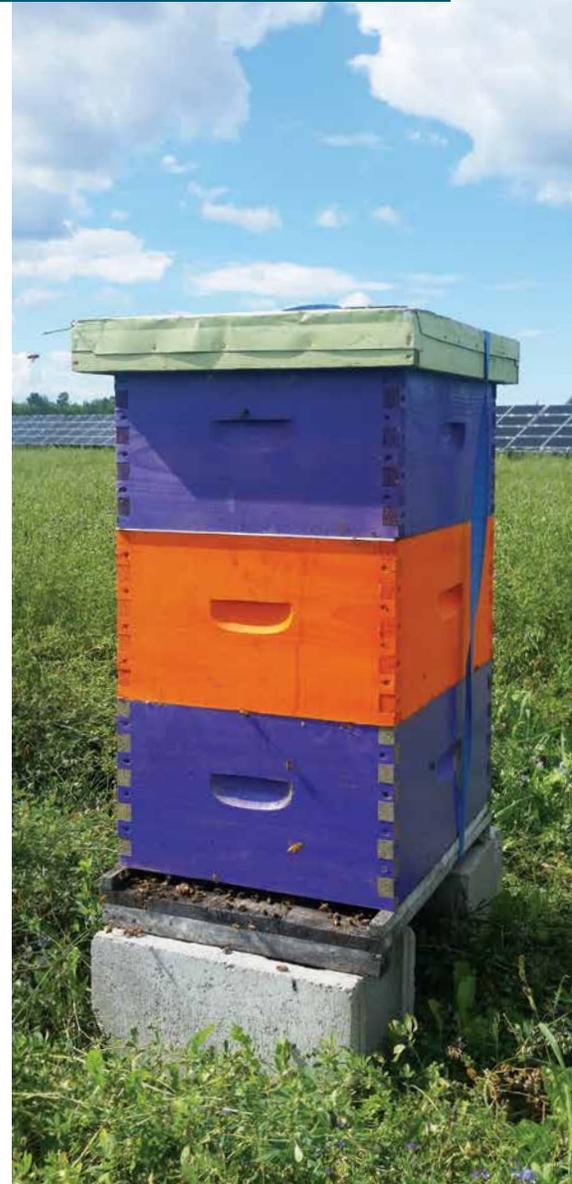


MOUNT MORRIS AGRIVOLTAIC STUDY



Co-locating Solar and Agriculture
at the Morris Ridge Solar Energy Center

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CONTENTS

Executive Summary	4		
Part One - Solar Grazing	6	Part Two - Solar Beekeeping	62
Morris Ridge Solar Energy Grazing Enterprise Budget	7	Morris Ridge Solar Beekeeping Report	63
I. Introduction	8	I. Introduction	64
II. Budget Assumptions	10	II. Beekeeper Survey	65
III. Model A - Grazer Purchases Lambs for Grazing and Sale	11	- Beekeeping in New York State	65
- Revenue	12	- Survey Methods	65
· Solar Grazing Compensation	12	- Survey Results	66
· Sale and Purchasing of Lambs	13	III. Landscape Analysis	69
- Operating Expenses	16	- Landscape Composition and Honey Production	69
- Investment (Fixed cost)	17	- Spatial Analysis Methods	69
- Estimated Returns	18	- Landscape Composition Results	71
IV. Employment	21	- Evaluation of Proposed Apiary Sites	72
V. Model B - Grazer Grazes Own Flock in Addition to Subcontracted Ewes	21	IV. Economic Analysis of Apiary Budgets	74
- Revenue and Expenses	22	- Economic Analysis Methods	74
- Returns	23	- Results from Apiary Budgets	77
VI. Sensitivity Analysis	26	- Apiary Economic Viability	79
References	28	V. Recommendations	80
Appendix	30	- Beekeeper Recruitment	80
		- Apiary Site Selection and Design	82
		- Manage Vegetation for Honey Production	83
		References	84
		Appendix	86
Morris Ridge Lamb Demand Survey	31	Future Market Opportunities for Solar-Raised Honey	97
I. Introduction	32	I. Background	98
II. Lamb Demand in Northeastern United States.	34	II. Summary	98
III. Lamb Demand in 2020 and Forecasts	34	III. Method	98
IV. Genesee-Finger Lakes Region Lamb Demand Survey	35	- Businesses Interviewed	98
- Survey Method	35	- Survey Findings	99
- Restaurant Survey Results	35	IV. Current Demand	99
- Retailer Survey Results	39	- Retailers	99
- Distributor Survey Results	39	- Craft Beverage	99
V. Lightweight Lamb Demand	40	- Food Manufacturers	99
VI. Regional Lamb Processing Capacity	41	V. Perspectives on Solar-Raised Honey	100
VII. Conclusion	42	VI. Key Insights	101
References	43	- Preparing the Market	101
Appendix	44	- Opportunities	101
		Appendix	102

EXECUTIVE SUMMARY

In 2019 as part of the Climate Leadership and Community Protection Act, New York State pledged to source 70% of its energy from renewables by 2030. That same year, the New York State Energy Research and Development Authority (NYSERDA) awarded a contract to EDF Renewables North America, a grid-scale, on- and off-shore wind and solar photovoltaic power producer and energy storage company, for the construction of its proposed Morris Ridge Solar Energy Center project, engineered to generate 177 megawatts of solar electricity (NYSERDA, 2019). The Morris Ridge project consists of six pods of ground-mounted solar arrays on approximately 1000 acres of leased, private land in the Town of Mount Morris in Livingston County, NY. EDF Renewables anticipates that the site will be operational in 2023 (EDF Renewables, 2021).

Agriculture is the principal industry and land use in the Town of Mount Morris (New York State Office of Real Property Services, 2019). Most of the Morris Ridge Solar Energy project will be installed on farmland that has historically been cultivated for commodities such as alfalfa, corn, soybeans, and wheat. Fields with ground-mounted solar panels present a new use. With thoughtful planning, the land may generate both energy and agricultural products—a dual-use. According to its 2019 Agricultural and Farmland Protection Plan *“(The) Town of Mount Morris prides itself on both its agricultural prowess and its sense of environmental responsibility. (The) Town must consider both simultaneously, however, and be sure to incorporate the needs of the Ag community in their laws for community solar installations.”* (Thoma Development Consultants, 2019)

“ *(The) Town of Mount Morris prides itself on both its agricultural prowess and its sense of environmental responsibility. (The) Town must consider both simultaneously, however, and be sure to incorporate the needs of the Ag community in their laws for community solar installations.*

~ (Thoma Development Consultants, 2019)

As it does on other facilities across North America, EDF Renewables plans to incorporate provisions for the co-location of agricultural activities within the Morris Ridge Solar Energy sites. This includes managed sheep grazing to control vegetation under and around the solar panels and beekeeping—as well as honey production—sustained by pollinator-friendly plant life. Already, solar sites across Europe, North America, and increasingly the northeastern United States have effectively integrated agricultural uses by co-locating crop production, grazing animals, and pollinator habitat on solar farms (Agrivoltaic Solutions, LLC 2020). EDF Renewables is experienced with dual-use solar projects, having successfully integrated sheep and honeybees at its Arnprior Solar site in Ottawa, Ontario, Canada.

The Town of Mount Morris commissioned this research to answer questions about the nascent solar-agricultural industry, assess opportunities to attract farmers to the EDF Renewables Morris Ridge Solar Energy Center, and identify viable markets for solar-raised products. The report addresses the current interest of local farmers in grazing sheep and establishing apiaries at Morris Ridge; summarizes surveys employed to discover regional demand for lamb and honey; and analyzes market opportunities for solar-raised lamb, honey, and related products.

The demand surveys revealed strong support for local and natural products at retail sites and restaurants, but a lack of familiarity with the concept of “solar-raised” foods. The lamb demand survey identified a robust and diverse desire for lamb in the Genesee and Finger Lakes regions, New York City, and neighboring states, with most respondents placing a high value on where and how lamb is raised. The honey demand survey found opportunities for honey and bee products in food manufacturing and beverage production, and through direct sales at gift outlets locally and statewide. The survey responses further revealed that source, flavor, and potential health benefits of solar honey were most important. Enterprise budgets are included detailing multiple product mixes and economies of scale for viable solar sheep grazing and beekeeping businesses.

The energy generated by the Morris Ridge Solar Energy Center will be key to New York State meeting its clean energy goals. The project can also support emerging opportunities for co-located solar and agriculture. Solar projects that include designs for agrivoltaic enterprises can foster agricultural innovation and economic growth. Through the Morris Ridge Solar Energy Center project, the Town of Mount Morris can protect the region’s agricultural heritage and be a leader in the state’s clean energy future.

THE TOWN OF MOUNT MORRIS

Nestled in the Genesee Valley about 30 minutes south of Rochester, the Town of Mount Morris is establishing itself as a leading community, helping New York State reach its goals under the Climate Change and Community Leadership Plan. The Town of Mount Morris installed electric vehicle (EV) charging stations and was one of the first communities in New York to enact a solar law, facilitating solar development in the town with clear rules and objectives. Now with more than 200 megawatts of projects approved or under construction, the town looks forward to creating partnerships between local businesses and the solar facilities by promoting agrivoltaic activities like solar grazing and hosting pollinators.



The Town of Mount Morris appreciates the opportunity to work closely with companies like EDF Renewables to help the Town achieve its mission to host renewable energy projects that bring financial and institutional benefits to the area for decades to come. This study further demonstrates the Town's commitment to strengthening the connection between renewable energy and agriculture, and we are thankful to the team of experts who thoughtfully prepared this study for the benefit of our region.

EDF RENEWABLES

For over 35 years, EDF Renewables has been providing clean energy solutions throughout North America. What helps to define us is our commitment to the communities in which we operate. Sustainability and corporate social responsibility form the core of every EDF Renewables project.

Our corporate sustainability efforts do not happen in isolation—they are part of our DNA. We believe that the world of energy is changing, and customers are becoming more involved in all aspects of the business. Transparency and engagement with community stakeholders are integral elements of the process.

As part of these efforts, we have a vested interest in maximizing the utilization of the land at our Morris Ridge solar project in a way that is financially responsible for EDF Renewables and provides additional benefits for the local community. We greatly value our relationship with the Town of Mount Morris and our partnership to deliver Morris Ridge Solar to the local community.

This exemplary study championed by the Town of Mount Morris and involving an impressive team of experts sets a framework for co-locating managed grazing and pollinating services within the Morris Ridge Solar Energy Center; we look forward to implementing this plan.



Photo courtesy of:
American Solar Grazing Association

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Part One SOLAR GRAZING



Morris Ridge Solar Energy Grazing Enterprise Budget

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I. Introduction	8
II. Budget Assumptions	10
III. Model A — Grazier Purchases Lambs for Grazing and Sale	11
IV. Employment	21
V. Model B — Grazier Grazes Own Flock in Addition to Subcontracted Ewes	21
VI. Sensitivity Analysis	26
References	28
Appendix	30

List of Figures

Figure 1: 2019 Hair Lambs Sold at New Holland Sales Stable	14
Figure 2: Breakdown of 2019 Hair Lamb Sales at New Holland by Weight	14
Figure 3: 2019 Woolled and Shorn Lambs Sold at New Holland Sales Stable	14
Figure 4: Slaughter Hair Lamb Price Seasonal Index at New Holland	15
Figure 5: 70–90lb. Hair Lamb Prices, New Holland Auction	15

List of Tables

Table 1: Model A Budget Assumptions — Grazing Lambs	12
Table 2: Enterprise Budget: Grazing Lambs	19-20
Table 3: Possible Subcontracts by Acreage, Sheep, and Expense	22
Table 4: Subcontracted Graziers Responsibilities	23
Table 5: Budget: Grazing Own Ewes and Subcontracting	24-25

I. INTRODUCTION

Co-locating sheep grazing with utility-scale solar photovoltaic (PV) systems is a relatively new trend in the United States, and thus reviews of successful business models and availability of estimated enterprise budgets are limited. Many studies report on the cost savings of grazing sheep versus traditional mechanical mowing and trimming for vegetative management of solar sites, but few report on the profitability to the grazier from grazing sheep or lambs. To date, this nascent industry reports varying returns depending upon scale of PV systems, region of the country, and the business model adopted by the sheep grazier. This study builds upon current literature by estimating sheep graziers' returns from grazing a utility-scale PV system in western New York—the Morris Ridge Solar Energy Center.

The Morris Ridge Solar Energy Center is a proposed solar photovoltaic facility of up to 177 MW which may include up to 83 MW of energy storage, located in Mount Morris, NY, in Livingston County. The facility will safely generate enough clean, renewable electricity to power 38,000 New York households and offers the possibility of agrivoltaics: co-locating agriculture and solar development. This project proposes to graze sheep on its 1060-acre site; this research develops an economic profitability analysis of two different scenarios: grazing lambs only and grazing ewes.

Sheep production in the United States has been in decline over the past few decades; however, consumer demand for lamb is strong and to meet this growth the U.S. imports over half of the lamb consumed domestically. Utilizing sheep in agrivoltaics offers a unique opportunity to the U.S. sheep industry to expand production, but successful expanded production is predicated on profitability to the solar developer and sheep operator.

Solar grazing sheep can reverse the course of an industry that has been shrinking nationally, ALBeit with pockets of growth. In 2021, the U.S. Department of Agriculture (USDA) reported 2.96 million ewes nationally, down 1% annually, and down 3% in five years due to sheep operator retirement, predator concerns, labor concerns, lack of markets, and import competition. New York mirrors recent national trends: in 2021 ewe inventory was down 7% annually to 50,000 ewes, and down 2% in five years. However, a broader view reveals that ewe inventory in New York State is up 32% over 10 years compared to the 6% contraction in ewe numbers over this time nationally. The U.S. sheep industry has observed pockets of growth likely in response to the attractiveness of the number one consumer market in the U.S., New York City, the growth of multicultural culinary tastes in the U.S., and the growth of the hair lamb market, which doesn't require feedlot finishing.

