Journal of Cooperatives

Volume 42 *2026* *Page 103 - 132*

A Needs Assessment and Financial Feasibility Tool for Solar Energy Grazing Service Cooperatives

Summer Santillana, Nicole Tommell, Todd M. Schmit*, Yunjie Li, & Roberta M. Severson

Contact:

Todd M. Schmit, *Professor, 350A Warren Hall, Charles H. Dyson School of Applied Economics and Management, Cornell University, Ithaca, NY, 14853, USA, tms1@cornell.edu, telephone: +1-607-255-3015, fax: +1-607-255-9984* ***(Corresponding author);***

Summer Santillana, *Graduate Research Assistant,* ***Yunjie Li***, *Former Graduate Research Assistant;* ***Roberta M. Severson,*** *Former Extension Associate;* ***Nicole Tommell***, *Extension Associate.: Charles H. Dyson School of Applied Economics and Management, Cornell University, Ithaca, NY, USA*

Funding Statement

Funding for this publication was made possible by the U.S. Department of Agriculture's (USDA) Agricultural Marketing Service through grant USDA-AMS-FSMIP-G-21-0004. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA

A Needs Assessment and Financial Feasibility Tool for Solar Energy Grazing Service Cooperatives

Summer Santillana, Nicole Tommell, Todd M. Schmit*,
Yunjie Li, & Roberta M. Severson

Abstract

Solar energy production uses land that can compete with agricultural operations. Agrivoltaics, the dual use of land for solar arrays and agriculture, may remediate concerns associated with the loss of farmland. Given relatively small sheep farms in the Northeast U.S. combined with potentially large utility-scale solar arrays in the region, farmer-owned grazing service cooperatives are a logical business model to consider. We conduct a needs assessment to gauge farmer interest and develop a financial feasibility tool to provide financial planning guidance. We discuss the implications of these activities and conduct sensitivity analyses regarding key parameters associated with the cooperative enterprise.

Keywords: sheep farming, solar energy, agrivoltaics, financial feasibility, cooperatives

Introduction

The Northeast region of the United States has experienced a significant policy shift towards solar energy in recent years as states in the region aim to reduce their carbon emissions and transition to a cleaner energy system. With the increasing demand for solar energy, farmland becomes one of the most suitable targets for solar developers as they are generally open with ample sunlight, flat, and closer to electrical infrastructure, all of which are essential and cost-effective for solar companies (Pederson and Lamb 2021). However, solar companies' interests in farmland as their source for solar energy production raise concerns about the permanent conversion of farmland from agriculture use.

According to Mow (2018), solar energy capacity in the year 2030 could reach 329 gigawatts (GW), which would require approximately 1.8 million acres of land in the United States. While this takes up only 0.1% of total farmland, there is growing concern over the land use impacts of solar energy development on fertile agricultural land, which can consequently displace farming and food production (Mow 2018). In New York alone, farmland is estimated to account for 84% of solar land growth through 2030 (Katkar 2021). Acknowledging the potential harm in agriculture production and farm viability, many states have proposed policies to address these issues.

The system of agrivoltaics can be introduced to, in part, balance the demand for agriculture production and renewable energy goals. Agrivoltaics, also known as co-location, refers to agricultural production, such as crops or livestock, raised under or near solar panels (Dohlman et al. 2024). As a major category of agrivoltaics, pairing livestock grazing and solar energy production is regarded as an efficient way to benefit both farmers and solar developers at the individual and industry levels. The emphasis on solar energy resources and best management practices for agrivoltaics presents an opportunity to grow the sheep sector in the United States.

Grazing sheep under solar arrays to control vegetative growth increases gross farm income derived by providing vegetative management services and drives a need for more sheep; however, with higher operating costs given likely increases in transportation to grazing locations more distant than current use. Accordingly, the opportunity calls for additional players (and sheep) in the marketplace, along with a coordinated and collaborative response to take advantage of the opportunity in a way that minimizes grazing services costs and maximizes financial returns to sheep farms.

Research previously conducted at Cornell University explored the potential for sheep farmers in New York State (NYS) to offer grazing services (Kochendoerfer and Thonney 2021). According to data from the New York State Energy Research & Development Authority (NYSERDA), they find an estimated 10.6 GW of solar installations are anticipated to be in planning or production phases by 2030, which could result in the conversion of over 68,000 acres of land to utility-scale solar. If fully utilized for grazing and assuming a stocking rate of three sheep per acre, 204,000 sheep would be required to maintain the land (Kochendoerfer and Thonney 2021). To put that in perspective, NYS is currently home to about 79,000 sheep, implying a sheep farming industry growth of 258% to meet new grazing demand (USDA 2022).

Author discussions with the American Sheep Grazing Association (ASGA) reveal that many individual farmers lack the necessary resources and negotiating skills to secure grazing contracts with solar array operators. Additionally, these solar array operators prefer to work with a single agent for contractual agreements and grazing logistics rather than multiple farmers. Negotiating individual agreements at scale is highly inefficient, creating significant barriers to entry and reducing financial feasibility. Thus, a cooperative business model could be a potential solution as it would centralize communications with solar energy stakeholders while coordinating the logistics with sheep farmers.

There is currently no contemporary research that examines the implications of co-locating sheep farming with solar energy developments through a farmer-owned grazing cooperative. This research provides a needs assessment for solar grazing informed by existing sheep and non-sheep farmers in the Northeast U.S. and a financial feasibility tool regarding the requirements for a successful cooperative business. Furthermore, we provide insights into key input values for a profitable cooperative (e.g., contract fees, member size, farm and array travel distances).

We continue with a description of the farm survey data and results. This is followed by a description of the financial feasibility tool and sensitivity testing on key financial parameters. We close with conclusions and directions for future research.

