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The agricultural, economic and environmental potential of co-locating utility scale solar with grazing sheep

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Cornell University

This report summarizes the results of a Rapid Response Fund project "Have Your Cake and Eat It Too Can grazing sheep on solar farms evolve to a profitable and climate resilient agrivoltaic strategy?" funded by the Cornell University David R. Atkinson Center for a Sustainable Future

The agricultural, economic and environmental potential of co-locating utility scale solar with grazing sheep

Large-scale solar encompasses multi-acre solar sites of ground-mounted solar panels, feeding electricity to wholesale buyers or community-based consumers. Currently, 1,462.93 megawatts (MW) of utility scale solar is installed in NYS, equating to approximately 10,200 acres of solar sites (5 to 8 acres are required per MW) powering 260,884 homes with 1.33% of the total state's electricity demand met by solar energy. An increase of utility scale solar sites is forecasted to reach another ~3,200 MW (~22,000 acres) between 2020 and 2023.[1]

New York State made a commitment in 2016 to obtain 50% of the state's electricity from renewable energy by 2030. Due to the commitment of New York State government to the Clean Energy Fund in 2016, the NYS solar industry has projected steady growth for the next decade. The goal of a variety of funding opportunities is to incentivize the growth of renewable energy sources with major funding managed by NYSERDA, New York State's Energy Research and Development Authority. The funding is designed to fast-track and sustain the growing solar electric market.

Site leases for solar fields are long term (25 to 40 years). Ideal site characteristics include treeless, flat, low-value land with easy road access for construction and low lease costs. Project developers use a host of criteria to find this land, searching for land that meets the criteria of the electrical grid, proximity to transmission capacity and ease of permitting. Environmental concerns during construction, operation, and decommission include soil erosion and compaction, stormwater runoff, herbicide contamination, the introduction of invasive species, and aesthetics.[2] Project developers must comply with a host of requirements by government authorities and the local land owners in order to successfully bring a solar project to operation.

Operation of solar sites in summer, which is the prime period for electrical generation, hinges on ensuring that the vegetation does not shade the panels. Typically, sites in warm, humid, summer continental climate zones are mowed two or three times per year and undergo one string trimming to remove the vegetation underneath the panels. To limit environmental impacts of vegetation management, a different system for solar sites was tested: grazing sheep.

The aim of this study was to compare economic and agricultural benefits and challenges of traditional land management strategies (mowing, string trimming) with rotationally grazed sheep on solar sites.

Data were collected from the Cornell University Musgrave Research Farm solar site located in Aurora, NY. Sheep were grazed between May and November 2018 to obtain agronomic and economic data, as well as to gather knowledge of the feasibility of grazing sheep on solar sites. Data for traditional management (labor and equipment running hours) were obtained from a landscaping contract for a comparable Cornell University solar site at Harford, NY.[3] Additionally, a survey was sent to three entities: 1) sheep farmers grazing solar sites; 2) landscapers maintaining solar sites; and 3) solar site managers. The survey collected data to assess economics of solar sites across NYS and the Eastern US and to gain a better understanding of co-located, agrivoltaic systems and the emerging solar grazing industry. The survey results were used to underpin agricultural and economic analyses of solar grazing for sheep farmers.

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[1] SEIA. 2018. Utility Scale Solar Power. Solar Energy Industries Assosciation, https://www.seia.org/initiatives/utility-scale-solar-power.

[2] Ifft, J. 2017. Large-Scale Solar Information and Research Needs for NYS, Cornell University David R. Atkinson Center for a Sustainable Future, Ithaca, NY.

[3] Scott Land & Yard Services, P.O. Box 13, Slaterville Springs, NY 14881.

Agricultural results

The 22-acre Musgrave solar site used for this study was established in 2017. It was abandoned as cropland by the research farm due to poor drainage. Three years prior to installation, the field had been used to grow wheat with legume cover crops. After installation of the panels, the site was reseeded with creeping red fescue and perennial ryegrass in areas where seeding was needed. Legume varieties like red, white, and Alsike clover, as well as alfalfa and birdsfoot trefoil volunteered throughout the site in the grazing season of 2018 and provided nutritious forage for the sheep. Honeoye-Lima silt loam is the typical soil of the area. A soil sample was collected and tested on January 20th, 2015. The sample contained low phosphorous, medium potassium, and very high calcium and magnesium levels. The soil pH was 7.5 and the organic matter content 4.5%. The soil sample drawn after a season of sheep grazing on November 16th, 2018 had pH of 7.6 and an organic matter of 6.6%. However, due to the limited duration of the grazing trial (1 grazing season), we cannot conclude that sheep grazing increased soil organic matter.