An objective of this project is to estimate an economic analysis of grazing sheep on a utility-scale solar PV system. The economic analysis is comprised of an enterprise budget of solar grazing at the site. This analysis used primary and secondary data to estimate revenue, investment (establishment) costs, operating costs, and profitability for two grazing scenarios: 1.) grazing lambs on the solar site, and 2.) grazing ewes by an established operator in the area and subcontracting the remaining vegetation removal needs to other sheep operators. The assumptions used in the enterprise budgets are based upon primary and secondary data and supported by USDA and the Livestock Market Information Center lamb market price data.

Literature Review

This project reviews two enterprise budgets and draws upon a third budget in its draft form to develop enterprise budgets for two solar grazing models.

The 2018 study of agriculture, economic, and environmental potential of co-locating solar with grazing sheep by the Cornell University David R. Atkinson Center for a Sustainable Future was a first of its kind study focusing specifically on financial returns from grazing solar. The authors surveyed a solar grazing operation (22 acres and 56 sheep) at Cornell's Musgrave Research Farm in Aurora, NY (Kochendoerfer, et al., 2018). Study findings estimated net income to the contracted grazier in two arrangements: 1) net income on a per acre basis, and 2) a per sheep head basis. In the per acre basis, for a single season at the Musgrave Research Farm, the net income was \$241 per acre. The net income was also described as \$94 per head for a directly contracted enterprise. The estimate included the solar grazing investment, compensation, mileage, and labor as grazing expenses, as well as the cost of general liability insurance. This was the first of three solar grazing enterprise budgets used to inform the Morris Ridge Solar Energy project. In addition to this study, Cornell researchers surveyed 14 other sheep farms from across New England (4 from New York State) to discover typical returns and labor costs for grazing service provided directly by the grazier or indirectly through a landscape firm.

Tracking labor use in solar grazing enterprise budgets is key to determining its economic benefit/cost ratio. The 2018 Cornell Atkinson study tracked labor requirements closely at the Musgrave site. In its 22-acre grazing trial it found that "utilizing sheep for site vegetation management required a total of 139 hours including travel time, resulting in 2.5 fewer labor hours than traditional vegetation management (mowing and string trimming) on site."

The Cornell Atkinson Center survey results from the four NYS solar graziers indicated that net income in New York State was \$509 per acre (per season) for a direct contracted grazier and \$274 per acre for a subcontracted grazier working under the terms of another firm for vegetation maintenance at a solar array. In the Eastern United States (10 surveyed graziers), the direct contracted net income was \$262 per acre and \$244 for the subcontracted grazier.

In 2021 the American Solar Grazing Association (ASGA) estimated a draft enterprise budget for 75 ewes on 25 acres (Lewis Fox, personal communication). The premise of the business model was that grazing compensation was the primary income source of the enterprise; gains from grazing ewes didn't contribute a significant income. On average, ewes purchased and then sold gained 5 pounds and were sold for the same price as purchased.

In 2021, North Carolina Cooperative Extension, NC Choices, A Center for Environmental Farming Systems Initiative, and the USDA's National Institute of Food and Agriculture adapted an enterprise budget from Virginia Cooperative Extension Publication 446-048. It estimated returns for a 100-ewe operation on a 25-acre solar site. The additional solar insurance required is \$300 per year. The estimated solar compensation is \$200 per acre per season. Gross income minus variable cost is referred to as returns above variable costs, or gross margin. In the North Carolina estimate, income over variable costs is \$84.24 per ewe.

A review of literature presented herein can be found in the Appendix and is summarized here. A comparison of income over variable costs across three studies range from 1.) \$5291 in a Cornell University study (56 ewes on 22 acres), 2.) \$5,655 for 25 acres and 75 ewes from an ASGA study, and 3.) North Carolina *Choices* (NC Choices) reported income of \$8524 for a 100-ewe solar

grazing operation. The net return for a subcontracted solar grazier in the Cornell study was \$1291 for 56 ewes on 22 acres. A literature review is available in the Appendix.

Costs not included in these studies are depreciation, the cost of debt financing, and the opportunity cost of capital. Additionally, these budgets didn't include the opportunity cost of agricultural managerial skill.

This enterprise budget draws upon the work of "Agricultural Integration Plan: Managed Sheep Grazing & Beekeeping" by Agrivoltaic Solutions, LLC for Morris Ridge Solar Energy Center, LLC, a subsidiary of EDF Renewable in 2020 (Morris Ridge Solar Energy Center Case No. 18-F-0440). The Agrivoltaic Solutions study proposed the site design and prescribed grazing plan for the Morris Ridge Solar Energy Center, which includes six geographically dispersed areas, or pods, which are divided into grazable areas following the layout of the solar arrays and employ portable fencing for creation of smaller interior paddocks. A set number of sheep are assigned to each pod and moved every 1-4 days, rotationally grazing among paddocks. The study also recommended critical investments that will reduce costs for sheep graziers including permanent perimeter fencing for the pods and arrays, and availability of water in each pod.

Study Objectives and Method

The grazing enterprise budgets were estimated using primary and secondary data. In addition to the literature reviewed, two current solar graziers were surveyed for this project. These graziers each have several years of experience solar grazing sheep in the Eastern U.S. Secondary market information was obtained from the USDA and the Livestock Market Information Center. The estimated budgets are a collective effort by the project team members and external review.



Photo courtesy of: American Solar Grazing Association

II. BUDGET ASSUMPTIONS

The enterprise budgets of grazing lambs for sale on the Morris Ridge site include key underlying assumptions of solar development provisions including:

- Secure perimeter fencing of the pods and arrays,
- Available well water or pond in each pod, and
- A barn or shop for secure storage of equipment such as a livestock trailer, sheep handling equipment, truck, and ATVs.

An enterprise budget estimates the return of grazing sheep on the project site. It deducts estimated costs from estimated revenue to determine whether the project is feasible. If net income (revenue less costs) is positive, it is indicative that the project could be profitable, given project assumptions.

The enterprise budget of two business models were estimated for the project:

Model A **Grazier purchases lambs for grazing and sale**

Model B **Grazier grazes their own flock in addition to subcontracted ewes**

The number of grazing days is assumed to be 5 months or 150 grazing days, May to October. The percent death loss during the grazing season is assumed at 3%. The project budget assumes that forage availability is mature when sheep/lambs arrive. Agrivoltaic Solutions recommended that sheep numbers be scaled down by 15–35 % during the first couple of years. The budgets make further assumptions regarding production matrices, marketing decisions, management decisions including hired labor and livestock guarding dogs, and unpaid family labor.

Stocking Rate and Stocking Density. One key decision within the budgets is establishing the stocking rate and stocking density, which together determine how many lambs or ewes are recommended for grazing.

The size of the Morris Ridge site is 1060 acres, which can support 2.5 ewes per acre or 9 lambs per acre according to authors' estimates and Agrivoltaic Solutions, LLC.

Stocking rate recommendations differ across studies and are adjusted as new information is gathered in this relatively new industry. In 2021, Kochendoerfer, Hain, and Thonney recommended a solar grazing stocking rate (number of sheep on the solar site) of 2.5 sheep per acre. In 2018, Kochendoerfer and Thonney recommended grazing 1 sheep per acre for marginal land, and up to 5 sheep per acre for improved pasture, with an average yearly stocking rate of 3 sheep per acre. In 2020, Agrivoltaic Solutions recommended a 3.6 sheep stocking rate for the 1060 acres with a proposed 3847 head. They

further recommend grazing a 2400-ewe breeding flock with lambs for a total equivalent of 3800 mature sheep at the proposed Morris Ridge site.

As lambs gain weight, the pressure on the solar site's pastures will improve, thereby increasing its stocking density. Stocking rate is not the same as stocking density. While stocking rate calculates the total number of animals on the entire Morris Ridge solar site for the entire grazing season, stocking density refers to the number of sheep or the liveweight of sheep on specific acreage of pasture for a specific time period. Another way to think about stocking density is animal concentration.

To allow for optimal plant regrowth, the time any flock spends in any one grazing paddock should not exceed four days. Stocking density is particularly important in the Morris Ridge Sheep Pasture Rotation and Grazing Plan because it is not yet confirmed that the Morris Ridge solar site can support the same number of lambs in May as it can in October. As the lambs grow in weight throughout the season, the stocking density—measure by liveweight—will increase.

This project assumes that the grazier's rotation and grazing plan will carefully account for forage quality throughout the growing season. To address the increasing stocking density of growing lambs, the model recommends a staggered marketing plan that alleviates the pressure on the stocking density by selling lambs at different sale dates throughout the grazing season, May to October. As pasture nutrients begin to decline as the season progresses, it is recommended that the grazier market some lambs mid-season, perhaps in July or August. It is recommended that up to 40% of lambs will be marketed mid-season, while the remaining 60% of lambs will be marketed in October or November. The exact number of lambs marketed—and when—will be at the grazier's discretion, based on pasture quality.

Livestock Guardian Dogs (LGDs). The recommendation of using livestock guardian dogs to protect sheep from predators on utility scale solar sites differs among researchers and solar graziers.

The net benefit—whether positive or negative—of LGDs depends upon operator characteristics and environmental conditions (Macon, 2019). A California study found that LGDs reduced lambs lost to coyotes by 43% and resulted in 25% fewer ewe losses in a 500-ewe flock (Bruno & Saitone, 2019). Bruno and Saitone found that the economic benefits of LGDs did not cover the costs, given their assumption of less than 100% of sheep saves. The study concluded that the economic effectiveness of LGDs depends upon site- and operation-specific factors including size of pasture, changes in elevation, tree cover, perimeter fencing, and ewe-to-LGD ratio.

In 2021, the USDA reported that during 2020, the death loss to sheep nationally was 210,000 ewes and 388,000 lambs. From 2016 to 2020, the average breeding sheep death loss was 6% and 12% for lambs. However, predator loss is only one of many reasons that sheep or lambs may die. In 2014, the USDA reported that 55% of sheep operations surveyed used fencing as the number one nonlethal predator control method, followed by use of LGDs by 41% of those surveyed (USDA, 2015). In 2014, the latest year in which a USDA predator survey was conducted, 28% of the death losses among sheep were attributed to predators and 36% among lambs (USDA, 2015).

One percent of adult sheep and 2% of lambs were lost to predators in New York State in 2014 (USDA, 2015). The total estimated value of the loss was \$74,000 and \$129,000, respectively, summing to over \$200,000. Predator losses to coyotes ranked number one among predators with reported losses of 347 sheep and 794 lambs, followed by lamb losses to eagles. New York sheep operators use various nonlethal predator control methods including fencing (82%), and approximately 30% each for LGDs, culling, removing carrion, and changing bedding.

Informal surveys found that some operators grazing ewes do not use LGDs and have not had serious losses, while other operators have had severe losses to predators. One report found that “the secure fencing around the perimeter of solar arrays makes the grazing area basically secure from terrestrial predators.” (Pennsylvania State Extension, 2020) The rate of sheep losses can be attributed to site and management characteristics. A grazier lambing on the solar site, for example, may sustain greater losses than a grazier running ewes. In conclusion, some solar graziers use LGDs, but most do not (Pennsylvania State Extension, 2020).

LGDs are included in the estimation of the grazing lamb scenario, but not included in the budget scenario whereby ewes only are grazed. The percent death loss during the grazing season is assumed at 3% for both ewes and lambs.

The project assumes herding dogs may be utilized on the solar site later, but neither the budget for lambs nor ewes includes an estimate for costs associated with use of herding dogs.

III. MODEL A — GRAZIER PURCHASES LAMBS FOR GRAZING AND SALE

In Model A, the budget assumes that lambs are purchased in April for grazing through the season and then a portion are sold during the summer, with the remainder sold in late October or November. It is assumed that the grazier sells about 40% of the lambs mid-season and about 60% of the lambs at the end of the grazing season.

With a stocking rate assumption of 9 lambs per acre on 1060 acres, the total number of lambs is 9540 lambs. A 3% death rate from natural causes and predators will yield a projected 9254 lambs to market.

The largest share of lambs will sell in October/November. It is assumed that lambs are purchased at about 35 lbs., graze 5 months, gain about 45 lbs. and are sold by November at about 80 lbs. According to USDA's Natural Resources Conservation Service (NRCS, no date), the forage/animal balance is a function of pasture supply and animal demand (NRCS, no date). In turn, pasture supply is a function of forage production and the seasonal utilization rate, whereas animal demand is a function of flock intake per day and the length of the grazing season. The grazier will have to calculate—or utilize publicly available grazing management calculators—the amount of forage available per acre and per rotation and compare this estimate to lamb needs by weight.

For the purposes of this enterprise budget, all lambs are assumed to be sold at the end of the season. Lambs

sold mid-season will weigh less than lambs sold at the end of the season, but will command a higher price per pound, so the math should compute the same as selling all lambs at the end of the season. Marketing will be challenged by the staggered marketing plan, however. An estimated \$5 per head is budgeted for marketing.

It is recommended that lambs are sourced out of state, for there are insufficient numbers of lambs in the region to efficiently purchase the required number of head. Lambs can be purchased from neighboring states, as far as Kentucky, Tennessee, and West Virginia to the south, and Illinois to Iowa in the Midwest. For this budget, the Midwest was selected for the source of lambs, given the availability of lamb sales and USDA price reports at a major sheep auction in Kalona, IA. Further, sourcing lambs from the Midwest minimizes transaction costs because flock sizes are generally larger than in the East.

Managing shipping costs from the point of purchase to the Morris Ridge Solar Energy project site can affect estimated returns. This budget estimates that a triple-decker trailer will require 8 trips to ship lambs approximately 600 miles east from Illinois. The cost per loaded mile is \$4. It is assumed that a smaller-sized trailer could cost the same per loaded mile but will require additional trips. It is also understood that securing close to 4000 lambs will require multiple subcontracts from multiple sheep producers and thus multiple transport arrangements and costs.

Table 1 delineates the budget's key assumptions including solar grazing compensation, production metrics, travel, wage rates, and the grazier's unpaid family labor compensation.

REVENUE

There are two streams of income available to the solar grazier: solar grazing compensation from the solar developer and the sale of lambs.

Solar Grazing Compensation

Sheep graziers are compensated for solar grazing to help recoup the costs of transportation to deliver lambs to the solar site, travel costs to check on lambs regularly, potential marketing costs at the end of the season, and managerial costs. From the solar developer's perspective, solar grazing expenses should be equal to or less than the budgeted amount for mechanical site vegetation maintenance.