Survey Data

To have a better understanding of the demand for and potential development of solar grazing cooperatives, a needs assessment survey was administered to gather input from current and prospective sheep farmers.[1] The survey was advertised through multiple communication channels and was pre-tested by the project advisory team including sheep farmers and livestock extension educators for clarity.

The survey opened online via Qualtrics on September 25, 2022, and closed on January 15, 2023. The survey was available both online and through hard copy (paper) versions. In some cases, educators worked with a single farmer or groups of farmers to assist in completing the survey online or in hard copy. It

[1] The full survey is available at: https://cornell.box.com/v/SolarSheepFinancialTool.

was promoted to extension educators representing 11 universities located in New England, New York, Ohio, and Mid-Atlantic states. It was also promoted through all Cornell Cooperative Extension (CCE) offices in NYS, through 13 sheep industry associations in the Northeast, and distributed nationally by ASGA and the American Sheep Industry Association (ASIA). The survey was also disseminated through press releases sent to agriculture trade publications and individual farmers through a database constructed of 1,700 email addresses of sheep farmers located within 11 Northeast states. A financial incentive was provided: people completing the survey and sharing their name and email address were enrolled in a random drawing for one of three $100 gift cards.

At the beginning of the survey, respondents selected one of eight descriptions that most closely characterize them:

1) I am a full-time sheep farmer grazing my sheep under solar arrays,
2) I am a part-time sheep farmer grazing my sheep under solar arrays,
3) I am a sheep farmer grazing my sheep <u>and</u> sheep I lease from others under solar arrays,
4) I lease some or all of my sheep to another person who grazes them under solar arrays,
5) I am a sheep farmer not currently grazing under solar arrays but interested in exploring,
6) I am a sheep farmer and am not interested in grazing my sheep under solar arrays,
7) I am a non-sheep farmer interested in grazing sheep under solar arrays, and

8) I am a new or beginning farmer interested in sheep farming and grazing under solar arrays.

A total of 1,327 responses were received. Of these, 474 failed simple farmer screening questions; 128 passed the screening questions but answered no others, and 122 passed the screening questions and gave their respondent type but answered no others. Hence, 603 observations (45%) were usable for analysis. The survey data contain numerous variables relevant to sheep grazing services under solar arrays that we consider for the cooperative.[2]

The breakdown of all respondents by type is shown in Figure 1. The most frequent type of respondents were sheep farmers who are not currently grazing under arrays but are willing to explore (47%). The next most frequent were full-time sheep farmers already grazing under solar arrays (17%). Overall, 34% of respondents were currently grazing their sheep under arrays either directly or contracted out with others.

The focus of our analysis is on the Northeast U.S.; however, the survey was available broadly and included valid responses from 44 different states. Respondents were categorized by Northeast (N = 392) and Non-Northeast (N=211) regions. The Northeast region includes 11 states in our analysis (NY, ME, MA, VT, CT, NH, PA, MD, NJ, DE, OH) and the District of Columbia. Summary statistics computed from current solar array graziers on the number and size of solar arrays grazed and the distance and time demands for different

[2] Additional questions on other potential cooperative services included input supply services, collective marketing, slaughter, processing, and branding activities were also included the survey but are not included here to focus on vegetative management services related to solar array grazing.

grazing activities were used to inform baseline parameters of the financial feasibility tool discussed later.

The primary reason for vegetative management services on solar arrays is to prevent shading of the panels. Mechanical mowing (using fossil fuels) can fulfill this objective like grazing sheep, but with perhaps less outward appeal for a renewable energy company. That said, the financial feasibility tool considers costs for supplemental mowing, as found necessary from the farmer survey. We consider three business segments associated with a grazing services cooperative in the survey, which is then carried through to the development of the financial tool.

The first business segment is contract negotiation. Contract negotiation services involve the negotiation process with array operators on the terms of the grazing contract. These terms include the payment per acre for grazing services, as well as responsibilities associated with providing water and fencing, the length of the grazing season, insurance requirements, and access to the site, among others.

The second business segment is mobilization. Mobilization services involve the collection and transport of members' sheep from farms to arrays at the beginning of the grazing season and returning those sheep back to the farms at the end of the season. The final business segment is shepherding. Shepherding services involve designated cooperative staff (shepherds) inspecting sheep on solar sites, attending to any husbandry and/or medical issues, and inspection, repairs, and relocation of fencing within the array as necessary. The needs assessment survey revealed existing graziers inspect sheep two times per week, on average. This is one of many parameters updateable in the financial tool that will be discussed in depth later.

Survey Results

Survey analysis provides useful insights into farmers' opinions towards different aspects of solar grazing and interest in being part of a user-owned cooperatively structured business. Given differences in sheep farming practices and utility-scale solar energy installations across the country, we limit our focus to the Northeast region subsample. Further, we aggregate the eight respondent types into four groups (A, B, C, and D) by the nature of their solar grazing activity and interests:

1) Sheep farmers whose sheep graze under solar arrays currently (1, 2, 3, 4),
2) Sheep farmers not grazing sheep currently, but are interested in pursuing it (5);
3) Existing, new, or beginning farmers without sheep considering solar sheep grazing (7, 8);
4) Sheep farmers not interested in solar sheep grazing (6).

In the needs assessment portion of the survey, we explore the industry need for and the likelihood of joining a cooperatively structured business to provide services on behalf of farmer members.[3] For example, the questions about contract negotiation services were:

---

[3] The needs assessment questions were phrased to allow for more than one legal form of a cooperatively structured business; i.e., beyond a cooperative corporation defined in state statute. For example, some cooperatively structured businesses; i.e., business that operate following cooperative principles, may be organized as Limited Liability Companies (LLCs) or Limited Cooperative Associations (LCAs), among other legal entities. Our intention of adding "other business owned by multiple farmers" was to allow for that possibility, while being clear that the farmer-member-owners had control and residual claimant rights (see full survey and instructions included within it). Follow on focus group discussions with survey participants revealed a generally consistent interpretation to our questions.