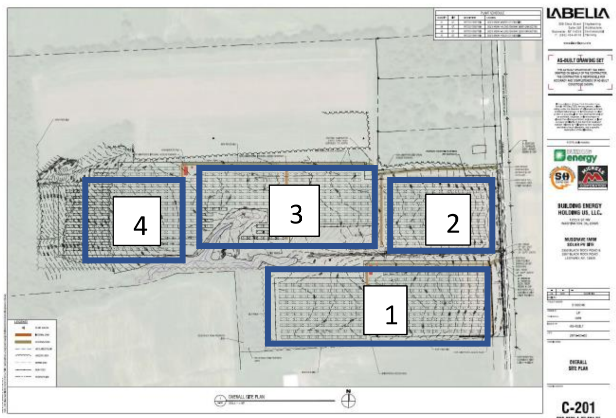

Figure 1. Site plan.

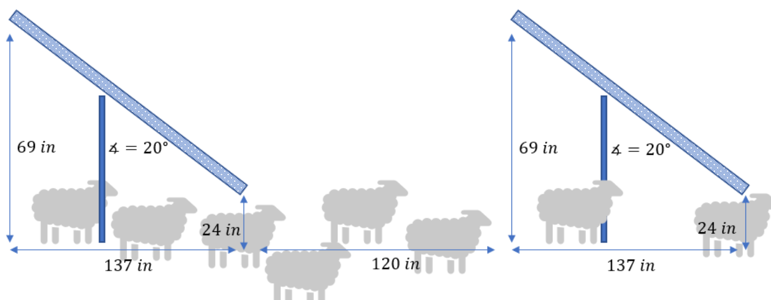

Figure 2. Panel dimensions.

The site was divided by permanent and Electronet® fencing into 4 plots for the grazing trial (Figure 1). The 56 Katahdin ewes (medium sized sheep less than 3 feet high with an average weight of 120 pounds) were rotated 8 times through the plot from the first time they were put on site on May 1st, 2018 until they were removed on November 5th, 2018. The *stocking rate* (total sheep on the site, per acre) was 2.5. The *stocking density* (number of sheep over a certain timeframe in subplots of the site, per acre) varied between 3 and 7 sheep per acre. The site was checked every three days. Each visit had a duration of ~45 minutes and included adding water to the water tank (Figure 3), checking animal health and welfare, and – when necessary – movement of the sheep into a new plot. All ewes were dry (non-lactating) when they were moved on site and breeding rams were introduced in September 2018 for January 2019 lambing. No health incidents were observed. No signs of internal parasites were detected. The sheep were FAMACHA scored (checking inner eyelids for color as an indication of anemia) on May

Figure 3. Water access and Electronet®.

28th, 2018; no barber-pole worm-caused anemia was detected. Additional 5-point checks for internal parasites[4] were conducted throughout the grazing season and did not lead to concerns about internal parasites. There was no need to conduct fecal egg counts. The ewes' body condition scores remained stable throughout the season, suggesting adequate levels of intake and nutrients. No predator issues were recorded, the chain linked fence proved to be enough protection; no guard-animals were necessary. The sheep had access to water and sheep mineral *ad libitum*. The water was provided from water tanks that flowed into troughs (Figure 3). Rest periods for the grazed forage varied between 18 and 48 days for plots 1 and 2, and between 21 and 29 days for plots 3 and 4. The rest periods were chosen to be relatively short due to fast growing vegetation and the priority of preventing panel shading. Shade prevention and vegetation management was successful; at no time throughout the grazing season did the vegetation shade the panels (Figure 4).


Figure 4. Vegetation management success.

Prior to each rotation, the vegetation in each plot was sampled and analyzed for the nutritive value for sheep. Throughout the grazing season the forage consisted of 39% grass (61% legumes and forbs) with more than adequate suggested levels of feed components for dry ewes (Table 1).

The sheep left the site healthy at the end of the season, with good body condition and low parasite load. The goals for both the solar company and the shepherd farmer were met in this grazing trial. Vegetation never shaded the panels, and the farmer was compensated at a profit for extra work at a remote location.

The sheep farmer, landscaper, and electrical operations contractors communicated regularly throughout the study period, resulting in full compliance with safety and profitable arrangement for all the solar site O&M providers.

Table 1. Stocking density, days grazed, dry matter consumed, and forage components compared with suggested component levels for dry ewes.