Successful sheep solar grazing requires that its economic benefits outweigh costs, and there is net economic benefit over traditional mechanical mowing. Reportedly, one of the largest solar utility developers commented that much of their operating and maintenance budget "is just eaten up by paying landscapers." (ASGA, 2020) A survey of solar developers revealed that the cost savings from using grazing sheep can range from 19–75% over mechanical maintenance (ASGA, 2020). When budgeting for sheep grazing, solar developers are encouraged to price economic benefits such as reduced wildfire risk from mowing sparks and routine damage to panels from thrown rocks into grazing offers (ASGA, 2020).

Solar grazing compensation rates differ depending on the scale of the utility. The most recent Cornell Atkinson study found that solar grazing compensation ranged from \$250 (subcontracted) to \$500 (directly contracted) per acre (Kochendoerfer, et al., 2021). ASGA reported that overall solar grazing compensation is \$250–\$750 per acre (personal communication). However, grazing income will be generally at the lower end of this scale on utility-scale photovoltaics (personal communication, 2021). According to Lexie Hain, co-founder of Agrivoltaic Solutions, LLC, utility scale solar rates for solar grazing are \$250–\$400 per acre. This enterprise budget for a utility-scale site assumed a grazing income of \$250 per acre per season to assess economic returns.

Solar Grazing Compensation	
Solar grazing compensation, \$ per acre per season ^{1,2}	\$250.00
Production Metrics	
Number of acres of solar grazing	1060
Stocking density, lambs per acre ¹	9.0
Number of lambs needed for grazing (Computed)	9540
Percent death loss (on solar site) ¹	3.0%
Number of sheep sold after grazing (Computed)	9254
Marketing Assumptions	
-- Purchasing Lambs	
Purchase price of lambs, \$/cwt. ³	\$241
Rate of gain, lbs. per day ⁴	0.30
Purchase weight of lambs, lbs.	35
Number of trips to purchase lambs ⁵	20
Miles traveled to purchase lambs	600
Transport rate, \$ per loaded mile ⁶	\$4.00
-- Selling Lambs	
Sale weight of lambs, lbs. ⁷	80
Weight gain solar grazing, lbs. per head (.3lbs./day, 150 days)	45
Sale price of lambs, \$/cwt.	\$169.21
Management Assumptions	
Hired labor, seasonal, full-time	6
Hired labor, \$ per hour	15
Round trip mileage to solar site, miles	70
Mileage rate ⁸	\$0.56
Operator & Unpaid Family Labor	
Value of owner operator manager labor	\$66,530.00
Value of hired labor, \$/hour ⁹	\$17.25

¹Agrivoltaic Solutions LLC, 2020.

²Kochendoerfer, N., L. Hain, M. L. Thonney, 2018.

³Compiled from U.S. Department of Agriculture & Livestock Market Information Center, Various dates.

⁴Ontario Ministry of Agriculture, Food and Rural Affairs. Predicting Lamb Finishing Weights, 2019.

⁵Compiled from Gradin, T. 2001.

⁶University of Nebraska, Lincoln. June 2020.

⁷A staggered marketing approach will be implemented with about 40% of lambs sold mid-season.

⁸Internal Revenue Service, 2020.

⁹U.S. Bureau of Labor Statistics, 2021.

Table 1. Model A Budget Assumptions — Grazing Lambs

Sale and Purchasing of Lambs

Calculation of purchase price, weight gain during the solar season, weight at sale, and end market are all critical choices that affect net returns. Choice of lamb breed and specific weight upon arrival at the solar site will be decided by the grazier.

Purchasing Lambs

U.S. sheep are concentrated in the West where range operators run thousands of head per flock on open range and desert. Fewer sheep, but increasing numbers, populate the Midwest and East in smaller farm flocks. California and the Northwest are characterized by a mix of smaller-sized operations and larger flocks. Thus, the distribution of sheep producers is also skewed, with most sheep producers dotted across the Midwest and East, with fewer operators in the West.

Within this heterogeneous landscape the sheep industry is further segmented by type of sheep and consumer market. In the West, larger-framed, woolled breeds that produce meat and wool are prevalent. By comparison, in much of Texas and throughout the Midwest and East, hair sheep (replacing woolled flocks) are increasingly popular. Hair sheep such as Katahdin and Dorper breeds are typically smaller framed and do not need to be shorn. Hair sheep are a popular choice for direct-to-consumer sales by producers and in ethnic communities.

By examining the local lamb market in western New York and the region, it was found that hair lambs weighing approximately 80 lbs. are a popular target market and thus dictate the type and weight of lambs purchased for this solar grazing enterprise budget. As the second largest national sheep auction in the U.S., the New Holland Sales Stable has been an important barometer for lamb sales in the northeastern United States. The USDA Agricultural Marketing Service (AMS) calls the auction a “nontraditional market,” stressing the fact that many lambs sold at the sale barn cater to multicultural markets and are not handled in USDA processing facilities.

A grazier can opt to graze hair lambs or woolled lambs. Currently, hair sheep are a popular choice for solar grazing in New York. The benefits may be natural parasite resistance and that the hair sheep do not need to be shorn. Katahdin lambs or a Katahdin/Dorper cross are a popular choice. Woolled lambs are perhaps not as popular among New York shepherds, but are imported from other states and are increasingly popular at the regional sale barn.

Historically, the New Holland market sold woolled and shorn breeds, but over the last ten years hair sheep have become increasingly popular and even eclipsed woolled numbers about five years ago. In the last few years, the pendulum has swung back again, with woolled breeds

now accounting for most sheep sold. In 2019, approximately 60% of the total supply of slaughter lambs at New Holland was woolled and shorn lambs, with the remaining 40% hair lambs (AMS, personal communication, 2021).

Hair lambs are smaller-framed sheep which mature at lighter weights compared to most wool breeds. For instance, Katahdin and Dorper lambs are typically less than 100 lbs. at harvest compared to the woolled lambs that are traditionally harvested in the West at 140–160 lbs. Preferred woolled breeds that sell at New Holland also sell at lighter weights than in western markets. Breeds include Suffolk, Hampshire, Suffolk/Hampshire crosses, or Dorset crosses to yield a medium-framed lamb. The Dorper/Dorset cross has become popular. Other popular smaller-breed woolled lambs are Cheviots and Southdown/Babydoll. A Katahdin/Dorset cross is also a popular choice.

Just under half of all lambs selling at Pennsylvania’s New Holland Sales Stable are hair sheep, selling at 70–90 lbs. and heading straight to harvest. By contrast, woolled lambs weighing 100 lbs. typically sell as feeder lambs in the West, for further finishing on a high concentrate diet and slated for harvest at around 140–160 lbs., depending upon breed and time of year. Woolled breeds that sell at New Holland will sell in a wide range of weights, from 50–90 lbs., with lower volumes selling up to 110 lbs.

It is recommended that the project look to the Midwest to source hair lambs. This is because rather than sourcing lambs from many smaller operations in the East, the grazier can reduce marketing costs by sourcing all the required lambs at several larger operations in the Midwest. Reportedly, several sheep producers in the Midwest can pool together about 3000 head of lambs or ewes for solar grazing in the spring (personal communication, 2021).

USDA/AMS reports provide lamb market prices. The largest auction market in the Midwest is Kalona Sheep and Goat Auction, Kalona, IA. In April 2019, 2020, and 2021 prices for hair lambs 35–45 lbs., choice, and prime yield grade 1 to 3 averaged \$190 per cwt., \$236 per cwt., and \$296 per cwt., respectively. The 2020 average was for March, before USDA/AMS suspended data collection due to COVID-19. The estimated lamb purchase price assumed in this project is \$241 per cwt.

While it is believed that direct-to-consumer sales prompted a lamb demand expansion in 2020 due to COVID-19, it is also expected that expanded lamb demand (and hence higher prices) pre-dates the pandemic and will continue in the next few years. Increased lamb demand in the U.S. is due to younger generations exploring at-home dining, new flavor experiences, and growing racial and ethnic diversity in the U.S.

Among hair lambs sold at New Holland in 2019, the greatest proportion of lambs sold by weight fell into the 70–90 lb. range (47%), followed by 50–70 lb. lambs (27%). Twenty percent of hair lambs that sold in 2019 were heavier than 90 lbs. (Figures 1 and 2).

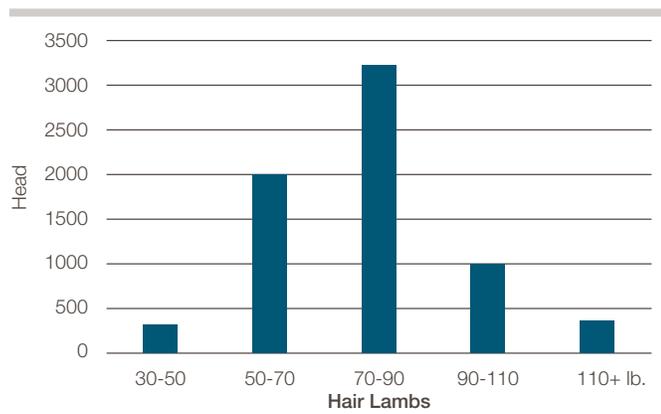


Figure 1. 2019 Hair Lambs Sold at New Holland Sales Stable Livestock Auction, No. of Head. Source: U.S. Department of Agriculture (USDA), Agricultural Marketing Service (AMS), 5/2021

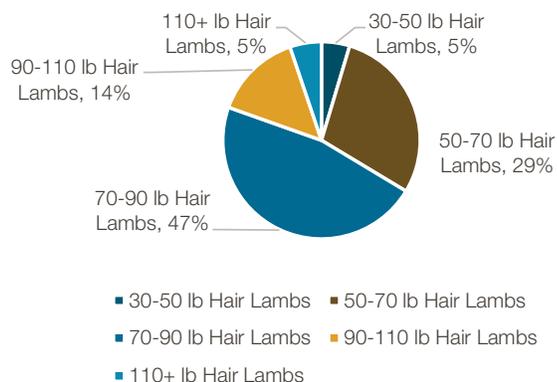


Figure 2. Breakdown of 2019 Hair Lamb Sales at New Holland by Weight. Source: U.S. Department of Agriculture (USDA), Agricultural Marketing Service (AMS), 5/2021

With close to one half of all hair lambs selling in the 70–90 lb. range, this is a possible target market weight for solar-grazed lambs. Working backwards, if a target lamb weighs 80 lbs. in November, after grazing on pasture for at least 5 months (gaining about 45 lbs.), the purchase weight is estimated at about 35 lbs. Thus, solar-grazed lambs raised for the 80 lb. October market are thought to be born in February.

The average harvest weight of lambs selling at New Holland is heavier for woolled breeds than for hair lambs (Figure 3). If woolled lambs were selected for grazing at the Morris Ridge site, the recommended target sale weight would be heavier, in the 70–130 lb. range.

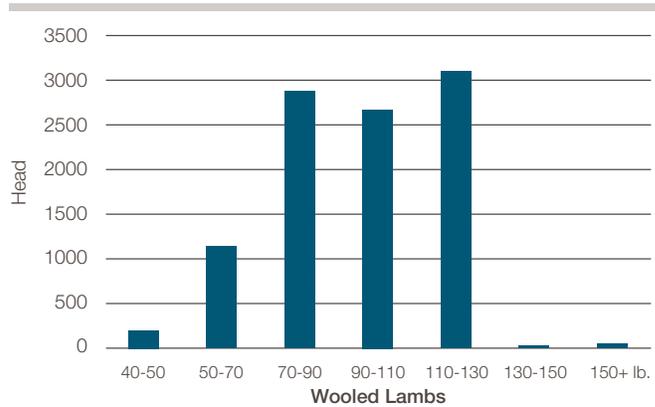


Figure 3. 2019 Woolled and Shorn Lambs Sold at New Holland Sales Stable Livestock Auction, No. of Head. Source: U.S. Department of Agriculture (USDA), Agricultural Marketing Service (AMS), 5/2021

In this study, solar grazing Katahdin hair sheep are assumed; however, grazing woolled sheep breeds is an option that can be explored. According to some industry insiders, the ethnic trade prefers woolled breeds because they produce more fat cover, have a better dressing percentage, and a preferred pink or white meat, not red as in Katahdin (personal communication, 2021). Another reason to consider solar grazing woolled breeds is that wool adds to the environmental story and helps to counter the anti-meat coalition, according to Megan Wortman, executive director of the American Lamb Board (personal communication, 2021). Woolled breeds selling at the New Holland auction are shipped primarily from the Midwest (Ohio, Indiana, Illinois), but also farther West (North and South Dakota). Depending upon timing of solar grazing, an enterprise budget for woolled breeds could include the cost of shearing and the possible receipt of a wool Loan Deficiency Payment (LDP). In the northeastern U.S., it is assumed that there is no value for lamb pelts, but possibly a net positive return from wool sales.

For many years, operators with woolled sheep flocks across the U.S. have received a double-digit pelt credit for woolled lambs when selling lambs. However, pelt credits have been depressed for shearling, and leather from hair sheep is not marketed. According to a 2019 Cornell study, there is no market for lamb hides. Processors are forced to treat hides as waste and pay for disposal.

The estimated enterprise budget for lambs assumes that lambs purchased will already have a host of select vaccines and ear tags or tattoos, identifying each head. It is possible that hair lambs will not require deworming, given natural parasite resilience; however, deworming on the solar site is also possible, although not included in the enterprise budget.

Sale of Lambs

The project will generate solar grazing compensation from the solar developer, in addition to revenue from the sale of lambs. This enterprise budget estimates that lambs are sold from the solar site at the end of the grazing period at 80 lbs. This approach is simplifying and yields approximately the same revenue as selling lighter-weight lambs for a higher per cwt. price mid-season. In practice, to adjust for changes in stocking rate as lambs gain weight, a staggered marketing approach is recommended whereby 40% of the lambs are sold mid-season and the remaining 60% are sold at the end of the growing season.