> *In your opinion, what is the industry's need for a cooperative or other business owned by multiple farmers to negotiate contracts between the site operator and whomever is providing vegetative management services?*
>
> and
>
> *How likely would you utilize a cooperative or other business owned by multiple farmers to negotiate contracts between site operators and people providing vegetative services if provided for a reasonable fee?*

Scores were assigned from 0 (not needed/not likely) to 4 (extremely needed/extremely likely), by increments of one for each ascending order of need/likelihood. Average scores and the percent of respondents rating services as needed/likely or above are computed by group and service component (Table 1).

Average industry scores were highest for farmers experienced with solar array grazing, demonstrating farmer cooperation on services is additionally valuable to them; i.e., they identify the potential for additional benefits through collaboration. Such results may be particularly useful in communications with existing sheep farmers but inexperienced in array grazing as their scores were generally the lowest among those considering it.

For those participating or interested in exploring solar grazing (A, B, C), mobilization and shepherding scores are lower than for contract negotiation (Table 1). This is consistent with feedback expressed in follow-on focus groups regarding animal health concerns for comingling of sheep and resistance to having others monitor their sheep. Scores above one, and frequently near or above two, demonstrate sufficient interest in exploring a cooperative business for the execution of collaborative grazing services. The relatively high scores for contract negotiation and shepherding by group D is recognition that these services would be valuable for the industry even though they have no interest in participating in array grazing themselves.

Barriers

Barriers in array grazing were asked to all survey respondents. Using a similar scoring system as above, average scores across barriers and differentiated by group are shown in Table 2. Experienced solar graziers were primarily concerned with travel distances and time demands for monitoring sheep during the season. Monitoring sheep represents a significant cost in farmers' time, fuel, and other expenses. They were also concerned with time and equipment constraints for supplemental mowing.

Sheep farmers not currently solar grazing see access to water, travel distances, and the cost of liability insurance as primary constraints. Availability of and access to water is part of the contract negotiation process. In many cases, drilling a well to access water on site for sheep is necessary and comes with a significant cost (at least initially). However, the relatively low value of this barrier for current solar graziers likely implies that this is often provided by array operators. Liability insurance requirements for array grazing are likely beyond insurance limits currently used by farm operators. Accordingly, the additional cost can be a significant issue for farmers and scored relatively high by group A as well.

New and beginning farmers particularly recognized capital constraints in terms of needed trucks and trailers. Mobilization and shepherding services require capital investments related to trucks, trailers, and fencing, along with the reinvestment of the depreciation of those assets over time. The primary barriers appear to align well with potential services that could be offered by a cooperative.

As part of any cooperative development process, gauging interest in members taking on leadership, investment, and governance roles is essential. Specifically, respondents were asked:

> *If a cooperative or other business owned by multiple farmers was formed to provide assistance to farmers grazing sheep under solar arrays and strengthen the viability of the sheep farming sector, what is your interest in the following to support this effort?*

The set of interests related to the cooperative are shown in Table 3, with average numerical scores presented by group. The scale of interests range from 0 (not interested) to 3 (very interested).

Some interests can be interpreted similarly; e.g., to become a "member owner of the cooperative" and to become a "part owner of the business." Members are often (and correctly) described as member owners as they have ownership rights and responsibilities of the business; however, member and/or non-member investment (say through a preferred stock offering that pays a dividend) is also possible (subject to the bylaws of the organization) that is also (and correctly) a form of ownership in the business, albeit often without additional control rights.

It is perhaps not surprising that current solar graziers (group A) rate being a paid "contract service provider" for the cooperative relatively high given their current industry experience; however, they also rank second across all groups in terms of interests in becoming “member owners”. Perhaps also consistent with their experience, they may recognize what they prefer to “do” and “not do” with respect to array grazing and, therefore, rank highly being a (nonmember) “customer” of the cooperative’s services. Perhaps most important is Group A farmers have the highest interest in investing in the business, providing guidance and leadership on the development of the business, and serving in a leadership capacity after the business is formed. Relevant experience is valuable to the development of a new cooperative and in using that experience to inform others who are considering being part of it.

While lower in relative magnitude, current non-array grazing sheep farmers rank being a member owner of the cooperative and providing guidance and leadership through the development process most important to them. Non-sheep farmers ranked being a member owner of the cooperative most important, perhaps, a reflection of less experience in sheep farming and the individual benefits they would receive by joining ownership with sheep farmers that have that wisdom to share.

The lower scores for becoming an investor in the business may well reflect the capital constraint issues described above. The time to generate adequate member equity support during the development of a cooperative often delays the start-up of the organization or even stops the process in its entirety. Accordingly, financial feasibility analyses, encompassing both operational and investment costs and returns to member investment are important in informing the development process. It is to this issue that we turn to next.

Financial Feasibility Tool

Financial evaluation is a critical component of the process of cooperative development as it informs potential members and investors the expected profitability of the venture and the sensitivity of the results on key parameters. In assessing the feasibility of a new solar grazing cooperative, we developed a financial feasibility tool for farmers that provide 10-year financial projections assuming a base set of input parameters (Santillana et al. 2025; Schmit et al. 2025).

The cooperative is assumed to be a closed membership cooperative whereby the demand for grazing services is tied to the supply of sheep provided by members. If users of the tool include cooperative growth (in terms of solar array acres managed), that growth is technically fulfilled by new members to the cooperative, with a comparable direct capital investment required (computed in the tool) based on the number of sheep. Of course, the cooperative can also meet demand growth from existing members (through farm growth); however, the associated revenue and cost implications in the tool are equivalent.

