 2002. The FAMACHA system for managing haemonchosis in sheep and goats by clinically identifying individual animals for treatment. Vet. Res. 33(5):509-529. https://www.vetres.org/articles/vetres/abs/2002/05/08/08.html

[40] Bath, G. F., and J. A. van Wyk. 2009. The Five Point Check© for targeted selective treatment of internal parasites in small ruminants. Small Ruminant Research 86(1):6-13. https://doi.org/10.1016/j.smallrumres.2009.09.009

[41] NYSAGM, Sheep and Goats – Sections: Health, Identification, Import & Export. www.agriculture.ny.gov/animals/sheep-goats

Prescribed Grazing Plan

The goal of any grazing operation in a power plant is the vegetation management on site to prevent panel shading. To implement a successful solar grazing operation on a solar site, the nutritional, flock management, and animal welfare needs of a sheep flock must be coordinated with the specific site characteristics. The operational management must be well planned to guarantee multiple benefits.

A PGP helps to ensure that the vegetation management targets of a given solar site are met. It enables the flock manager to adapt the plan to specific seasonal weather and forage growth conditions while providing guidance to ensure the vegetation remains below a targeted height. A PGP adapts flock management to specific site characteristics and helps co-location benefits to be realized.

Feasibility for managed sheep grazing at Wolf Hills Solar can be evaluated by creating a site-specific sheep stocking plan guided by conservation practice standards established by the USDA/NRCS Code 528 for Prescribed Grazing [42] and following protocols recognized by the USDA Conservation Planning Activity of the *Grazing Management Plan (CPA 110).* [43] The stocking plan establishes an initial annual stocking rate, or the number of sheep per acre a site can accommodate over a specific time period, as this is the major planning consideration for any involved grazing manager, and determines many things like access roads, water infrastructure, marketing, scaling of flock, etc. The determining factor of stocking numbers is the forage production potential across the grazing season.

Site Layout and Grazing Rotation

One of the first considerations of the design of a managed grazing program on a utility scale solar site is the spatial distribution of the fenced arrays, and the division into distinct areas. While some sites may have large, contiguous sections of array, other sites can be comprised of many smaller sections. Because sheep must be rotated across the entire grazed area, logistical constraints to movement, such as public roads, woodland, and non-project landowners must all be considered. If there are many of these constraints or if extensive trucking would be required to move the flock through their rotation, it will make sense to break the project down into several spatially distinct grazing areas that will each host its own smaller flock.

AVS has identified five potential grazing management areas that the Wolf Hills Project can be broken down into. These five management areas match the criteria for hosting a separate grazing flock, and each come with their individual considerations which are given a high-level review below. (**Error! Reference source not found.**)

[42] United States Department of Agriculture Natural Resources Conservation Service, Prescribed Grazing (Ac.) (528) Conservation Practice Standard https://www.nrcs.usda.gov/resources/guides-and-instructions/prescribed-grazing-ac-528-conservation-practice-standard

[43] United States Department of Agriculture Grazing Management Plan CPA 110: https://www.nrcs.usda.gov/sites/default/files/2023-09/FY24-CPA-110-Grazing-Management-Plan-10-22.pdf

The Wolf Hills Solar project is regarded as five management areas that are serviced by five sheep flocks (Figure 2). The separate sections (individually fenced arrays) within each management area, can further be subdivided into smaller grazing paddocks, at the discretion of the grazing manager.

Throughout the project, the fixed internal fencing may serve as outside fencing for grazing paddocks. There is the opportunity to create smaller grazing paddocks with flexible Electronet® fencing (164 ft in length) or poly-wire fencing. This fencing is portable and can be set up once in spring for the entire season or moved with each move into a new grazing paddock, at the discretion of the grazing manager.