It is recommended that the lambs will be sold direct to a buyer to reduce buyer and seller transaction costs. Selling direct avoids the potential price-depressing effect often observed when significant volumes arrive at auction. It also avoids auction commissions and transport costs. A marketing budget will be critical to secure a lamb market in October. The 2021 Morris Ridge Solar Lamb Survey of the Genesee Valley Region conducted by Letchworth Gateway Villages found that most restaurants surveyed already offer lamb, offer U.S. and local lamb, and recognize the value to their customer of the grass-fed, solar grazed story. The survey results suggest that marketing grass-fed, solar-grazed lambs might secure price premiums in regional restaurants. The projected volume of solar-grazed lamb is sizable, and it is thus noteworthy that restaurants will purchase frozen product (personal communication). Preliminary outreach to buyers in the area found that selling a significant volume of lambs should not be a problem (personal communications).

The estimates made in this study focused on producing an 80 lb. hair lamb that is ready for sale in October. This decision was based upon the most popular weight class at the regional auction in New Holland, PA.

Lamb prices are not typically their highest of the year in the fall, but sale during this period allows the solar grazer to also benefit from the secondary source of income, the solar grazing income. Slaughter lamb prices nationally and at the New Holland Sales Stable auction exhibit strong seasonality. Prices are relatively high early in the year, gain towards the high-demand period of Easter holidays in late March and April, weaken in the summer, and then begin to gain through the fall and December holidays.

Figure 4 is a seasonal lamb price index which reveals that if the average annual price is indexed at \$100, first-quarter prices are 15% higher than the annual average, second-quarter prices are 6% higher, third quarter prices are 13% lower, and by the fourth quarter, averages fall to 8% lower than the annual average. In real terms—adjusting for inflation—over the past three years, prices gained 3% in the two months from October to November, and 6% from November to December.

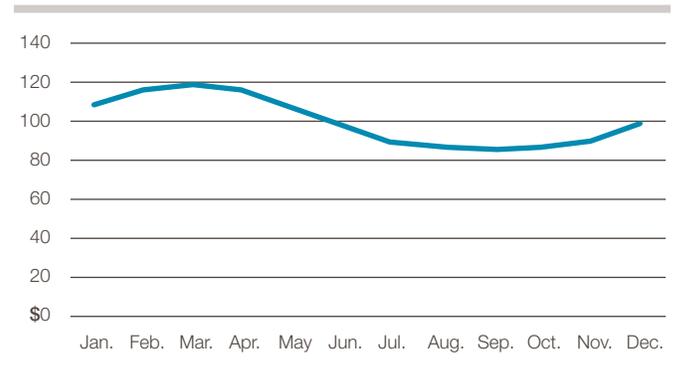


Figure 4. Slaughter Hair Lamb Price Seasonal Index at New Holland, PA Auction, 70-90 lbs., Good & Choice 1-2, 2018-6/2021. Source: Compiled from U. S. Department of Agriculture (USDA), Agricultural Marketing Service (AMS) sheep data.

From 2018 to May 2021, the average price of 70 to 90 lb. hair lambs at New Holland Sales Stable livestock auction was \$166.55 per cwt. in October and \$171.87 per cwt. in November, for a simple average of \$169.21 per cwt (Figure 5) (USDA/AMS, 2021). Therefore, \$169.21 per cwt. is used as an estimated sale price for solar-grazed lambs.

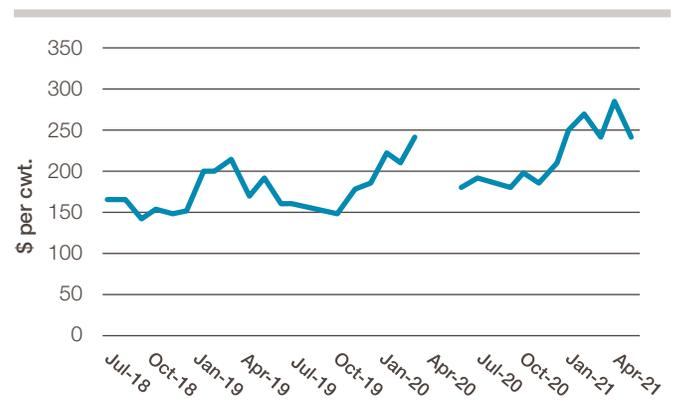


Figure 5. Hair Lamb Prices, 70-90 lb. New Holland, PA. Source: USDA, Agricultural Marketing Service (AMS), 5/2021.

Achieving top dollar for solar-grazed lambs can depend upon maintaining muscle through the loin and uniformity in lamb weight, which, in turn, yields consistency in size of cut (Wortman, personal communication 2021). Consistency in size of cut is critical to calculating plate cost in the traditional food service sector; however, this may not be as important in markets for which lambs are sold by the carcass (Wortman, personal communication 2021).

OPERATING EXPENSES

Operating expenses—also known as variable costs—vary with the volume of production, the number of sheep grazed, or the acreage contracted. Operating expenses are split into three categories: sheep expenses, labor expenses, and other expenses.

Operating expenses — Sheep expenses

Sheep operating expenses include lambs purchased, salt and minerals for the sheep, and a budget for medical care for the sheep. Purchasing lambs for grazing can account for an estimated 62% of total operation costs.

Operating expenses — Livestock Guardian Dogs

Livestock guardian dogs (LGDs) are expected to guard lambs from predators and reduce lamb losses at the solar site. In the literature there is a general rule of thumb that one LGD is recommended for 100 ewes but is it unlikely that a flock of 1000 ewes will have more than 6 LGDs (an average of 1 LDG per 167 head) (Redden, et al., 2015). This project assumes 1 LGD per 200 lambs. Dan Macon, county director, livestock and natural resource advisor, University of California, recommends a constant evaluation of the need for predator protection against the cost of providing it (Macon, personal communication).

LGDs factor into the budget as a project establishment, or investment cost, a cost of depreciation, and as an operating cost. The initial investment of LGDs for a dog that is ready to go to work is an estimated \$1000 (Redden, et al., 2015) to \$1500 (Macon, personal communication), which includes the purchase price, plus 12–18 months of food and veterinary costs. An average of \$1250 per LGD is assumed for this project.

Operating costs of LGDs per year for food and veterinary costs range from \$300, (Macon, personal communication) to \$500 (Redden, et al., 2015) to \$864 (Bruno, et al., 2019). A weighted average of \$800 per year is estimated per LGD per year for dog food and veterinary care for this project. The estimated cost is prorated for the five-month solar grazing season.

Operating expenses — Labor expenses

Labor expenses include hired labor and payroll taxes. Hired labor may cost up to about 10% of total operating expenses. According to Agrivoltaic Solutions LLC, it was estimated that four full-time personnel will be required for the Morris Ridge project. A more conservative estimate of one year-round family employee and five full-time seasonal employees is recommended.

Labor requirements include, but are not limited to, the following:

- Check for sheep health,
- Ensure solar panels are free from vegetation,
- Maintain rotational grazing,
- Ensure adequate feed and water supplies,
- Check for soil and forage health (conduct soil and forage quality tests),
- Conduct mechanical mowing and trimming,
- Ensure guardian dog health, and
- Maintain secure perimeter and interior fencing.

Five full-time, seasonal laborers are paid to work 8 hours per day, 30 days per month* for 6 months at an average rate of \$17.25 per hour using 2020 wages reported by the U.S. Bureau of Labor Statistics for “farmworkers, farm, ranch, and aquacultural animals.” A housing stipend may be warranted. The project may also explore the employment of seasonal shepherds holding H2-A visas.

Operating expenses — Other expenses

Other operating expenses vary, from the cost of shipping lambs to the solar site to insurance to mechanical vegetation management to the American Lamb Checkoff.

Shipping Lambs

Hauling lambs to the solar site is an important cost to solar grazing lambs. Costs will vary depending on distance traveled and trailer capacity. Reduced trips and full loads will help keep costs down. A lower-cost option is to hire a triple-decker sheep trailer (Grandin, 2001), rather than a double-decker trailer.

Fencing

A rotational grazing plan is recommended for the project, which will require temporary fencing in paddocks and the repositioning of fencing routinely over the course of the grazing season. The project will total an estimated 1060 acres and is proposed to be split into 6 pods of varying sizes. In turn, the pods are split into permanently fenced arrays, which again are split into paddocks. “Paddocks are created using planned permanent perimeter fencing

*Footnote: Shepherds are paid for a round the clock presence while monitoring sheep in the field.

and portable, battery charged ElectroNet fencing. The ElectroNet is a lightweight portable fencing material energized using a portable battery, battery/solar combination, or 110V power supply” (Agrivoltaic Solutions, 2020).

The grazing plan is designed such that sheep are rotated from paddock to paddock every one to four days (Agrivoltaic Solutions, 2020). Under this recommendation, over 400,000 feet of ElectroNet fencing will be required, at a cost of \$0.045 per foot.

Mechanical Trimming

According to the Cornell Atkinson Center Study, prevention of shading is the key priority for the solar site owners and operations and maintenance (O&M) divisions (2018). The Agrivoltaic Solutions grazing plan for the project is designed to perform 95% of vegetation maintenance, with a small amount of mechanical trimming (Agrivoltaic Solutions, 2020). This translates to 5% of the 1060 acres, or 53 acres to be mechanically mowed and trimmed. For this study, an estimated 10% of the project acreage will require mechanical mowing and trimming. Relevant capital expenses include a 70-horsepower skid steer and 72-inch mower, in addition to a heavy-duty string trimmer and string. String for the trimmer is included in the operating budget. Labor hours will also have to be allocated to mechanical trimming.

Soil Tests and Forage Tests

According to the Town of Mount Morris Agricultural and Farmland Protection Plan, there is a concern that “farmers operating on rented land tend to be more reluctant to make long-term capital investments in their business” (Thoma Development Consultants, 2019). Preserving farmland and quality of farmland can thus be an important objective of the grazing contract. Ensuring pasture and sheep health will require routine soil and forage tests.

It is recommended that soil tests are conducted once per year, at the same time each year, and forage tests conducted twice a year during the growing season. In the 2018 Cornell Atkinson study, 18-48 days prior to each rotation a forage test was conducted and analyzed for the nutritive value for sheep. Thus, at a minimum, forage test should be conducted every 48 days, or at least twice during the grazing season. The soil and forage testing sites should be no larger than 20 acres each.

Insurance

Two general categories of insurance are recommended for a solar grazer: Livestock insurance and the coverage required by the solar developer. It is recommended that the sheep grazer purchase livestock insurance to protect the sheep or lambs from unexpected death or theft, which is an estimated \$10,800 (annually) for the project. It is also recommended that the sheep grazer purchase professional liability insurance, which may cost up to \$1800.

Professional liability insurance protects the business against any alleged professional negligence not related to the solar developer’s equipment. It is further recommended that the solar grazer register as a Limited Liability Corporation (LLC) or corporation for further protection.

An estimated \$5000 per year is estimated to meet the requirements of the solar developer to protect against damage to the solar equipment and solar site for this project. This estimate may not be scalable to smaller or larger projects and warrants an inquiry to an insurance agent. An example of insurance required by a solar developer could include general liability (\$1M per occurrence/\$2M aggregate), auto liability (\$1M per occurrence), umbrella/excess liability (\$1M per occurrence—this can be waived with a higher general liability limit), and workers’ compensation (\$1M per occurrence, if applicable). By comparison, in the 2018 Cornell Atkinson study, insurance to the direct contractor was \$5709 per year.

The \$5000 quoted above does not include workers’ compensation. Payroll taxes including FICA, unemployment, and workers’ compensation are included under operating labor expenses at 20% of labor costs.

Lamb Checkoff

The lamb checkoff is a national program to fund promotional activities by the American Lamb Board. It is funded by fees, or assessments, paid by sheep producers, breeders, and processors. By federal law, all sheep or lambs, including ewes, rams, feeder and market lambs, breeding stock, and cull animals are subject to the national lamb checkoff at the time of any sale. Each producer, feeder, or seedstock producer is obligated to pay U.S. \$0.007 per lb. liveweight for lambs purchased. If the producer is also the first handler that processes lambs, he or she is also responsible for a U.S. \$0.42 per head assessment. In this study it is assumed that the grazer is not also the lamb processor and thus U.S. \$0.42 per head is not assessed.

INVESTMENT (FIXED COST)

The initial capital investment can be considered a fixed cost for this project. It is estimated that the capital investment for the Morris Ridge project is \$277,865. The initial capital investment includes a 4x4 truck, livestock trailer, ATVs, fencing for paddocks, water totes, water pump, portable handling equipment, a livestock guardian dog, signage, skid steer, mower, and heavy-duty string trimmer. The larger equipment such as the pickup and skid steer are estimated at pre-owned values.

The project assumed that the six pods of the solar site will each require an ATV, water pump, and ATV trailer to carry water. The project assumes that the solar developer will provide water (a pond or new well) within each pod. It is thus up to the solar grazer to transport water from its source in each pod to the paddock in which the sheep

are grazing. For smaller solar sites, the grazier is most often responsible for hauling water to the site.

The estimated capital costs are \$29 per head and \$262 per acre for the 1060-acre project. By comparison, a study by Cornell found that the capital investment for a 22-acre site running 56 sheep is \$30 per sheep and \$77 per acre, assuming the perimeter fencing is already in place (Kochendoerfer, et al., 2021).

A longer-term contract may be preferred by the grazier to pay for the capital costs over a longer term and reduce the year-to-year costs. Alternatively, the solar developer can help defray some of the up-front costs in exchange for a lower year-to-year fee from the grazier.

The capital investment will, in part, be a function of upfront capital investments made by the solar developer. The availability of fencing and water will be pivotal to the grazier's capital investment. For this project, it is assumed that each pod and array will be permanently fenced by the solar developer. It is therefore the responsibility of the solar grazier to cross-fence paddocks within the larger array.

ESTIMATED RETURNS

Table 2 presents the enterprise budget for grazing lambs at the Morris Ridge Solar Energy site, revenue, operating costs, fixed costs, and profitability metrics. The estimated enterprise budget produces positive accounting and economic returns, signaling that the project will yield the grazier positive profits, and that the selection of grazing lambs for sale at the season's end is a prudent use of resources among alternatives (Table 2).