The outputs of the financial tool include standard financial statements: an income statement, balance sheet, cash flow statement, and statement of member equities by year. In our setting, operational revenues are derived solely from lease payments by solar array operators to the cooperative for grazing services. There are several operating and capital expenses related to the costs of services, management expenses, capital investment, and depreciation. Revenues and costs are a function of the growth of the business over time.

Output sheets also include the calculation of cooperative-level returns; i.e., return on investment (ROI), return on assets (ROA), net present value (NPV), and internal rate of return (IRR), and member-level returns based on member distributions (patronage refunds) and equity investments; i.e., ROI, NPV, and IRR.

The financial tool allows for customizing profit distribution through unallocated equity and cash and stock patronage refunds.[4] Patronage refunds are based on member use; i.e., the number of sheep provided for grazing. The tool is set up to consider stock patronage refunds as either qualified or nonqualified distributions. The allocation affects to whom (the cooperative or the member) and when income taxes are paid. For our illustrative example, we assume 10% of profits is retained as unallocated equity, 70% is distributed as a cash patronage refund, and 20% is distributed as qualified stock patronage refunds.

The tool allows for three sources of investment to initially capitalize the business: direct member investment, grants, and debt. As such, liabilities include a working capital loan, a long-term loan (portion of initial capital investment), and deferred revenues from grant funding (portion of the initial capital investment). Operational cash flows include net income from operation, other income (e.g., grants), and depreciation and amortization (as an adjustment to reconcile net income to net cash). Investment cash flows are limited to cash outflows from capital investment for equipment.[5] Financing cash flows relate to the change in long-term debt, cash patronage refunds, qualified stock patronage refunds redeemed, and new member stock investments based on sheep demand for grazing.

---

[4] The tool assumes that retained patronage refunds are redeemed using a revolving fund plan with revolving period set by the user (5 years in our example).

[5] The tool assumes fully depreciated assets generate no residual cash flow from their disposition (sale).

Typically, financial feasibility is evaluated over a project horizon to demonstrate economic viability from the perspective of members or potential investors and using metrics that account for capital recovery and the time value of money. For ease of exposition, our illustrative example considers minimum financial feasibility as the cooperative level NPV = 0 using a discount rate of 8%. Users of the tool can impose their own financial feasibility conditions (e.g., cash flow constraints, minimum IRR, ROI, etc.) and preferred discount rate based on the cost of capital or prevailing interest rates.

Input Parameters

Table 4 presents the input parameters required in the financial tool and the default values applied for our illustrative example. Importantly, all the listed parameters are adjustable by the user for their own purposes and sensitivity analyses. The tool is constructed with two input worksheets designed for easy customization. The primary input sheet includes fundamental assumptions and topline parameters such as investment funding, profit distribution, numbers of members/arrays, farm/array size, grazing payment rate, etc. The second input sheet provides more detailed coefficients such as grazing densities, equipment investment, depreciation schedules, maintenance costs, mileage rates, fuel price, etc. Detailed instructions for using the tool are available in Santillana et al. (2025).

The model includes a base year (year 0) where member recruitment is completed, the business is established, financial resources are obtained, a core management team and board of directors are functioning, and capital investments are completed prior to the first year of grazing services. As indicated above, the tool assumes all costs incurred in the base year (operational and capital) are satisfied by a combination of upfront member investment, loans, and grants; in our example we selected 40%, 40%, 20%, respectively.[6]

Revenue

As discussed above, cooperative revenue is based on lease payments from solar array owners to the cooperative for vegetative management services. Lease payments are agreed upon through contract negotiation with array owners and can vary based on other conferred responsibilities associated with the vegetative services provided. Recent solar lease payments in the Northeast U.S. range from $250 to $750 per acre (ASGA 2020). The lease payment rate is updateable by the user to understand at what payment rate the user-established financial feasibility condition is satisfied.

Given that revenue is accrued on a per acre basis, the cooperative's income is highly dependent on the size of the arrays being serviced. Additionally, the total acreage of solar arrays being serviced determines the number of sheep required. While the total solar acreage and number of sheep are important, another aspect that importantly informs the cooperative's feasibility is the number of and distance between farms, arrays, and cooperative locations, collectively defined as "nodes" in the model.

Costs

The baseline example uses a 27-week grazing season (Kochendoerfer and Thonney 2021). Wage rates for cooperative employees and contractors follow

[6] The grant is treated as a one-time payment in the base year. Following financial accounting principles, the grant is classified as "other income" It shows up in the income statement amortized over its useful life and also in the balance sheet as deferred revenue. Since the grant is received as cash in the base year, there is a cash inflow in cash flow statement by the full amount, and the amortized amount of "other income" is subtracted from the net income in the cash flow statement.

prevailing wage rates in the region (Table 4). To account for increases in business skills and inflationary pressures, we assume lease payments increase 3% per year, while operational costs (i.e., labor and supplies) and capital investments (i.e., fencing, trucks, and trailers) increase 2% per annum. Capital expenditures on trucks, trailers, and fencing have an eight-year useful life, and all-terrain vehicles (ATVs) have a ten-year useful life. For simplicity in financial budgeting, all are depreciated using the straight-line method.

Contract Negotiation

Costs for contract negotiation include effort by the core management team, liability insurance requirements, and legal services (Table 4). The core management team is composed of a Chief Executive Officer (CEO), Logistics Supervisor, Contract Specialist, and Member Relations/Marketing Manager. The core management team are salaried employees of the cooperative with benefits and their size over time is a function of growth in grazing services. We assume accountant services are contracted out (no benefits). A five-member board of directors receives annual compensation of $5,000 per director.