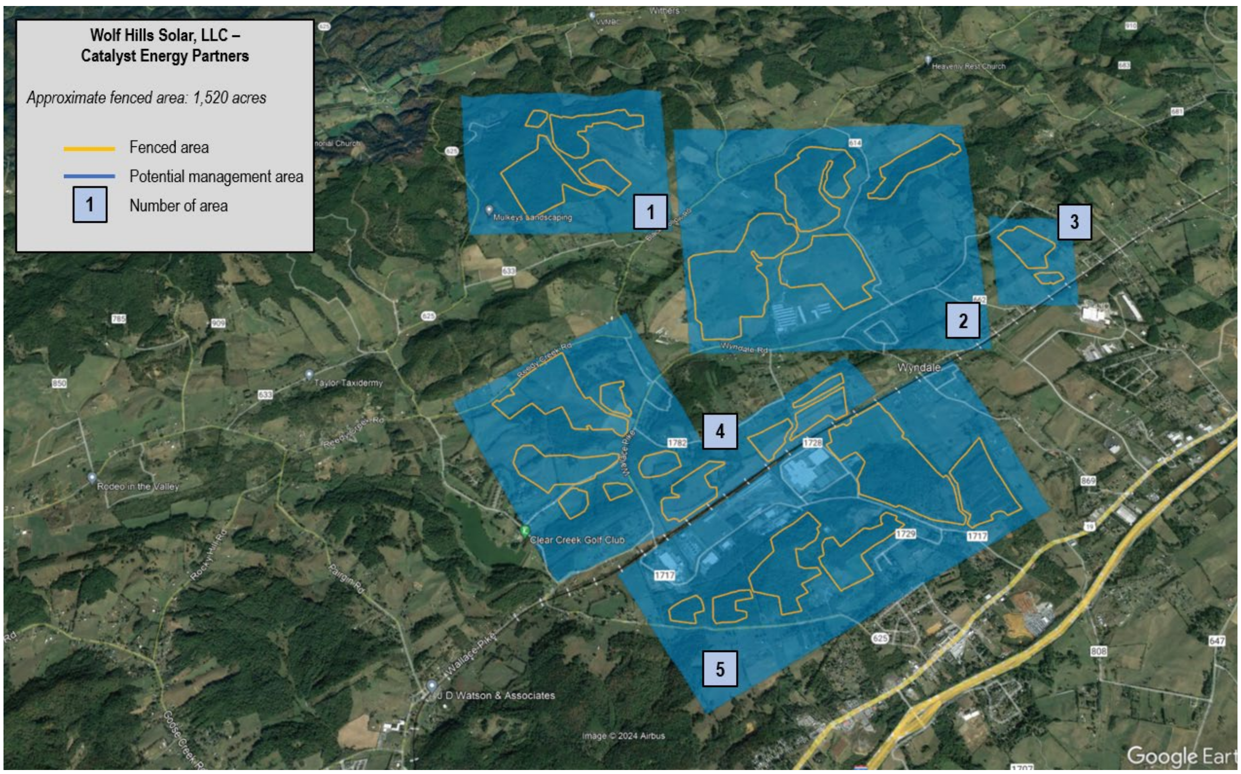

Figure 2. Wolf Hills Solar project layout. The project is structured into five management areas.

- ***Management area 1*** will be built on an estimated 228 acres of woodland. This section will be reseeded and AVS estimates its initial forage production potential will be relatively lower for some time. No roads cross the area and no trucking will be involved; sheep movement would be efficient. AVS estimates forage production in the range of 60% of AUM prediction in the initial years.
- ***Management area 2*** will be built on an estimated 558 acres of pasture, hay field, and crop land, with some cleared wooded land in the Northeast section. AVS estimates forage production in the range of 80% of AUM prediction in the initial years. This area is spatially divided by Rt 614 which may require some amount of trucking on a routing basis to the arrays to the Northeast; however, sheep movement would be fairly efficient, and aside from the Northeast section, no trucking would be involved.

- ***Management area 3*** will be built on an estimated 50 acres of pasture. No roads would have to be crossed and most of the acreage is on a contiguous field, making flock moves very easy. AVS estimates forage production in the range of 90% of AUM prediction in the initial years.
- ***Management area 4*** will be built on an estimated 308 acres of hay ground, pasture, and cropland. This section is ideal for co-location with grazing sheep as the area is located on smaller roads, with two roads (Wallace Pike and Wyndale Rd) to cross between the separate sections. AVS estimates forage production in the range of 80% of AUM prediction in the initial years.
- ***Management area 5*** will be built on an estimated 376 acres of woodland and hay ground. This area is spatially divided by Rt 1717 which may require some amount of trucking on a routing basis to the arrays to the Northeast; however, sheep movement would be fairly efficient. AVS estimates forage production in the range of 60% of AUM prediction in the initial years.