Net cash income

Net farm income of \$271,588 per year is revenue less operating (or variable) costs. Income over variable costs is an estimated \$256 per acre on the 1060-acre project, which is marginally higher to previous studies of \$226 (ASGA, 2021) to \$241 (Kochendorfer, 2018) per acre for 25-acre sites.

Depreciation

Depreciation is a cost of doing business. Instead of incurring the cost of equipment in one lump sum, depreciation allows the cost of using equipment to be spread out over time while revenue is generated from its use. Depreciation can be thought of as using up a portion of an asset during project operations. The large equipment, such as the pickup truck and skid steer, are valued as purchased pre-owned equipment. Except for the truck, which is thought to last 5 years, heavier equipment is expected to last 10 to 15 years, with salvage values at an estimated 10% of the equipment's initial cost. Smaller equipment is expected to last three years. Depreciation is an estimated \$49,058.

Net farm income

Net cash income less depreciation is net farm income. Net farm income is an estimated \$222,530. The estimated profit per lamb is \$24 and the estimated profit per acre is \$210.

Return to unpaid operator's labor

The return to unpaid operator's labor, capital, and management is the net farm income less the value of family labor. The budget has thus far calculated accounting costs, not economic costs. However, it is important to include opportunity costs because funds and labor invested could have been used in an alternative enterprise. Opportunity costs are defined as the value of output that was foregone because scarce resources such as labor, sheep, and equipment were directed to solar grazing instead of an alternative enterprise. It is the value of the opportunity not realized because resources were used to solar graze rather than their next best use.

Family Labor

One such opportunity cost is the cost of unpaid family labor; the grazier could have chosen alternative work. The primary contractor, the solar grazier, will work the solar project full-time, year-round. The operational portion of the project of sheep on the solar site may be five to six months, but it is assumed that off-season activities may include negotiating and securing the next year's grazing contract, securing a lamb supply and market, obtaining insurance, and lining up hired labor. It is also understood that all equipment and electric fencing will have to be well maintained, with some necessary repairs. The tandem goals of maximizing graziers' returns and maintaining site sustainability will likely require site visits and off-season research.

The opportunity cost of family labor is estimated by using the U.S. Bureau of Labor Statistics report on "Farmers, Ranchers, and other Agricultural Managers" in New York in 2021, which was \$66,530 per annum per a 40-hour week.

The return to unpaid operator's labor, capital, and management is \$156,000 or \$147 per acre and \$17 per lamb. This means that the project is profitable. In fact, the project will return above-normal profits, which are profits above that which covers family labor and all costs.

This budget assumes the grazier secures financing for the project. If the graziers use their own capital, then the economic analysis would continue, deducting the opportunity cost of capital from the return to unpaid operator's labor, capital, and management. The foregone return on the grazier's assets that could have been used in an alternative enterprise is the opportunity cost of capital. This addition would assume that the grazier has 100% equity in their assets, without the need for debt financing, which would be defined as the return to operator's labor and management.

MODEL A - GRAZING LAMBS ENTERPRISE BUDGET

INCOME	Number	Unit	Price	Unit	Total
Lambs sold	9254	head	\$169.21	cwt	\$1,252,686.91
Grazing income	1060	acre	\$250.00	acre	\$265,00.00
Total Income					\$1,517,686.91
OPERATING EXPENSES – SHEEP	Number	Unit	Price	Unit	Total
Lambs purchased	9540	head	\$241.00	cwt	\$804,699.00
Salt and minerals	868	bags	\$35.00	per bag	\$30,364.03
Medicine	9540	head	\$3.00	head	\$28,620.00
Subtotal					\$863,683.03
OPERATING EXPENSES – LABOR	Number	Unit	Price	Unit	Total
Hired labor (5 seasonal, full-time)	9600	hours	\$17.25	hour	\$165,600.00
Payroll taxes (FICA, unemployment, workers comp, etc.)	165,600	dollars	20%	of total	\$33,120.00
Subtotal					\$198,720.00
OPERATING EXPENSES – OTHER	Number	Unit	Price	Unit	Total
Hauling to site (Using a triple decked trailer, traveling 600 miles)	20	trips	\$4.00	per loaded mile	48,000.00
Mileage (150-daily 70-mile round trips)	70	round trips	\$0.56	mile	\$2744.00
Fuel, gas, oil	1	number	\$20,000.00	mile	\$20,000.00
Insurance required by solar company			\$5000.00	total	\$5000.00
Livestock insurance			\$10,800.00	total	\$10,800.00
Insurance -- Professional Liability			\$1800.00	total	\$1800.00
Marketing (Assume direct marketing)	9254	head	\$5.00	per lamb	\$46,269.00
Soil test (1 per season every 20 acres)	53	test sites	\$10.00	per test	\$1060.00
Forage quality test (2 per every 20 acres/season)	53	test sites	\$40.00	per test	\$4240.00
Livestock Gaurdian Dog (LGD) costs	48	dogs	\$800.00	per year	\$19,200.00
Mechanical vegetation management (fuel and oil) (10% of total acres)	106	acres	\$5.65	per acre	\$598.90
String for trimmer	2	rolls	\$65.00	per roll	\$130.00
Payroll, accounting, legal & other professional services	1.0	professional	\$2000.00	per service	\$2,000.00
American lamb checkoff -- Live animal weight assessment	740,304	lbs.	\$0.007	per lb.	\$5182.13
Interest on operating capital	\$1,246,099		6.0%	annual rate	\$74,765.94
Interest on fixed investment	\$277,865		6.0%	annual rate	\$16,671.91
Subtotal					\$183,695.94
Total Operating Expenses (total variable cost)					\$1,246,098.97

INVESTMENT (FIXED COST)	Number	Unit	Price	Unit	Total
Truck, 4x4 (used)	2	number	\$20,000.00	total	\$40,000.00
Livestock trailer	2	number	\$10,000.00	total	\$20,000.00
ATV	6	number	\$10,000.00	each	\$60,000.00
Shop 30'x48'	1	number	\$25,000.00	each	\$25,000.00
110 Gallon Fuel Transfer Tank	2	tank	\$1000.00	each	\$2000.00
Electronet fencing for paddocks (2 miles)	10,056	feet	\$1.20	per foot	\$12,067.20
Energizer for fencing paddocks	6	per paddock	\$300.00	each	\$1800.00
Water tanks (700 gallon each)	6	tanks	\$400	per tank	\$2400.00
Water IBC Tote (Water cube)	4	number	\$300	per cube	\$1200.00
Water pump (diesel)	1	number	\$500	per pump	\$500.00
Portable handling equipment	1	system	\$3000	total	\$3000.00
Livestock Guardian Dog (LGD)	48	dogs	\$1500	per dog	\$72,000.00
Signage (100-sign pack)	100	signs	\$1098	total	\$1098.00
Livestock scale	1	scale	\$300	total	\$300
70-horsepower skid steer (used)	1	number	\$30,000	total	\$30,000.00
72-inch mower	1	number	\$6000	total	\$6000.00
Heavy duty string trimmer	1	number	\$500	total	\$500

Total Fixed Costs **\$277,865.20**

Net Farm Income (return to unpaid family labor and management)

Net cash income, projected return (income - variable costs)	\$271,587.93
Depreciation	\$49,057.56
Net farm income (less depreciation)	\$222,530.37
Profit per acre (net farm income/total acreage)	\$209.93
Profit per sheep (net farm income/number of sheep)	\$24.05

Return to Unpaid Operator's Labor, Capital and Management (ROLCM)

Net farm income	\$222,530.37
Unpaid family labor/Project manager	\$66,530.00
Net farm income (less unpaid family labor)	\$156,000.37
Profit per acre (including family labor)	\$147.17
Profit per sheep (including family labor)	\$16.86

Return to Unpaid Operator's Labor and Management

Net farm income (less unpaid family labor)	\$156,000.37
Possible return on equity (5% fixed costs and lambs)	\$54,128.21
Return to operator's labor and management	\$101,872.16
Profit per acre	\$96.11
Profit per sheep	\$11.01

Total investment	\$277,865.20
Annual rate of return on investment (including opportunity cost of family labor)	56.14%
Years to pay off investment (including opportunity cost of family labor)	1.78

Table 2. Model A - Grazing Lambs Enterprise Budget

The annual rate of return on the investment is 56%. This is calculated as net farm income divided by the total investment. The time to pay off the investment is 1.8 years, estimated by dividing the capital investment by net farm income.

The positive accounting and economic profit suggest that the estimated abnormal profits (above all labor and

other costs) will attract new entrants to the industry in a competitive market and bring these costs down to \$0 (which means the grazer is covering all costs and receiving a compensation of \$66,530). It is possible that as the solar grazing industry grows and the bid process becomes more competitive, the cost per acre paid to the grazer by the developer may be reduced while maintaining profitability for the grazer.

IV. EMPLOYMENT

Grazing lambs at the solar site will stimulate local and regional economic development by creating jobs. The project will employ personnel, but it will also stimulate a multiplier effect that can benefit employment in western New York beyond the immediate labor requirements of the project itself.

A contribution study can quantify the direct, indirect, and induced employment effect from solar grazing lambs at the project. The IMPLAN modeling software calculates employment multipliers through surveys of input-output factor relationships across U.S. industries. The input-output multipliers for the IMPLAN Sector 13—non-cattle and non-poultry livestock—are examined here.

It is estimated that the project will create full-time employment positions, which is denoted by the direct employment effect. In turn, this direct effect will promote employment in backward-linked industries in what is known as the indirect effect. The indirect effects are the inter-industry purchases as they respond to the demands of the directly affected industry (solar grazing). The sheep graziers employed—including the primary operator—will purchase goods and services including equipment, fuel, and fencing from the local community. Lamb purchases will be an important indirect effect but are not projected to occur in the local community. Instead, lamb purchases will promote employment and economic development in the national sheep industry.

A second multiplier effect, the induced effect, can be quantified in a contribution analysis. The induced effects reflect spending by households compensated by solar

grazing income. Lamb producers most likely spend most of their income in their local economy on goods and services from work gloves to dining out. The induced effect represents the impacts on all local industries caused by the expenditures of household income generated by sheep grazing.

The project assumes 1 full-time position employed by the owner-operator and 5 full-time seasonal jobs. The 5 seasonal positions—at 6 months each—equate to 2.5 full-time positions. Thus, the project will create 3.5 full-time positions. Employment multipliers from IMPLAN and compiled in an American Sheep Industry Association study (Shiflett, 2011) indicate that the direct effect of those full-time jobs will generate an additional 1.4 jobs being added in the indirect effect and an additional 0.90 jobs in the local economy in an induced effect for a total contribution effect of 5.8 jobs. Thus, nearly 6 jobs will be created in the Mount Morris region as a direct result of the project solar grazing activities, further boosting local employment and stimulating local economic development, in addition to the jobs created for the operation and maintenance of the project.

It is expected that Utility Scale Solar Energy (USSE) facilities may bring sheep infrastructure to New York State, particularly sheep winter housing facilities, and increase the demand for hay and grain. Kochendoerfer and Thonney report that USSE facilities may spur the development of new business such as veterinarians, barn-builders, slaughterhouse operators, butchers, and other farm service providers (Kochendoerfer, et al., 2021).

V. MODEL B — GRAZIER GRAZES OWN FLOCK IN ADDITION TO SUBCONTRACTED EWES

An enterprise budget for a second, separate model is estimated to reveal possible returns from an alternative grazing plan. In this model, a local sheep producer is awarded the project contract for the season. The local sheep producer will graze their flock on the Morris Ridge site and subcontract the remaining sheep grazing to other graziers.

Many of the assumptions and costs assumed in Model A, grazing lambs, hold for Model B, grazing ewes and subcontracted ewes.

REVENUE AND EXPENSES

The budget assumes the sheep producer is local to western New York and will run 200 hair ewes on the site. The sheep operator's breeding program may strategically take advantage of solar grazing. It is assumed that lambs are born in December through February, weaned, and sold for the high-priced Easter market and then ewes are sent to the solar site in May for grazing through October. The sheep producer's rams will also be grazed to breed mid-season. Providing summer and early fall pasture for ewes can reduce pressure on the sheep producer's pasture and enable the producer to harvest hay for winter feeding.

A unique parameter of this model is that fixed costs for the solar site will be prorated for one half of the year. This budget is not a whole-farm budget, but for the solar grazing enterprise only. Except for the purchased signage for the project, the sheep producer is expected to use the capital equipment at the home base, in addition to the solar site. All capital investments will be used throughout the year at the solar site and at the producer's farm. This assumption reduces the cost of depreciation by one half. Breeding ewes are not included in depreciation. It is assumed that the ewes are born and raised, not purchased, as is the case of an established sheep operator.

It is expected that there will be five subcontracts (the first to the direct contractor and the remainder to the subcontractors), associated with the following outline of Mount Morris sections 1–6, as detailed in the Agricultural Integration Plan (Agrivoltaic Solutions, LLC in 2020).

	Acres	Sheep (at 3.6 sheep per acre)	Subcontracting Expense @ \$125 per acre
Section 1	65.6	236.16	N/A
Section 2	243.6	876.96	\$30,450
Section 3	131.9	474.84	\$16,488
Section 4	263.9	950.04	\$32,988
Section 5	246.4	887.04	\$30,800
Section 6	108.5	390.6	\$13,563
Total	1,060	3,816	\$124,288

Table 3. Possible Subcontracts by Acreage, Sheep, and Expense

The primary contractor may be responsible for the following:

- Insurance,
- Soil and forage tests,
- Mechanical mowing and trimming,
- Signage

Reportedly, subcontracting with the project will allow regional sheep producers to 1.) generate a new revenue stream, 2.) interrupt the parasite life cycle on the farm, and 3.) stockpile forage for the winter (Bridge, 2020).

The primary contractor can pay for insurance required by the solar developer, which is valued at about \$5000 per year. It will have to be determined whether subcontractors are covered under the primary contractor's policy. The grazer is also expected to carry professional liability insurance and livestock insurance.

Another responsibility of the primary contractor may be mechanical mowing and trimming. With this requirement, the site owner of the project will provide for regular inspections of all acreage and sheep and ensure that solar panels are free of vegetation and that the sheep and pastures are being cared for according to contract stipulations. Soil and forage testing can also be the responsibility of the primary contractor. As stated, this task will help the contractor determine whether the subcontracts are being upheld.