Liability insurance costs are measured on a per acre basis and set at an individual farm rate of $50 (ASGA 2020). Since the cooperative negotiates insurance rates to provide coverage for all members, we estimate a rate of $30/acre; approximately 60% of the cost for individual farms. We assume the cooperative's legal service fees to be two-thirds of individual farm fees given economies of scale from multiple, similar contracts across arrays and years. Advisory team input on individual farm legal costs implied a $380 per contract fee (Table 4).

Nodes

One of the main purposes of the cooperative is to decrease costs by increasing travel efficiencies for mobilization and shepherding. This is done by decreasing the total number trips for mobilization and shepherding relative to individual farm actions. Put differently, depending on farm size and location, multiple farms may be served during a single mobilization trip to and from arrays. Similarly, sheep from multiple farms at one array require one shepherd trip rather than a trip by each individual farm that has sheep on the site. Depending on node distance, sheep at multiple arrays can be monitored during a single shepherding workday.

A higher proportion of array acres from larger arrays (i.e., less nodes) will require lower lease rates to meet the same feasibility condition than with a higher proportion of array acres spread across multiple smaller arrays (i.e., more nodes). The argument equally applies to proportion of sheep provided by larger or smaller farms.

To illustrate the financial tool, we assume in year one that the cooperative is servicing three solar arrays: one small array at 25 acres, one medium array at 80 acres, and one large array at 500 acres (Table 5). The number of sheep needed for grazing is based on an average stocking rate of 3 sheep per acre (ASGA 2020). In our baseline, a minimum of 1,815 sheep is required. The model allows for allocation of sheep from farms based on average farm sizes input by the user. Our baseline includes two small farms at an average of 100 sheep each, three medium farms with an average of 220 sheep each, and one large farm with 1,000 sheep.

Mobilization

A relatively short duration for mobilization at the beginning (and end) of the grazing season implies high capital utilization (trucks and trailers) for a limited time. Relative to capital required for shepherding during the season, purchasing all trucks and trailers necessary for mobilization implies underutilized capital during the grazing season. Accordingly, the tool computes the number of trucks and trailers required for each service based on user input values. Ultimately, the model assumes ownership of capital for shepherding services and contracts out for additional hauling services need for mobilization ($4.50/mile, CCE-FC 2022). For ease of exposition, the algorithm to compute custom haulers for mobilization is included in Appendix 1.

Shepherding

Shepherding involves evaluation of sheep health on the solar arrays during the grazing season and monitoring fencing and vegetative conditions. Costs related to shepherding services include transportation, fencing materials, labor, and fuel. For ease of exposition, the computation of total shepherding hours and assets is included in Appendix 1 for the interested reader.

Based on the needs assessment survey, we include one supplemental mechanical mowing per season (adjustable by the user) that is outsourced to landscape contractors at a rate $60 per hour and one-half hour per acre (CCE-FC 2022). Alternatively, the cooperative could consider buying their own mowers and trimmers and employ labor for mechanical mowing. In either case, they represent different forms of costs to the cooperative that in competitive markets should be similar for the business. For simplicity, we assume these services are contracted for.

Costs of fencing are a function of paddock size (Table 4). We assume paddock sizes are evenly distributed among 1, 2, and 5 acre paddocks, for an average paddock size of 2.67 acres and 1,294 linear feet of fencing. Initial fence installation time is one hour per acre, and preexisting fencing requires repair and adjustments of half of that amount.

Financial Results – Baseline Illustration

Considering the high end of the range for lease payments in the Northeast U.S. of $750 per acre and the input parameters from Table 4, the minimum financial condition of positive NPV at the cooperative level is achieved ($752,084). Subsequently, we reduce the lease payment to identify the minimum lease payment that meets the financial feasibility condition. For our example, the minimum lease payment is $627 per acre. A detailed examination of the results is available to the interested reader from Schmit et al. (2025).

Sensitivity Analyses

For the first sensitivity analysis we examine differences in the minimum lease payment if all arrays are in a single size category (Table 6). For each case, we leave total acres serviced approximately constant (605 acres). Specifically, to limit the number of arrays to whole numbers, we adjust the number of arrays to the nearest whole number. For example, 7.56 medium arrays are required to service 605 acres (605/80). We round up the number of arrays to 8 (640 acres).

As expected, profitability is highly sensitive to the number and size of arrays. To meet our financial feasibility condition, lease payments to service only small or only medium arrays exceed the maximum payments experienced in recent years. Sufficiently large arrays are simply necessary to capture collaborative cost savings.

In a similar fashion, we consider the sensitivity of our baseline results to changes in the distribution of farms by size, while holding the number and size of arrays at the baseline (Table 7). As specified in the tool, we adjust the percentage of sheep sourced from alternative sizes of farms to: all small farms, all medium farms, and all large farms.

As expected, minimum lease payments decrease with increases in the proportion of sheep sourced from larger farms. From the only-small to the only-large scenarios, the number of farms required decreases from 18 to 2. The results are relatively less sensitive than in the case for arrays but still demonstrate the importance of securing a sufficient number of sheep from larger farms (i.e., less farm nodes) to capture scale efficiencies. In addition, the only-medium scenario indicates minimum lease payments below the maximum experienced in the region recently. While scale economies play a substantial role, the baseline condition represents a situation where a heterogenous membership conditions meets financial goals. The result is consistent with many contemporary farmer-owned cooperatives whereby a relatively small proportion of members make up a relatively large portion of patronage activity.

Finally, we consider financial sensitivity to the average distance between nodes (farms, arrays, and co-op locations). Average distances between nodes range between 20 and 100 miles, with all other input values set at the baseline (Table 8). As expected, minimum lease payments increase with travel distance given higher transportation costs (travel time, fuel). Given the number of nodes in the baseline (6 farms + 3 arrays + 1 co-op = 10) and the array and farm size distributions, expanding the average distance between nodes has a significant influence on financial feasibility.