Initial Stocking Rate Calculation

The initial stocking rate is established via a grazing rotation plan that utilizes terminology defined by the NRCS. [44] Establishing an initial stocking rate as a guide will prevent over-grazing and detrimental effects to the vegetation root system. The initial stocking rate can then be verified over time by grazing experience.

Based on weather, climate, and forage growth data, it can be assumed that the sheep will be grazing year-round. It should be assumed that the site will be serviced approximately 6 times throughout the season to ensure successful vegetation management and keep the vegetation below the leading panel edge.

The nutritional requirements of sheep vary depending on the stage of production and development (growing lambs, mature ewes or rams, breeding, gestating, or lactating ewes). AVS recommends (and assumes for this initial analysis) that the grazed sheep are in uniform stages of production, and are mature ewes that are dry, breeding, or in early gestation. Forage removal by sheep (grazing success and shade prevention) depends on stage of production and body weight, as well as dry matter content of the forage.

In Spring and Fall, forage growth is slowed due to cooler temperatures, and dry matter content is low (18%-25%). Starting in mid- to late June and extending into August in the Northeast is typically when vegetation growth may outpace the rate of removal by grazing sheep. At the same time, stand height and forage dry matter content increases gradually (25%-30%). Both compounding factors can lead to tall stands of mature grass with lower palatability due to increased dry matter, causing the sheep to lower their feed intake due to heat–feed refusal.

Further terms used in the grazing plan are the bare ground ratio: areas without significant vegetation cover, including but not limited to access road, graveled areas surrounding inverter pads, or small patches without established ground cover, the refusal ratio, an estimate of forage mass refused by the grazing flock [45], and

[44] Butler, L., J. Cropper, R. Johnson, A. Norman, G. Peacock, P. Shaver, and K. Spaeth. 2003. National range and pasture handbook. USDA National Resources Conservation Service, Washington, DC, USA:214. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=48472.wba

[45] Smith R., M, Panciera, A. Probst. 2010. Using a Grazing Stick for Pasture Management. Cooperative Extension Service. University of Kentucky College of Agriculture. http://www2.ca.uky.edu/agcomm/pubs/agr/agr191/agr191.pdf

the ground cover ratio, the area shaded by panels. Compared to dry matter production in unshaded areas, forage production is lower in areas shaded by panels. [46] [47]

A rotational grazing system as should be employed on the project site, involves moving grazing animals from one pasture to another to achieve the desired management objective ovel panel shading avoidance (also referred to as *Prescribed Grazing by the NRCS).* [48] Any grazing system can be expressed by the number of subunits (paddocks) of the pasture entity, the number of services (rotations) per year, the length of each rotation, the grazing period (days within each paddock), and the deferment or pasture rest period after each grazing.

Then, a stocking calculation can be performed, expressed by the of animals grazing a unit of land across a full year, described in animals per unit of land (acres). The relationship between the number of animals and area of land at any instant of time is described as stocking density.

*Based on expected site conditions and assumptions made above, AVS estimates that an average of 2,179 sheep could initially be grazed on the project. (**Error! Reference source not found.**)*

Based on seasonal forage growth variation, speed and rotation timing, and deferment will be adjusted by the grazing manager to correctly address forage conditions. Table 2 below predicts uniform (average) rotations across one full calendar year.

Table 3. Initial stocking rate calculation.

Management Area	***Area 1***	***Area 2***	***Area 3***	***Area 4***	***Area 5***	***Total/ Average***
Grazing unit, ac	236.0	578.3	51.6	319.4	389.7	1,575.0
Grazing start, date	1/1/24	1/1/24	1/1/24	1/1/24	1/1/24	1/1/24
Grazing end, date	12/31/24	12/31/24	12/31/24	12/31/24	12/31/24	12/31/24
Grazing, da	365	365	365	365	365	365
Sheep flock details						
Sheep BW, lb	140	140	140	140	140	140
Daily intake, %BW	3	3	3	3	3	3
Daily intake, lb DM	4.2	4.2	4.2	4.2	4.2	4.2
Forage production details						
AUM (NRCS data)	3.7	5.4	6.4	5.8	4.0	5.1
Forage availability, %	100	100	100	100	100	100
Forage, tons DM/ac	1.4	2.0	2.4	2.2	1.5	1.9
Bare ground ratio, %	10	10	10	10	10	10