Date	Plot	Sheep	Time, days	DDM per head, lb	DM, % of forage	% of dry matter							
						DDM	CP	NDF	Ca	P	Mg	K	S
5/24/18	2	23	25	2.54	18.4	61.0	17.8	54.0	0.67	0.34	0.31	2.53	0.23
5/24/18	4	33	29	1.92	15.2	58.7	18.1	50.5	0.89	0.33	0.34	2.20	0.24
6/18/18	1	23	25	15.35	23.3	68.3	14.6	47.2	0.96	0.32	0.28	2.06	0.19
6/22/18	3	33	71	3.38	24.3	60.0	14.1	50.8	0.90	0.22	0.23	1.71	0.28
7/16/18	2	23	18	7.40	28.3	63.3	12.8	51.2	1.08	0.27	0.31	1.73	0.21
7/16/18	4	33	65	1.45	25.1	62.0	14.3	48.4	1.17	0.27	0.25	1.86	0.23
8/2/18	1	23	48	3.46	23.5	56.3	14.1	57.8	0.60	0.38	0.27	2.13	0.19
9/19/18	2	23	49	1.77	19.9	62.3	19.9	42.5	1.23	0.34	0.35	2.35	0.27
Suggested levels for 150-lb dry ewes				3		55.0	10.0		0.40	0.20	0.18	0.80	0.26

[4] https://www.wormx.info/.

Economic results

During the grazing trial at the 22-acre Musgrave site, all farm-side economic data for vegetation management (grazing) were recorded. Investment costs, income, and operating costs to establish benchmarks per head of sheep and per acre are shown in Table 2.

Investment costs included: water tanks, troughs, and a small water transfer pump water pump to fill the troughs, as well as Electronet® fencing and a charger to divide sections for rotational grazing. Mileage included depreciation and was calculated at $0.54 per mile. The sheep were checked every three days amounting to 63 checks in the 188-day grazing season. 47 hours were spent on-site checking the sheep; 139 hours were spent including the drives to and from the site. Labor was valued at $15 per hour. The site was subcontracted from a landscaping business, and Lexie Hain received $250 per acre for her grazing efforts. Income statements for both scenarios (contracted directly and subcontracted) are shown in Table 2. General liability insurance was covered by the landscaping business and was subtracted as a cost only in the directly-contracted scenario. In the subcontracted scenario the insurance was covered by the landscaping business. Ideally, sheep farmers would contract directly with the site O&M contractor because, given an ideal stocking rate, sheep alone will be enough to provide vegetation management and prevent panel shading so that the tools of a landscaping company would not be needed.

Table 2. Income statement for grazing 56 sheep on 22 acres.

Item	Total	Per acre	Per head of sheep
Investment	$1,690	$77	$30
Grazing income			
Directly contracted	$11,000	$500	$196
Subcontracted	$5,500	$250	$98
Grazing expenses			
Mileage	$2,125	$97	$38
Labor	$2,084	$95	$37
General liability insurance	$1,500	$68	$27
Directly contracted total	$5,709	$260	$102
Subcontracted total	$4,209	$191	$75
Net			
Directly contracted	$5,291	$241	$94
Subcontracted	$1,291	$59	$23

Labor

Landscaping data obtained from the comparable 10-acre Harford site[3] were used to establish values for required labor per acre for traditional management (mowing and string trimming). The 10-acre site required 16 hours of mowing (8 hours, twice per year), as well as 140 h of string trimming underneath the solar panels (Figure 5) per year. That amounts to a total labor requirement of 156 hours per year for a 10-acre site. Extrapolating to the 22-acre Musgrave site, the traditional vegetation management requires 36 hours (18 hours twice a year) of mowing and 308 hours of string trimming per year, amounting to 344 total labor hours on site. Mowing was conducted with equipment comparable to a 70-horsepower skid steer machine and a 72-inch mower at 3 mph speed. The ground can be uneven, especially in newly established solar sites. Depending on the design of the site, the panel rows are narrow, making it time consuming to navigate without damaging the solar panels. Five-point turns are needed at the end of panel rows to navigate to the next row for mowing. Mowing occurs two times per year. Heavy duty string trimmers are used to string trim underneath the solar panels.

Utilizing sheep for site vegetation management required a total of 139 hours including travel time, resulting in ***2.5 times fewer labor hours*** *than traditional vegetation management (mowing and string trimming) on site.*

Contracts and insurance

Solar site owners range in corporate size, hierarchy, and site management structure. Some have an internal division that manages the operations and maintenance (O&M) while others hire a specialty firm to execute these functions. The O&M managers are responsible for the year-round performance of the array, including vegetation management. During the growing season, prevention of shading will be the key focus of an O&M manager's job with respect to power production and module performance, while operating cost-consciously. Many O&M

managers have business management or electrical engineering backgrounds and operate entirely remotely – from urban offices – and may only make an annual site visit. They tend not to be familiar with farms, farmers, or vegetation, and often lean heavily on landscape subcontractors for knowledge in this area.