As average distances between nodes approaches 100 miles, minimum lease payments exceed maximum payments experienced historically in the region. Overall, each additional mile of average distance in our baseline example translates into roughly $3.50 premium to the per acre lease payment to meet our financial feasibility condition.

Conclusions

Local, state, and federal policy support for expanding renewable energy production in the United States is increasing, with aggressive renewable energy goals. The opportunity for farms to expand vegetative management services with solar array operators is relatively large given that less than 10% of solar acres are currently grazed by sheep. The opportunity can present benefits to sheep farmers given that the services provided result in (free) feed for sheep and compensation for those services. However, understanding increases in costs involved in providing those services, relative to current practice, are ultimately required to understand the potential implications for industry growth.

Given the relatively large size of solar arrays in or planned for production in comparison to the size and distribution of sheep farms in the Northeast U.S., grazing demands for most arrays will require sheep from multiple farms. The results of a needs assessment survey to current and prospective sheep farmers demonstrate sufficient interest by current solar graziers, sheep farmers not yet experienced in solar grazing, and new farmers interested in entering sheep farming that involves solar grazing to explore a cooperative business model for coordination and management of grazing services across farms and solar sites.

The differences in expected barriers to grazing sheep under solar arrays across types of farms is informative in developing effective cooperative development information sessions for collective action.

The barriers expressed are explicitly considered in the development of a financial feasibility tool for a proposed farmer-owned solar grazing cooperative. The tool considers a detailed analysis of the costs associated with contract negotiation, mobilization, and shepherding services and identifies minimum lease payment rates required by solar array operators for financial business success. Additional analysis showed financial sensitivity to various model parameters such as number of solar arrays, distribution of sheep from farms, mobilization period, and average distance between farms and arrays. The tool allows for customization of numerous input parameters based on individual situations such that users can evaluate projected changes in financial returns in real time with the tool.

The financial tool is designed to allow for easy customization across alternative input parameters such as capital investment endowments, labor rates, fuel costs, and the size of the core management team. Accordingly, the financial model can serve as an updateable tool throughout the process of cooperative development with interested farmers and provide useful information to lenders and government agencies for potential financial support.

The baseline results presented here are based on fixed parameter assumptions. Incorporating stochastic processes on primary model parameters through monte carlo simulation or other means can provide a more complete feasibility assessment that takes into account risk. For example, lease payments by array operators are, ultimately, a function of electricity prices through the demand for solar energy. Similarly, mobilization and shepherding services come with large demands for fuel for which prices are quite volatile. Incorporating risk on these parameters provides a more informed depiction of long-term financial success and identifies opportunities for risk management such as through hedging and fixed contract arrangements.

Reference

ASGA. 2020. "Utility Dive Does a Deep Dive on Solar Grazing." American Solar Grazing Association. https://solargrazing.org/utility-dive-does-a-deep-dive-on-solar-grazing/.

Cornell Cooperative Extension - Franklin County (CCE-FC). 2022. "Custom Rates & Fees." Cornell Cooperative Extension, Cornell University. https://franklin.cce.cornell.edu/resources/2022-custom-rates-and-fees

Dohlman, E., K. Maguire, W.V. Davis, M. Husby, J. Bovay, C. Weber, and Y. Lee. 2024. "Trends, Insights, and Future Prospects for Production in Controlled Environment Agriculture and Agrivoltaics Systems." *U.S. Department of Agriculture, Economic Research Service,* Report No. EIB-264. https://doi.org/10.32747/2024.8254671.ers.

Katkar, V., J. Sward, A. Worsley, and K.M. Zhang. 2021. "Strategic Land Use Analysis for Solar Energy Development in New York State." *Renewable Energy* 173:861–875. https://doi.org/10.1016/j.renene.2021.03.128.

Kochendoerfer, N., and M. Thonney. 2021. "Grazing Sheep on Solar Sites in New York State: Opportunities and Challenges." White Paper, Department of Animal Science, Cornell University. https://bpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/c/9310/files/2021/03/Solar-Site-Sheep-Grazing-in-NY-v2.1.pdf.

Mow, B. 2018. "Solar Sheep and Voltaic Veggies: Uniting Solar Power and Agriculture." *National Renewable Energy Laboratory (NREL).* https://www.nrel.gov/state-local-tribal/blog/posts/solar-sheep-and-voltaic-veggies-uniting-solar-power-and-agriculture.html.

Pedersen, B., and B. Lamb. 2021. "Agrivoltaics: Producing Solar Energy While Protecting Farmland." Center for Business and the Environment, Yale University. https://cbey.yale.edu/research/agrivoltaics-producing-solar-energy-while-protecting-farmland

Santillana, S., T.M. Schmit, N. Tommell, Y. Li, and R. Severson. 2025. "How to Financial Feasibility Tool: Agrivoltaics Solar Sheep Cooperatives." Extension Bulletin, EB 2025-10, Charles H. Dyson School of Applied Economics and Management, Cornell University, Ithaca, NY, USA.

Schmit, T.M., S.D. Santillana, N. Tommell, Y. Li, and R.M. Severson. 2025. *Financial Feasibility Tool for a Farmer-Owned Agrivoltaic Sheep Grazing Cooperative*. Version 1.0. Cooperative Enterprise Program, Charles H. Dyson School of Applied Economics and Management, Cornell University. https://cornell.box.com/v/SolarSheepFinancialTool

United States Department of Agriculture (USDA). 2020. "2020 State Agriculture Overview for New York." National Agricultural Statistics Service, Washington DC https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NEW%20YORK.