[46] Andrew, A. C., C. W. Higgins, M. A. Smallman, M. Graham, and S. Ates. 2021. Herbage Yield, Lamb Growth and Foraging Behavior in Agrivoltaic Production System. Frontiers in Sustainable Food Systems 5 (Original Research). https://www.doi.org/10.3389/fsufs.2021.659175

[47] Kochendoerfer, N., C. E. McMillan, M. A. Zaman, S. H. Morris A. DiTommaso, and S. Grodsky. 2024. Co-location of sheep grazing and solar energy production yields agro-technological synergies. In preparation.

[48] USDA Natural Resource Conservation Service (NRCS) Prescribed Grazing (Ac.) (528) Conservation Practice Standard https://www.nrcs.usda.gov/resources/guides-and-instructions/prescribed-grazing-ac-528-conservation-practice-standard

Refusal ratio, %	30	30	30	30	30	30
Ground cover ratio, %	20	20	20	20	20	20
Forage prod., shade, %	42	42	42	42	42	42
Available forage, tons DM/ac	0.8	1.2	1.4	1.2	0.9	1.1
Grazing system						
Number of subunits (paddocks)	10	25	5	20	20	80
Number of services (rotations)	6	6	6	6	6	6
Rotation length, da	61	61	61	61	61	61
Grazing period, da	12	2	12	3	3	7
Deferment (rest period), da	49	58	49	58	58	54
Stocking calculation						
Annual stocking rate, sheep/ac	1.1	1.5	1.8	1.6	1.1	1.4
Stocking density, sheep/ac	11	38	9	33	23	111
Total sheep	***248***	***875***	***94***	***519***	***442***	***2,179***

To prevent overgrazing, maintain residual vegetative cover of at least 4-6 inches, and facilitate sod development, an *initial* annual stocking rate of 1.4 sheep per acre should not be exceeded. Ongoing monitoring and visual observation should guide stocking rates with adjustments as needed to maintain the vegetation at a minimum of 4-6 inches tall and at maximum below the leading edges of solar panels.

Supplemental mowing may become necessary to compensate for the difference in relative forage removal and help to keep vegetation height within the necessary height limits. This should be first limited to alley mowing between the panel rows, which will cut down the available forage by 40% – 70%, while still maintaining forage for the sheep to graze below the panels. The pace and location of mowing should balance the rotation schedule, vegetation height, and feed supply for the sheep. Supplemental mowing may be performed on an as-needed basis. Requirements for supplemental mowing vary year to year, depending on temperature and precipitation.

The forage growth estimates used in this PGP originate from the NRCS Web Soil Survey. [49] However, actual forage yields depend on many different variables including, but not limited to, annual precipitation, air and soil temperatures, seedling success of pasture mixes, historical field use, the previous level of soil and crop management and resulting nutrition levels, quality of hayfields, as well as the practice skill level of the flock manager in avoiding management mistakes. The PGP is intended to serve as a guidance document and can produce well informed estimates of forage growth and resulting stocking rates, but it cannot predict with certainty the carrying capacity of the land, and it cannot replace ongoing observations made by the grazing manager. It is therefore advised to continuously check the assumptions made and not to rely on these predictions conclusively.

[49] United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey version 2019 https://websoilsurvey.nrcs.usda.gov/app/

Summary

In a plan using a high degree of management intensive, forage and rotational grazing oversight, in "typical," seasonal conditions for developing stand of forage growth, a total of up to 2,179 sheep (1.4 sheep per acre annual stocking rate) may be grazed with five different flocks in the five management areas of the Wolf Hills Solar, LLC project, using a 365-day grazing season in 6 annual rotations with an average of 7 grazing days per paddock and 54 days deferment, a rotation defined 5-5; 7: 54 da, according to NRCS convention. This initial stocking rate will likely increase over time as forage production rebounds post construction and seedings become more vigorously established.