The primary contractor may provide additional provisions such as portable, electric net fencing for interior cross-fencing, distribution of water from its source (well or pond) to the sheep, guard dogs, sheep minerals, and any necessary medical or veterinary assistance.

The sheep producer faces a unique objective function. The grazer is responsible for vegetation removal on the 1060-acre site and aims to minimize costs of subcontracts and maximize solar compensation revenue. Informal discussions with current solar graziers concluded that the primary contractor would receive \$250 per acre—as assumed in the previous model of solar grazing lambs—and the subcontracted solar grazer(s) would receive \$125 per acre, or half of the primary contractor compensation.

The primary contractor will provide the subcontractor with a detailed contract. The contract could provide an incentivized compensation structure, whereby the subcontracted grazer has a financial incentive to achieve the multiple goals of the contract, including items specified in Table 4. For example, if reduced mechanical mowing and trimming is required of the primary contractor, the subcontractor may receive a bonus.

Some general recommendations for subcontracting include having a lawyer review the contract, putting all communication between primary contractor and subcontracted grazer in writing, and not assuming, as primary contractor, that the pastures, solar panels, water sources, or animals will be treated a certain way (Grzeskiewicz, 2018).

RETURNS

The estimated returns from grazing a sheep producer's ewes in addition to subcontracting the site to ewes is presented in Table 5. A recommendation of 2.5 ewes per acre could be the maximum stocking rate, but subcontractors could opt for a lower stocking rate.

The net cash income (before depreciation is deducted) is \$107,510. The deduction of depreciation brings net farm income to \$102,225. The return to unpaid operator's labor, capital, and management is \$35,695 and \$96 per acre.

The interest on fixed capital assumes that half of the required capital investment is financed. The sheep producer will likely already have most, if not all, of the necessary investment. The annual rate of return on the investment is 65%. This is calculated as net farm income divided by the total investment. The time to pay off the investment is 1.5 years, estimated by dividing the capital investment by net farm income.

The return to operator's labor and management subtracts the value of family labor and subtracts the possible return on equity. The foregone return on the grazier's assets

that could have been used in alternative enterprise is the opportunity cost of capital. In the project, the opportunity cost of using sheep and equipment for solar grazing rather than their next best use is estimated at 5% of the value of its fixed costs and the purchase value of its ewes (200 ewes at \$80 per cwt., and 150 lbs., or \$24,000). The assets utilized in this project have a value that could have been employed elsewhere to produce sheep, raise row crops, or graze cattle. The return to the operator's labor and management is \$30,144.

The accounting and economic profit of a primary sheep producer grazing their own flock and subcontracting the remaining acres to ewes are positive. As in Model A, it is understood that in a competitive market, profits that are estimated above all costs could be bid down to \$0. This means that the sheep operator will still receive compensation equal to opportunity cost, but that the grazing compensation may be reduced through competitive bidding among graziers. The grazier who accepts the lowest compensation rate, in some cases, may receive the solar contract.

Morris Ridge Goals:	Subcontracted Graziers' Responsibilities:
Vegetation removal from solar panels	<ul style="list-style-type: none"> Solar panels are free of vegetation.
Land and water resource protection	<ul style="list-style-type: none"> Timely sheep rotation among paddocks. Proper water delivery to sheep, storage, and drainage.
Preservation of agriculture	<ul style="list-style-type: none"> Sheep health is well maintained. Subcontractor can operate a financially feasible enterprise.
Community sensitivity	<ul style="list-style-type: none"> Care for sheep health (check animals sufficiently often to mitigate illness and conduct preventative care). Guard dogs maintained (do not threaten solar site workers or neighbors). Herding dogs maintained (do not threaten solar site workers or neighbors). Exterior perimeter fences and signage are well cared for The site is for sheep grazing, only; it is not a storage site for personal trucks, trailers, equipment, RVs, etc. The subcontractor cannot live on the solar site.

Table 4. Subcontracted Graziers' Responsibilities

MODEL B - GRAZING OWN EWES & SUBCONTRACTING BUDGET

INCOME	Number	Unit	Price	Unit	Total
Grazing income	1060	acre	\$250.00	acre	\$265,00.00
Total Income					\$265,00.00
OPERATING EXPENSES – SHEEP	Number	Unit	Price	Unit	Total
Salt and minerals	19	bags	\$35.00	per bag	\$665.00
Medicine per 200 ewes	200	head	\$3.00	head	\$600.00
Subtotal					\$1,265.00
OPERATING EXPENSES – SUBCONTRACT	Number	Unit	Price	Unit	Total
Subcontracted graziers	994.3	acres	\$17.25	hour	\$124,287.50
Subtotal					\$124,287.50
OPERATING EXPENSES – OTHER	Number	Unit	Price	Unit	Total
Mileage (150-daily 70-mile round trips)	150	round trips	\$0.56	mile	\$5880.00
Fuel, gas, oil (on-site trucks, ATVs, skid steer)	200	per ewe	\$5.3190	mile	\$1063.83
Insurance required by solar developer			\$5000.00	total	\$5000.00
Livestock insurance			\$100.00	total	\$100.00
Insurance – Professional Liability			\$1800.00	total	\$1800.00
Soil test (1 per season every 20 acres)	53	test sites	\$10.00	per test	\$1060.00
Forage quality test (2 per every 20 acres/season)	53	test sites	\$40.00	per test	\$4240.00
Dog Food	50	bags	\$30.00	per 50-lb. bag	\$1500.00
Mechanical vegetation management (fuel and oil) (10% of total acres)	106	acres	\$5.65	per acre	\$598.90
String for trimmer	2	rolls	\$65.00	per roll	\$130.00
Interest on fixed investment	\$27,511		6.0%	annual rate	\$1650.68
Interest on operating capital	\$148,576		6.0%	annual rate	\$8914.55
Subtotal					\$31,937.96
Total Operating Expenses (total variable cost)					\$157,490.46

INVESTMENT (FIXED COST)	Number	Unit	Price	Unit	1/2 Total prorated for a 6 month grazing season
Truck, 4x4 (used)	1	number	\$20,000.00	total	\$10,000.00
Livestock trailer	1	number	\$10,000.00	total	\$5000.00
ATV	1	number	\$10,000.00	each	\$5,000.00
ATV trailer	1	number	\$800.00	each	\$400.00
Fencing for paddocks	42,503	feet	\$0.045	per foot	\$956.32
Water IBC Tote (Water cube, 275 gal.)	2	number	\$400	per cube	\$400.00
Water pump (diesel)	1	number	\$500	per pump	\$250.00
Portable handling equipment	1	system	\$3000	total	\$1500.00
Herding dogs	2	dogs	\$500	per dog	\$500.00
Signage (100-sign pack)	1	pack	\$1098	total	\$549.00
Livestock scale	1	scale	\$300	total	\$150.00
70-horsepower skid steer (used)	1	number	\$30,000	total	\$15,000.00
72-inch mower	1	number	\$6000	total	\$3000.00
Heavy duty string trimmer	1	number	\$500	total	\$250.00
Electronet fencing for paddocks (2 miles)	10,056	feet	\$1.20	per foot	\$12,067.20
Total Fixed Costs					\$55,022.52

Net Farm Income (return to unpaid family labor and management)

Net cash income, projected return (income - variable costs)	\$107,509.54
Depreciation (prorated for 1/2 year)	\$5284.60
Net farm income (less depreciation)	\$102,224.94
Profit per acre (net farm income/total acreage)	\$96.44

Return to Unpaid Operator's Labor, Capital and Management (ROLCM)

Net farm income	\$102,224.94
Unpaid family labor/Project manager	\$66,530.00
Net farm income (less unpaid family labor)	\$35,694.94
Profit per acre (including family labor)	\$33.67

Return to Unpaid Operator's Labor and Management

Net farm income (less unpaid family labor)	\$35,694.94
Possible return on equity (5% of investment and ewe value)	\$5551.13
Return to operator's labor and management	\$30,143.82
Profit per acre	\$28.44

Total investment	\$55,022.52
Annual rate of return on investment (including opportunity cost of family labor)	64.87%
Years to pay off investment (including opportunity cost of family labor)	1.54

Table 5. Budget: Grazing Own Ewes and Subcontracting

VI. SENSITIVITY ANALYSIS

Both solar grazing models are based upon estimates, and thus there are variables at play depending upon unique management decisions and market conditions. Many variables are within the graziers' control, but in some parameters, such as negotiating the purchase and sale price of lambs, the grazier may have limited authority.

It is also possible that the variables estimated in these models may differ depending upon the design of the solar site. Labor is a significant cost to the project, and any labor-saving measures that the solar developer can build into the site will see immediate returns. For example, cost savings will be realized if water is readily available within each pod, array, and even paddock (Agrivoltaic Solutions, Moore, personal communication). Other potential labor costs-savings include positioning electric outlets at the end of a row of solar panels periodically throughout an array and paddock (Moore, personal communication). Savings associated with having readily available electricity for fencing, power tools, and lighting can be significant.

Some risk factors are highlighted here that can have a substantial effect on the project's bottom line.

Lamb Prices

The project faces important price risk in both the purchase and sale prices of lambs. There are a host of variables that may vary from the estimates presented herein, only one of which is the sale price of lambs. If the price of lambs sold drops 10%—from \$169 to \$152 per cwt.—while all other variables remain the same, revenue does not cover the opportunity cost of labor, and the return to unpaid operator's labor and management drops from \$101,872 to \$25,553. The profit per acre drops from a \$96 profit to a \$24 loss, and the return per lamb drops from a profit of \$11 per head to a loss of \$2.79 per lamb. The economic negative returns to the operator's labor and management suggests that if sale prices drop 10%, then the capital invested in the project may see more positive returns in an alternative enterprise.

Additional risk variables included in both models include:

- **Availability of Skilled Labor** —particularly skilled labor that can independently identify and treat sick lambs and sheep and can operate mowing equipment—is another important input variable that can face uncertainty. A survey of solar developers by ASGA revealed that a “key challenge to scaling up is finding local shepherds” (ASGA, 2020). Securing skilled seasonal labor may be a challenge in western New York and the project may have to offer a higher level of compensation and/or offer enticements such as a housing stipend. Qualified laborers directly impact the volume of lambs sold and flock health.
- **Lamb Losses** due to a range of reasons and lamb losses due to predators is largely unknown. Predator problems can be very site specific. It is possible that sheep loss due to predators could be a major cost to the project. Predator or other death losses could reduce the number of head for sale at the end of the season, negatively impacting returns, but also present a public relations concern if dead sheep are viewed by the community. Although permanent and mesh fencing will be utilized, predators such as coyotes can dig under fences and are known to jump higher than deer (Moore, personal communication). It is assumed that lambs and ewes will face predators; the question is with what measures, and at what cost, can the potential predator problem be mitigated.
- **Guardian Dogs** can be part of a predator control solution, but it is uncertain whether guard dogs will pose a high-cost liability. By one account, guardian dogs are 100% worth the trouble (Moore, personal communication). However, ASGA reported that at some USSE facilities, guard dogs created “too much of a liability” (ASGA, 2020). That is, dogs posed too much of a safety risk to people. Guard dogs are costly and potentially threaten project solar workers and neighbors. Guard llamas or donkeys are a possible alternative and would eliminate the need for purchased dog food, but their effectiveness is questionable.
- **Contract Length** The length of contract may be critical to the project's long-term success from the perspective of grazier and solar developer. The grazier could face reduced transaction costs stemming from the development of long-term relationships with potential lamb sellers and subcontracted graziers. Furthermore, as mentioned earlier, a longer-term contract could be preferred by the grazier to pay for the capital costs over a longer term and reduce the year-to-year costs. Alternatively, the solar developer can help defray some of the up-front costs, in exchange for a lower year-to-year fee from the grazier.
- **Subcontracting** can be challenging for both parties. A mid-season default could lead to higher-cost mechanical vegetation management backup plan, if replacement ewes cannot be sourced.
- **Solar Developer Investment** The budgets estimated here for grazing lambs or ewes made important assumptions about the upfront investment made by the solar developer. Some initial capital expenditures borne by the grazier may be reduced if the solar developer invests more heavily in site infrastructure such as fencing, access to electric outlets for the electric fence charger, and water availability. These budgets assumed the solar developer will provide permanent, exterior fencing for the pods and arrays.

However, permanent cross fencing inside the pods to create additional subdivided interior paddocks would help reduce graziers' capital costs, as well as significant labor costs in setting up and moving electric fencing to accommodate grazing rotations.

Conclusion

This project estimated two solar grazing budgets:

- 1) grazing lambs with a staggered marketing plan, and
- 2) grazing a producer's own flock with subcontracts for the solar site's remaining vegetation removal.

Both budgets relied upon primary assumptions from current graziers and secondary sources. To the project teams' knowledge this is the first known utility-scale solar budget and therefore assumptions were made regarding scale.

Both budgets estimated profitable returns by several different accounting and economic metrics. Economic profitability included the cost of depreciation and the opportunity cost of the grazier's time and the opportunity cost of capital. The budgets estimated abnormal profits which means that some profit remained after accounting for all costs and the operator's time. In a competitive market, abnormal profits can be bid down by competing graziers accepting lower compensation rates to secure solar grazing contracts.

Future research is recommended to test the robustness of the budget estimates. A comprehensive review of the budget by graziers and academics, alike, is recommended and a comprehensive sensitivity, or risk, analysis is also recommended. A cursory sensitivity analysis revealed that a 10% drop in the sale price of lambs resulted in a negative return to the operator's labor and management.

This study revealed that sheep grazing can be a favorable agrivoltaic practice providing local, grass-fed, solar-grazed lamb (in a market where over half the lamb consumed is imported), providing positive sheep producer revenue, supporting agricultural employment, and rebuilding agricultural infrastructure. Further, as utility-scale solar energy systems expand across the country, solar grazing can be the demand catalyst to reverse contractions in the U.S. sheep industry.