Appendix 1. Mobilization and Shepherding Computations

Custom Haulers during Mobilization

The computation for the number of custom haulers (*H*) can be expressed as:

$$(1)\ (N_s/S_t)T \leq D_m h$$

Subject to:

$$(2)\ T = \big(n(d/s)\big) + (n-1)t$$

$$(3)\ N_s = n_a a s_r$$

$$(4)\ S_t' = N_s T / h D_m$$

$$(5)\ H = S_t'/c$$

where T is the total time needed to mobilize sheep, n is the number of nodes, d is the average distance between nodes, s is average driving speed, t is the time required to load and unload sheep, N_s is total sheep, n_a is the number of arrays, a is average acres per array, s_r is the stocking rate, S_t' is sheep per trip, h is hours per day, D_m is days for mobilization. H is the number of haulers, and c is trailer capacity. Total outsourcing costs are based on total hauler miles and a per mile contracting rate. The cooperative-owned assets used for mobilization accrue labor and fuel costs.

Appendix 1. Mobilization and Shepherding Computations (cont.)

Shepherding Hours and Capital Requirements

The computation of total shepherding hours and assets can be expressed as:

$$(6)\ T_s = V_s\left[\left(n_s(d/s)\right) + (n_s - 1)t_s N_{s,a}\right]$$

$$(7)\ N_t = T_s/(d_w h_s)$$

where T_s is time required each week during the grazing season for shepherding, V_s is number visits per week, n_s is shepherding nodes (i.e., exclude farm nodes), d is average distance between nodes, s = is average travel speed, t_s is shepherding time per sheep, $N_{s,a}$ is average number of sheep per array site, N_t is number of trucks for shepherding (equal to the number of shepherds), d_w is days worked per week by shepherds, and h_s = shepherd hours worked per day.

Table 1.. Industry need for and likelihood of individuals using cooperative grazing services, by group.

		Contract Negotiation				Mobilization				Shepherding			
		Industry[b]		Individual[c]		Industry		Individual		Industry		Individual	
Group[a]	N	Avg.	Need+	Avg.	Likely+	Avg.	Need+	Avg.	Likely+	Avg.	Need+	Avg.	Likely+
A	75	2.09	69%	2.24	70%	1.86	59%	2.02	65%	2.00	72%	2.03	66%
B	229	1.98	65%	1.70	43%	1.61	48%	1.27	36%	1.64	52%	1.44	41%
C	37	1.89	73%	2.05	62%	1.81	62%	2.00	64%	1.39	46%	1.17	35%
D	51	1.86	71%	0.97	26%	1.66	57%	1.28	31%	2.03	71%	1.19	44%

Source: Author survey, Northeast U.S. region.

[a] Respondents by group include: A = Sheep farmers whose sheep graze under solar arrays currently; B = Sheep farmers not grazing sheep currently but interested in pursuing; C = Existing, new, or beginning farmers without sheep considering solar sheep grazing; and D = Sheep farmers not interested solar sheep grazing.

[b] The industry scores represent the average industry need (Avg.) for a cooperative to provide the service of respondents in that type, where not needed = 0, somewhat needed = 1, needed = 2, very needed = 3, and extremely needed = 4. Need+ represents the percent of respondents that answered needed or higher.

[c] The individual scores represent the average likelihood that respondents would use those services of the cooperative, where not likely = 0, somewhat likely = 1, likely = 2, very likely = 3, and extremely likely = 4. Likely+ represents the percent of respondents that answered likely or higher.

Table 2. Barriers to solar sheep grazing, average scores by group.[a]

Barrier	**All** N = 392	**A** N = 75	**B** N = 229	**C** N = 37	**D** N = 51
Easy access to water	1.79	1.16	2.01	1.78	1.73
Travel distance to monitor sheep	1.79	1.50	1.94	1.50	1.79
Cost of insurance	1.77	1.38	1.89	1.83	1.79
Insurance requirements	1.68	1.24	1.84	1.43	1.79
Negotiating the contract	1.62	1.08	1.79	1.62	1.70
Time on site to mow or trim	1.62	1.44	1.74	1.33	1.54
Access to person willing to lease my sheep	1.58	0.97	1.75	1.65	1.67
Time on site to monitor sheep	1.52	1.24	1.60	1.32	1.73
Lack of knowledge about solar grazing	1.52	1.23	1.58	1.62	1.58
Equipment needed to mechanically mow or trim	1.50	1.40	1.55	1.49	1.44
Access to handling equipment at the solar site	1.48	1.10	1.51	1.64	1.82
Identifying the array operator	1.43	0.77	1.69	1.16	1.43
Access to trucks/trailers to move sheep	1.14	0.96	1.13	1.73	0.98

Source: Author survey, Northeast U.S. region.

[a] Respondents by group include: A = sheep farmers whose sheep graze under solar arrays; B = sheep farmers not grazing sheep currently but interested in pursuing; C = existing, new, or beginning farmers without sheep considering solar sheep grazing; and D = sheep farmers not interested solar sheep grazing. Average scores are computed where not a barrier = 0, small barrier = 1, medium barrier = 2, and large barrier = 3.

Table 3. Interests in actions of the cooperative, average scores by group.[a]

Interest	**All** N = 392	**A** N = 75	**B** N = 229	**C** N = 37	**D** N = 51
Become a member-owner of a cooperative	1.59	1.82	1.58	2.00	0.91
Provide guidance & leadership to develop & launch the business	1.38	1.67	1.37	1.60	0.76
Be a "customer only" with access to services when needed	1.36	1.90	1.20	1.56	1.00
Become part owner of the business	1.23	1.70	1.12	1.58	0.66
Serve in a leadership capacity (director, officer, committee)	1.19	1.71	1.09	1.25	0.69
Be a paid contract service provider	1.14	1.85	0.96	1.32	0.66
Become part of the paid management team	1.09	1.61	0.92	1.20	0.91
Become an investor in the business	1.00	1.60	0.83	1.24	0.59
Become a paid employee	0.93	1.51	0.75	1.12	0.63

Source: Author survey, Northeast U.S. region.