Contracts for the vegetation maintenance may be expressly for single passes of a mower or may be comprehensive multiyear agreements. Where solar sites are dispersed geographically, regional solar O&M managers may contract for the vegetation management with local firms, typically landscape contractors or sheep farmers in each region. A formal legal contract is typically required by the solar operator. The legal departments at O&M firms that review outside contracts can insist on a lengthy review process. As the solar asset itself is quite valuable once operational, this sometimes-meticulous review process is justified in the eyes of the operator. The downside for a sheep farmer or small landscaping business is that they are entirely at the mercy of these contracts and may not be able to afford legal support of their own. This risk of liability is why emerging industry associations such as the *American Solar Grazing Association* now offers free contract examples to sheep farmers who wish to become solar graziers. This legal support should prevent farmers from unnecessary exposure to liability and potential expense. The best contracts for sheep farmers will offer a regular payment schedule for their services at the site and automatic renewal for multiyear contract extensions.

Solar O&M firms typically require any contractors on their sites to carry insurance. They may have a suite of requirements that more closely resemble the liability needed for a construction firm than for small farm or local landscaper. Farmers may be able to negotiate different aspects of the coverage, using these added fees as leverage in negotiating their payments. Solar graziers typically find that, after a season or more, O&M managers gain trust in their performance and see that the liability is quite low from grazing sheep, waiving the more stringent insurance requirements and/or easing up on the stricter contract requirements as everyone gains familiarity with the arrangement.

Solar grazing in the Eastern United States and New York State

In a survey of sheep farmers grazing solar sites, 14 total sheep farms responded, and of that 4 were in New York State. Survey respondents reported a total of 3,503 acres of utility solar grazed in the eastern US, with 79 acres in NYS. All grazed sites were established between 2012 and 2018. The grazing season was March to December, but in NYS it was April to November due to more extended grazing periods farther south. Average stocking rates were lower in the US average east of the Mississippi (3 sheep per acre) compared with NYS (4 sheep per acre). A variety of sheep were used for solar grazing; hair sheep like the Katahdin and Dorper breeds were most prevalent. On average, sheep farmers drove 42 miles (US) and 27 miles (NYS) from their home farms to the solar site grazed with sheep. The grazing contracts were mostly directly between the solar site O&M contractors and the sheep farmer. Less often, but also prevalent, the contracts were bid upon and obtained by landscaping contractors and then subcontracted to a sheep farmer. This system has the advantage of no additional insurance needs for the farmer, as well as the security of a landscaping company being available to remove invasive plant species. These contracts are renewed through a bidding process. With a few multi-year exceptions, sheep farmers obtained yearly contracts. From the survey, the O&M managers reported budgets of $868 per acre per year for vegetation management in 2018. Per acre income and expenses for sheep farmers under direct or subcontracts in New York State and the Eastern United States are summarized in Table 3.

Table 3. Per acre income and expense of solar grazing in New York and across the Eastern United States.

	New York State		Eastern United States	
	Directly contracted	Subcontracted	Directly contracted	Subcontracted
Income	$555	$320	$326	$308
Expenses	$46	$46	$64	$64
Net	$509	$274	$262	$244

Conclusions

Grazing sheep on solar sites is a cost-effective method to control on-site vegetation and prevent panel shading (Figures 5 and 6). At no time in the growing season did vegetation shade the panels. It was less labor-intensive than traditional landscaping services and, thus, less expensive. The grazing trial at the Musgrave solar site was a full success for the site owners and operators, as well as the sheep farmer.

Figure 5. After mowing, prior to string trimming.

Figure 6. Rotationally grazed with sheep.

New marketing strategies could emerge for solar farm-raised, grass-fed lamb that can also be a direct benefit for small-scale sheep farmers from co-locating sheep grazing with renewable energy.

More thorough research is needed to investigate the environmental impact of traditional landscaping vs grazing to control vegetation on solar sites. Future studies are needed to assess long term impacts like soil response and pasture quality, and the effects of grazing on pollinator plants or invasive species. A broad variety of soil quality indicators should be measured, such as soil organic carbon sequestration and the possibility of creating carbon sinks through grazing, soil nitrogen responses, and changes in bulk densities. Herbicide use and run-off in traditional vegetation management systems on solar sites should be investigated. The suitability for co-locating grazing with pollinators by the enhancement of pollinator plant species, effective grazing management, and control of invasive species should be explored. An important question for the successful management of solar sites with sheep will be determining what stocking rates and densities should be chosen. Future research is needed to establish sound recommendations.

Solar site developers should include amenities like on-site wells and power outlets as well as high quality, predator-proof fencing to reduce investment costs for sheep farmers. Multi-year contracts should be used to encourage more sheep farmers to become interested in grazing solar sites and to ensure that agricultural land will remain in production.