Photo courtesy of: American Solar Grazing Association

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LITERATURE REVIEW

	Acreage	No. of Head		Income over Variable Costs	Income over Variable Costs per Acre	Income over Variable Costs per Sheep
2018 Cornell University David R. Atkinson Center for a Sustainable Future (1), Solar grazing experiment, Musgrave Research Farm in Aurora, New York	22	56	Directly contracted	\$5291	\$241	\$94
			Subcontracted (no insurance cost)	\$1291	\$59	\$23
2019 Cornell University David R. Atkinson Center for a Sustainable Future ¹ , Survey of solar graziers	Survey of 14 graziers on a total of 3,503 acres in eastern U.S.	NA	New York State — Directly contracted		\$509	
		NA	New York State — Subcontracted (no insurance cost)		\$274	
		NA	Eastern U.S. — Directly contracted (no insurance cost)		\$262	
		NA	Eastern U.S. — Subcontracted (no insurance cost)		\$244	
Spring 2021 Draft, American Solar Grazing Association (ASGA)	25	75		\$5655	\$226	\$75
2021 North Carolina <i>Choices</i> ²	25	100		\$8524	\$340	\$85

¹“The agriculture, economic, and environmental potential of co-locating utility scale solar with grazing sheep”

²NC Choices, a Center for Environmental Farming Systems Initiative; North Caroline Cooperative Extension; USDA National Institute of Food and Agriculture

Morris Ridge Lamb Demand Survey

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I. Introduction	32
II. Lamb Demand in Northeastern United States	34
III. Lamb Demand in 2020 and Forecasts	34
IV. Genesee-Finger Lakes Region Lamb Demand Survey	35
V. Lightweight Lamb Demand	40
VI. Regional Lamb Processing Capacity	41
VII. Conclusion	42
References	43
Appendix	44

List of Figures

Figure 1: Lamb Markets	32
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List of Tables

Table 1: How Consumers Define Quality	33
Table 2: Defining Consumer Transparency	36
Table 3: Survey Question: Would your customers be interested in purchasing local, grass-fed, solar grazed lamb?	38
Table 4: Survey Question: Would you be interested in purchasing local, grass-fed, solar grazed lamb?	38
Table 5: Survey Question: Open-Ended Comment Question	39

I. INTRODUCTION

Estimating current and potential demand for lamb in the Genesee-Finger Lakes Region of western New York and regionally is central to estimating the profitability of grazing sheep on solar sites in the Mount Morris, NY, area. Successful sheep production is predicated upon having a viable market for lambs and maintaining or expanding demand. A lamb demand survey was conducted in May 2021 to assess regional demand in western New York, with a formal food service survey as well as an informal survey of the ethnic lamb market.

Defining demand is key to understanding the current lamb market and its potential for expansion. Lamb demand is the amount of lamb consumers purchase, coupled with the price at which consumers are willing to pay for lamb. Demand is about price and quantity purchased. In order to promote lamb, expand demand and grow the industry, more lamb will have to be sold at constant or higher prices. That is, if the solar projects in the vicinity of the Town of Mount Morris inject a large number of lambs into western New York, and prices weaken due to the increase in supply, lamb consumption will increase regionally, but at lower, not higher prices. This isn't industry-expanding demand growth. The increase in volume of lambs must be met with constant to higher prices to encourage flock rebuilding and other investments in sheep infrastructure.

The American Lamb Board (ALB) is to be commended for its ongoing efforts to develop lamb demand marketing strategies to reach U.S. consumers. Its efforts will help guide marketing efforts of solar grazed lambs in the Mount Morris area and across expanded agrivoltaic sites in the U.S. In 2020, a partnership between the ALB. and Texas retailer H-E-B resulted in American lamb sales increasing 47% year-on-year. Further, in 2020, Taziki's Mediterranean Cafe and ALB. partnered for the first-ever American lamb chain restaurant promotion that included all 90 locations in 17 states.

Most people living in the U.S. do not eat lamb, or do so very seldomly, while a smaller segment of Americans eat lamb regularly both at home and away from home. On average, Americans eat less than 1 lb. of lamb annually, compared to about 58 lbs. for beef, 50 lbs. of pork and 95 lbs. of poultry. In the U.S. a minority population comprised of some ethnic groups and Millennials eat lamb more often. Many cultural and ethnic groups consume lamb regularly as a part of their customs and religious observations. A 2010 study revealed that just 35% of America's population in 2008 consumed a disproportionate 58% of the lamb available (Shiflett, et al. 2010).

Lamb demand in the U.S. is seasonal. Western and Greek Easter are important spring holidays, trading significant volumes; additional lamb-centric holidays include

Eid al-Fitr and Eid al-Adha (often observed in the summer months) and December holidays observed across multiple cultures and religious traditions.

The closest substitute for U.S. lamb is imported lamb. Nationally, about 60% of the lamb consumed is imported, primarily from Australia and New Zealand. Imported lambs rapidly took a foothold in the U.S., expanding 65% over the past 10 years and doubling over 20 years. There are multiple reasons for this growth including reduced sheep inventory in the U.S., relative competitiveness of imported product, and consistency of size and quality of imported product.

The U.S. lamb industry is characterized by three distinct but overlapping industries (Figure 1). The largest market is the mainstream market, which comprises about 85% of all lamb sales in the U.S. It caters to the largest retail chains and mainstream food service sector. Historically it has supplied feedlot finished, woolled, fat and heavy lambs weighing 120 to 160 lbs. The second largest market is the lightweight (ethnic) lamb market catering to ethnic demand at retail and food service. The lightweight trade is characterized by hair or woolled lambs weighing roughly 50 to 110 lbs. The third market is the direct-to-consumer market characterized by farmers markets, community supported agriculture (CSA), and online sales. Figure 1 is not stagnant, for the crossover sections between the three markets is believed to be growing.

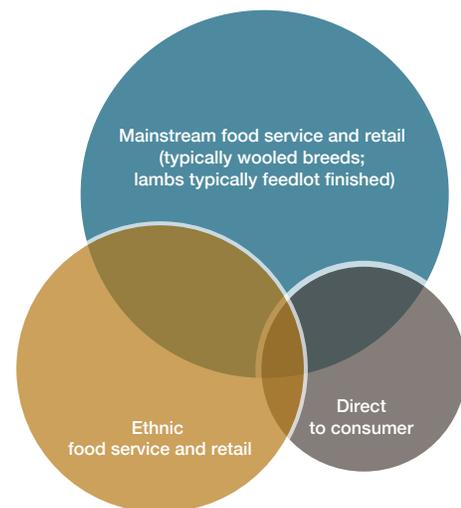


Figure 1. Lamb Markets

Figure 1 Lamb Markets within the mainstream lamb market, about 60% of sales prior to the COVID-19 pandemic were through the food service sector with the remainder channeled to retail. As COVID-19 ascended in March 2020, food service lamb sales quickly contracted as the food service sector shut down and retail lamb

sales expanded; however, the food service sector is expected to recover fully in coming years.

Overall, lamb penetration at food service, the percent of restaurants that serve a particular food, flavor, or ingredient, remains low outside of mainstream fine dining restaurants, but it is growing (Datassential, 2018). While lamb penetration at fine dining restaurants is high at 62%, lamb penetration at other more casual restaurants is much lower but is also growing (Datassential, 2018). This suggests the importance of surveying a variety of restaurants to accurately reflect industry trends. Steakhouses are important at 83% penetration, as are Mediterranean restaurants at 91% penetration. Among restaurant chains and independents (not fine dining restaurants), 62% of all entrée lamb on menus can be found at Indian & Mediterranean cuisine. Overall, lamb has a 23% penetration rate at ethnic restaurants, compared to 10% for non-ethnic restaurants.

Lamb demand by U.S. consumers reflects a complex web of demand attributes including price and quality. According to Midan Marketing, quality is further defined by lamb that is categorized as Prime, Lean, Premium and Humanely Raised (Uetz, 2019). Other considerations include marketing claims such as No Antibiotics Ever, All Natural, and Sustainably Raised.

Prime	Humanely Raised
Lean	Premium
No Antibiotics Ever	All Natural
No Added Hormones Ever	Bright Pink
Sustainably Raised	Certified Tender
Locally Raised	Organic
Vegetarian-Fed	Heritage

Table 1. How Lamb Consumers Define Quality. Source: Uetz, M. 2019. From Tyson Fresh Meats. Spring 2018 Consumer Monitor.

According to research by Midan Marketing, the ALB should focus on the industry’s “continued ability to provide consumers with high-quality sheep and lamb products in a way that sustains the lamb industry and its families, employees, and communities, and does not reduce the capacity of the environment to provide for the needs of future generations.” (Uetz, 2019) It is believed that solar grazing sheep can meet this demand, be it through mainstream or ethnic markets.

Lamb demand in the U.S. is significant and expanding as seen in the gaining popularity of Asian, Indian, Middle Eastern, African, and Southern Europe cuisine. As detailed in Midan Marketing’s June 2021 Multicultural report to the American Lamb Board, one “factor that could be influencing lamb’s popularity in recent years is growing demand among first-generation Americans

from the Middle East and Southern Europe where lamb is closer to a food staple in their diets.” According to Midan, non-White meat eaters purchase lamb more often than White meat eaters. One in four Asian meat eaters have purchased lamb in the past month, while one in five Hispanic and Black meat eaters have also purchased lamb. It is believed that ethnic consumers account for the highest per capita consumption of U.S. lamb.

Demand for lightweight lambs is growing, and by several anecdotal accounts, supply is expanding. According to Reid Redden, director of the Texas A&M AgriLife Research and Extension Center at San Angelo, TX, “between 30-50% of the lambs in the U.S. are going to non-traditional markets, a market in which consumers prefer a smaller, leaner animal (Gewin, 2021).” Furthermore, “during the pandemic, ethnic markets took on some of the excess supply due to the drop-off in foodservice (Gewin, (consumption). (Gewin, 2021).

Marketing efforts geared toward ethnic populations are not a one-size-fits-all campaign. A 2011 study by Texas A&M found that the two most important drivers of the lamb buying, and preparation behavior of ethnic consumers are differences in race/ethnicity and religion (Williams, et al. 2011). Ethnic lamb consumers are a diverse market segment that includes Asians, Greeks, Hispanics, Jews, and Muslims. Within the Muslim community, further market segmentation in lamb demand is documented including consumers from Eastern Europe, the Middle East, and North Africa (Williams, et al. 2011).

There are multiple potential marketing options for solar grazed lambs in the Mount Morris area that may be created by catering to niche and ethnic markets.

- Sell niche lambs to a processor and fabricator that will supply upscale foodservice and retail whereby the local, grass-fed, solar grazed story will command a price premium. Part of the marketing campaign may indicate that supporting a domestic, solar grazed lamb product helps justify the deployment of solar projects on agricultural land, a strategy that helps address climate change in the Northeast. However, in selling the grass-fed, solar grazed story, price will remain a consideration. Additionally, consistency in cut size and quality will be paramount to attract and sustain a hyper-targeted consumer.
- Market lightweight lambs direct to an ethnic processor. Ethnic processors supply primarily ethnic consumers who customarily eat lamb regularly and in observance of religious celebrations. Such buyers seek lighter weight lambs, near 100 lbs., and will likely be price conscious first and quality conscious second.
- Without further investments in marketing, local and regional processing, fabrication, and distribution, direct lamb sales from Mount Morris area sheep graziers to consumers are not recommended at this time.

II. LAMB DEMAND IN NORTHEASTERN U.S.

The Northeastern U.S., and New York City are historically the strongest lamb demand markets in the U.S., In its 2021 first quarter report, Midan Marketing found that through March 2021, “in terms of U.S. regions, the Northeast continues to outsell the rest of the country by a large margin - whether measured by dollar sales or volume sales.” Midan continued: “New York, as usual, sold the most dollars and pounds of lamb of any market in the United States.”

In the year through March 2021, retail dollar sales of lamb in the Northeast increased 22% to \$148 million and pounds sold jumped 15% to 17.7 million lbs. (Midan, 2021). By comparison, lamb demand in the second-most popular region, the Southeast, was \$83.2 million and 9.3 million lbs. sold in the year to March 2021 during the same timeframe.

In the year ending March 31, 2021, retail lamb demand in New York City expanded year-on-year. Dollar sales gained 19% to \$91.8 million, and pounds sold gained 12% to 7.3 million lbs. The shoulder was the most popular cut followed by ribeye, leg, and loin. However, the ribeye is highest-valued cut by a significant margin, followed by the shoulder, loin, and leg. In the year ending March 2021, the ribeye averaged \$14.78 per lb. at retail.

Datassential reported to the American Lamb Board in July 2018 that in the food service sector, lamb is slightly more favored in the Northeast than in other regions, followed by the West. Of fine dining restaurants serving entrées, 61% in the Northeast offer lamb (lamb penetration), compared to 59% in the West, 58% in the South and 54% in the Midwest.

III. LAMB DEMAND IN 2020 AND FORECASTS

U.S. lamb made headlines in 2020. The pandemic prompted an uptick in retail lamb sales, record high prices at wholesale, and strong prices at live lamb auctions. “Lamb has had a tremendous 2020 and continues to track far ahead of prior year sales levels in 2021,” reported 210 Analytics’ Anne-Marie Roerink in an interview with *The Food Institute*. Ms. Roerink continued: “When the supply for beef, chicken, and pork was tight ... out-of-stocks drove people to experiment with other proteins, including lamb. ... Adventurous millennial eaters and home chefs have fueled a good portion of retail demand, but there’s another factor that’s been boosting lamb’s popularity in recent years—growing demand among first-generation Americans from the Middle East and southern Europe, where lamb is a staple.” (Beaton, 2021)

Fresh lamb at retail was the only meat category tracked by 210 Analytics to show positive year-on-year sales growth in early 2021. In the year through March 2021, U.S. consumer demand for lamb at retail expanded significantly compared to the prior 12 months (Midan, 2021). Lamb retail dollar sales increased 27% year-to-year and pounds sold expanded by 19% (Midan 2021). In 2020 and the first-half of 2021, national wholesale lamb prices hit record highs (national retail prices are not tracked publicly) and in 2021, the live lamb market followed suit.