[a] Respondents by group include: A = sheep farmers whose sheep graze under solar arrays; B = sheep farmers not grazing sheep currently but interested in pursuing; C = existing, new, or beginning farmers without sheep considering solar sheep grazing; and D = sheep farmers not interested solar sheep grazing. Average scores are computed where not interested = 0, somewhat interested = 1, interested = 2, and very interested = 3.

Table 4. Updateable input parameters for financial tool and baseline values.

Parameter	**Baseline Value**
General	
Solar grazing land anticipated in year 0 (acres)	605
Annual growth rate of solar grazing acres (percent)	5
Stocking rate (sheep/acre)	3
Length of grazing season (weeks)	27
Fuel price ($/gallon)	4.00
Average driving speed, mobilization/shepherding (miles/hour)	45
Average distance between farms and arrays (miles)	50
Annual inflationary cost rate (%)	2
Annual inflationary lease rate (%)	3
Supplemental mechanical mowing cost ($/hour)	60
Average time spent mechanical mowing (hours/acre)	0.5
Useful life of trucks & trailers (years)	8
Useful life of ATVs (years)	10
Annual truck maintenance cost ($/truck)	1,000
Annual trailer maintenance cost ($/trailer)	500
Annual ATV maintenance cost ($/ATV)	200
Core Management Team	
Chief Executive Officer ($/year)	75,000
Logistics Supervisor ($/year)	55,000
Contract Specialist ($/year)	55,000
Member Relations & Marketing ($/year)	55,000
Accountant, Contract ($/year)	55,000
Member Directors (number)	5
Director compensation ($/year)	5,000
Benefit rate (%)	30
Investment & Equity	
Investment allocation, Grant/Loan/Member common stock (%)	20/40/40
Capital investment loan interest rate (%)	8
Loan amortizations term (years)	10
Working capital loan ($)	250,000
Working capital loan rate (%)	7
Discount rate (%)	8
Allocated equity patronage refund revolving period (years)	5

Table 4. Updateable input parameters for financial tool and baseline values.

Parameter	Baseline Value
Contract Negotiation	
Farmer legal fees ($/contract)	250
Farmer liability insurance cost ($/acre)	50
Mobilization	
Contracted custom haulers (drivers + equipment) for mobilization ($/mile)	4.5
Large trailer capacity for mobilization (sheep)	75
Loading/Unloading time on site, farm/array (hours)	1
Labor hours available per day (hours/day)	24
Mobilization period: Time available to move sheep to/from arrays (days)	14
Mobilization periods per season	2
Shepherding	
Wage rate, shepherding services ($/hour)	40
Half ton truck price for cooperative purchase ($)	75,000
Medium trailer price for cooperative purchase ($)	15,000
Medium trailer capacity for shepherding (sheep)	25
Fuel mileage of half ton truck (miles/gallon)	20
Average shepherding visits (visits/week)	2
Time to shepherd (hours/sheep)	0.05
Days per week shepherding (days/week)	7
Labor hours available per day (hours/day)	8
Fence Installation	
Wage rate, fence installation ($/hour)	40
New fencing installation set up time (hours/acre)	1
Fencing repair and adjustment time (hours/acre)	0.5
Installation time – small array (hours)	5
Installation time – medium array (hours)	10
Installation time – large array (hours)	20
Single spike netting, 164' x 35" ($)	135

Table 5. Baseline parameters of array and member size for financial feasibility projections.

Solar Arrays	Arrays	Array size	% of arrays	% of acreage
Small array	1	25	33	4
Medium array	1	80	33	13
Large array	1	500	33	83
Total	3	605	100	100
Total sheep required = 1,815 (3 sheep/acre x 605)				
Farms	**Members**	**Farm size (Sheep)**	**% of Farms**	**% of Sheep**
Small farm	2	100	33	10
Medium Farm	3	220	50	35
Large Farm	1	1,000	17	55
Total	6	1,858	100	100
Total sheep available = 1,858				

Note: Sheep available must be at least as large as sheep required. Given integer values for arrays and farms in our illustrative example, the number of sheep supplied is close to but not exactly the number of sheep required.

Table 6. Minimum lease payments as the distribution of solar arrays by size change.[a]

	Number of Solar Arrays			
Distribution	Small (25 acres)	Medium (80 acres)	Large (500 acres)	Payment ($/acre)
Baseline	1	1	1	627
Only small	24	0	0	1,318
Only medium	0	8	0	829
Only large	0	0	1	549

[a] Total acres of arrays serviced is held approximately constant at 605 acres, subject to rounding for integer array counts. Payment represents the minimum lease payment to meet the financial feasibility condition of positive NPV at the co-op level over the 10-year planning horizon (8% discount rate).

Table 7. Minimum lease payments as the distribution of member farms by size change.[a]

	Sheep by farm size (%)				
Distribiuon	**Small (100 sheep)**	**Medium (220 sheep)**	**Large (1,000 sheep)**	**Total farms**	**Payment ($/acre)**
Baseline	10	35	55	6	627
Only small	100	0	0	18	854
Only medium	0	100	0	8	667
Only large	0	0	100	2	551

[a] Total number of sheep held approximately constant based on 605 total array acres, subject to rounding for integer farm counts. Payment represents the minimum lease payment to meet the financial feasibility condition of positive NPV at the co-op level over the 10-year planning horizon (8% discount rate).

Table 8. Profitability and minimum lease payments as average distance between nodes change.[a]

Distance	**Payment ($/acre)**
20	526
30	560
40	592
50 (baseline)	**627**
60	661
70	696
80	732
90	766
100	802

[a] Payment represents the minimum lease payment to meet the financial feasibility condition of positive NPV at the co-op level over the 10-year planning horizon (8% discount rate). All other input values set at the baseline (Table 4).