It is hypothesized that the COVID-19 pandemic triggered a renewed interest in lamb which will be sustained for some time. Anne-Marie Roerink, Principal at 210 Analytics, explained:

“Pre-pandemic, restaurants had the bigger portion of lamb sales, certainly in dollars. But it was exactly those white tablecloth restaurants that were heavily affected by the lockdowns. So, people started to experiment with different meats and the lamb enthusiast banked on their ever-growing meat IQ to include lamb in their regular meal lineup instead of this being something made during the holidays only. The sustained strength in lamb sales demonstrates that this may be a trend with staying power.”
~ (Campbell, 2021)

In its June 2021 report to the ALB, Midan Marketing forecast an increase in meat demand as the economy rebounds and consumer confidence expands. Expanded stimuli checks and COVID-suppressed spending may translate to expanded meat and lamb expenditures in 2021 moving forward.

IV. GENESEE-FINGER LAKES REGION LAMB DEMAND SURVEY

SURVEY METHOD

A food service and retail lamb demand survey were commissioned by EDF Renewables North America and the Town of Mount Morris in Livingston County, NY, to assess the current market penetration of lamb in the Genesee-Finger Lakes Region. The survey assessed the market potential for grass-fed, solar-raised lamb that would be raised on the same land developed for large-scale solar facilities in the region.

The specific survey objectives were as follows:

- Assess whether expanded lamb demand is feasible in western New York,
- Assess the demand for grass-fed, solar grazed lamb,
- Assess the competitiveness and acceptance of current lamb pricing.

The survey was conducted by Letchworth Gateway Villages, Juniper Economic Consulting, and Agrivoltaic Solutions, LLC. Letchworth Gateway Villages (LGV) is a municipal alliance committed to advancing rural development in the Genesee Valley. Through network-building, technical assistance, and research, LGV serves as a vehicle for cultivating the regional partnerships needed to build a 21st century rural economy. Juniper Economic Consulting, Inc. is an agricultural economic consulting firm which conducts agricultural value-added feasibility studies and has 18 years' experience analyzing the U.S. sheep industry. Agrivoltaic Solutions is a New York-based firm whose founding partners have commercial livestock and agricultural management expertise running their own farm and solar grazing enterprises throughout New York and Vermont. Agrivoltaic Solutions specializes in providing grazing and beekeeping consulting services for commercial photovoltaic installers and operators.

This lamb demand survey explained to respondents that the survey is part of a larger study to assess the feasibility of co-developing land for both conventional agriculture and photovoltaic power generation or "agrivoltaics." It was explained that the project's objective was to open new doors for local farmers and the region's growing food industry, while also optimizing the design of solar energy facilities.

The survey was distributed to regional restaurants, distributors, and retailers in the greater Genesee Valley region, including Rochester. The survey list was compiled by LGV using a combination of restaurants and food industry contacts in LGV's database. LGV has cultivated a network of forward-thinking food and beverage industry stakeholders via its Growing Food Tourism project. Additional survey recipients—those in Rochester—were compiled using the project team's professional contacts.

The survey was sent to 62 restaurants, distributors, and retailers in May 2021. Twenty-two survey recipients responded yielding a 34% response rate. Responses included 17 restaurants, 4 distributors, and 1 retailer. Not all responses were usable for analysis, as will be explained further.

The food service and retail lamb demand survey were an online survey. Potential survey respondents were first contacted by LGV to assess a willingness to participate in the survey. LGV later contacted those who agreed to participate by phone, after the survey was released, in order to help increase participation with over-the-phone assistance. Those willing respondents that answered at least 80% of the survey were entered into a drawing for a gift bag including products from industry supporters, a value of \$50.

RESTAURANT SURVEY RESULTS

The survey results from regional restaurateurs positively projected a continued and expanded lamb demand in the Genesee-Finger Lakes Region of western New York and beyond. Restaurant respondents were characterized by chefs, chefs/owners, and owners. Surveyed restaurants spanned different types of restaurants including ethnic, fine-dining, farm-to-table, and delis. A total of 17 restaurants responded to the survey. Of those, 15 restaurants submitted usable responses. Two of the restaurants that began the survey submitted an insufficient number of complete responses, making the surveys unusable.

The survey revealed that U.S. and local lamb penetration in the Genesee Region is strong, which is promising for expanding lamb demand in the area. Key survey findings that support expanded lamb demand growth in the Genesee-Finger Lakes Region include:

- 93% of the restaurants surveyed currently serve lamb
- Lamb is a menu item that is served year-round by 73% of survey respondents, rather than only seasonal
- 47% of restaurants reported they have seen increased lamb sales over the past five years, 7% reported a decrease in lamb sales, 27% reported they were not sure, and there was a 19 % nonresponse rate.
- 53% of surveyed restaurants purchased U.S. or local lamb over imported product
 - » 27 % reported serving U.S. lamb only and 40% reported U.S. and local lamb.
- 67% of surveyed restaurants responded that their customers care where their lamb is sourced or how it was raised.
- 60% of surveyed restaurants feel that lamb is a good value for its price.

- When asked, “Would your customers be interested in purchasing local, grass-fed, solar grazed lamb if it became available,” 47% responded “yes,” and 47% responded they were “not sure.”

The survey results found that lamb is already popular within Genesee-Finger Lakes Region year-round but is featured with varying degrees of prominence on menus. When asked, “Do you currently serve lamb on your menu?” 93% of respondents served lamb on their menus and 7% did not.

The survey found that Genesee-Rochester restaurants serve lamb throughout the year, which means it is not only a seasonal or special occasion offering, but a regular menu staple. The survey revealed that lamb is a menu item that is served year-round by 73% of responding restaurants, and not served year-round by 20% of restaurants. The remainder were nonresponses.

If lamb is not served year-round, the survey asked, “When do you typically offer it?” Respondents commented: “When a customer asks for it,” “Seasonally,” “We offer it as a rotating, featured menu item, probably every five weeks,” and “On special occasions at certain times of the year.”

Lamb is a small portion of restaurant meat sales. Restaurateurs reported that lamb represents 1–30% of total meat sales, with an average of 9%. In the U.S. overall, lamb is typically a small portion of meat sales, but on average, it is one of the highest-valued proteins.

Nearly one-half of respondents have seen their lamb sales increase in recent years. Forty-seven percent of restaurants reported they have seen increased lamb sales over the past five years, 7% reported decreases, 27% reported not sure, and there was a 19% nonresponse rate.

Increasing demand of U.S. lamb, specifically, must be a project objective, within a broader market that may be dominated by imported product. Imported product can be price-competitive and attractive to some buyers due to its reported consistency of quality. In general, imported lamb are often smaller-sized cuts relative to U.S. mainstream lamb, so cut size may be a point of preference. It is a positive sign for expanded U.S. lamb demand that 53% of respondents reported that they purchased U.S. and/or U.S. and local lamb. Twenty-seven percent reported U.S. lamb only, 40% reported U.S. and local lamb, and 47% of responses checked Australian or New Zealand lamb. Seven percent reported “not sure.” as their choice. Respondents could check multiple sources.

Meeting the desires of new and existing lamb consumers will require tapping into a tapestry of needs defined broadly as product “transparency” (Uetz, 2019). Transparency includes the concerns cited in Table 2, including local, ethnic, environmentally sensitive, and ethically sourced. Consumers will purchase lamb if they

feel they are receiving a value for their money, and value can be multi-dimensional as delineated in Table 2.

<i>Is it safe in the long-term?</i>	<i>Is it locally produced?</i>
<i>Is it healthy?</i>	<i>Was the worker treated fairly?</i>
<i>Is it Organic?</i>	<i>Was the animal treated humanely?</i>
<i>Was it minimally processed?</i>	<i>Is it GMO free?</i>
<i>Ethically sourced?</i>	<i>Environmentally sensitive?</i>

Table 2. Defining Consumer Transparency

Promoting and growing demand for grass-fed, solar grazed lamb in western New York will require a marketing campaign. ALB. Executive Director Megan Wortman recommended a package marketing campaign that helps chefs understand lamb’s health benefits and versatility and suggests where to purchase lamb, where and how to have it processed and how to prepare it (personal communication). Most importantly, educating chefs about the grass-fed, solar grazed story will be critical. Solar grazing may be a strategy for continued siting of solar projects on agricultural land, as opposed to converting agricultural land to solar energy production without having a viable plan for co-location of solar and agriculture.

Marketing efforts that capitalize on the story of grass-fed, solar grazed lamb will likely fulfill multiple consumer demand attributes including local, all-natural, and environmentally and socially sustainable. When asked, “Do your customers care where your lamb is sourced or how it was raised?” 67% said “yes”, 7% reported “no”, 20% reported “not sure”, and 6% did not respond.

While hair sheep breeds are currently a popular choice for solar sites, grass-fed, solar grazed woolled breeds might warrant future research. If the grass-fed, solar grazed story can include wool production, this might provide additional consumer appeal. The same marketing strategies could apply. Consumer support of wool products sourced from sheep grazing at solar facilities can help support the fight against climate change.

A key challenge to expanding demand for lamb is beef demand. Beef is the number one substitute to lamb with 67% of respondents reporting that beef is the protein that competes most closely with lamb. One respondent reported meat substitutes (e.g., Impossible Burger, or Beyond Meat) (7%), and one respondent reported pork (7%). There were 20% non-responses.

If lamb supply increases dramatically in western New York, then regional processing capacity will likely be challenged. It is uncertain whether federally inspected harvest and fabrication facilities currently exist in the region to meet increased demand at food service and

retail venues. The U.S. lamb market typically sells some carcasses (perhaps less than 15% of lamb trade is carcasses), but mostly further fabricated fresh or frozen lamb cuts are sold in a box to food service and retail. By contrast, the ethnic trade predominately sells carcasses.

When restaurant owners were asked, “How do you predominately buy your lamb?” 80% reported by the lamb cut, 7% reported by the whole carcass, and there were 13% nonresponses. More specifically, 27% selected frozen by the cut, 33% selected fresh by the cut, and 20% reported fresh and frozen by the cut, with the remaining percentage nonresponses.

Thirty-three percent of survey respondents reported that the choice of lamb purchased—fresh or frozen, and by the cut or whole—does not change according to the time of year. Seven percent reported that their choice of how lamb is purchased does change. One respondent explained that their restaurant purchases lamb fresh by the lamb cut, but that sometimes they buy a whole lamb. There was a 60% nonresponse rate to this question.

One lamb marketing challenge in selling lamb is to market the entire lamb. Maximizing margins requires selling lower-valued primals such as the shoulder, as well as the higher-end middle meats such as the rack. One marketing design is to segment the market into lower- and higher-end customers. Another approach is to build food service and retail marketing outlets. Marketing can educate chefs at fine dining establishments to utilize the entire lamb and feature all lamb primals, from appetizers to center-of-the-plate items. Marketing can also assist retail butchers with further fabrication possibilities. Underlying meeting consumers’ needs for transparency (defined in Table 2), is the paramount importance of providing a consistently high-quality eating experience. Additionally, consistency in size of cut is important to estimating plate costs in the food service sector.

Restaurateurs were asked, “What cuts of lamb meat do you typically buy?” with multiple responses available. Some of the more popular responses included: ground lamb (47%), rack (33%), and shank (33%). Other mentions: leg (bone-in) (20%), leg, boneless (20%), loin chop (20%), lamb kabobs and stew meat (13%), and shoulder (7%). There were zero mentions for the sirloin chop. Two other open-ended responses included “belly” and “whole saddle, fat cap on.”

Local restaurants typically work through distributors to source proteins. Thus, sourcing lamb from the same distributor that provides other proteins reduces transaction costs. Seventy-three percent of respondents reported that they purchase their lamb from a distributor/importer. Twenty percent of respondents reported purchasing “direct from producers.” There was 7% nonresponse rate.

Most restaurateurs purchase lamb fresh by the pound, while one respondent purchased lamb live. When asked how much respondents pay for live lamb, one answer was received: \$550 per head. For those respondents that purchase fresh lamb by the pound, four responses were received: A minimum of \$6.50 per lb., a maximum of \$21 per lb., an average of \$12.63 per lb. and a median of \$11.50 per lb. One respondent commented, “\$18 to \$24 per lb., depending upon the cut.”

The minimum price of \$3.50 per lb. for frozen lamb was reported, with a maximum of \$12 per lb., the average was \$7.58 per lb. Again, prices will vary depending upon cut, \$9 per lb. for rack and \$3 to \$4 per lb. for ground lamb.

Historically, lamb prices are volatile year-to-year, as well as seasonally. In 2020 and into 2021 through June, lamb repeatedly hit and then exceeded record highs. In June 2021 the lamb cutout (a composite of all primals at whole-sale) was valued at \$5.15 per lb. Lamb retail prices are not publicly available, although some featured lamb cut prices (sale prices) are available. By comparison, the June 2020 cutout was \$3.53 per lb. and \$3.43 per lb. in June 2019.

Sixty percent of those surveyed responded that yes, they feel that the lamb is a good value for its price, 20% responded no, and there were 20% nonresponses. This finding is significant because in mid-2021 lamb prices were at a record high. This is also significant because respondents are indicating that their customers already see value in lamb at current high prices, and relative high prices compared to other proteins.

While \$12.63 per lb. was the reported lamb price paid, \$10.72 per lb. is the optimal average price per lb. that the respondents would pay for lamb. A few respondents recognized that price depends on the cut of lamb purchased. When respondents were asked, “Is this high, low, or on par with the price for other kinds of meat served at your restaurant,” 40% of respondents commented that the price of lamb is high compared primarily to beef; 33% commented that the price of lamb was “on par” with other meats and 27% did not respond).

When restaurateurs were asked “Would your customers be interested in purchasing local, grass-fed, solar grazed lamb if it became available,” 47% responded yes and 47% reported not sure; there was a 6% nonresponse rate. When the restaurant respondents were asked to expand upon their responses, the following comments were received (Table 3).

This survey confirms that promoting grass-fed, solar grazed lamb can benefit by telling its story: The grass-fed, solar grazed lamb is raised locally, it is ethically raised, and promotes agriculture and environmental sustainability.

Survey Question: **Would your customers be interested in purchasing local, grass-fed, solar grazed lamb if it became available?**

Survey responses	Survey responses when asked to explain further:
Yes (47%)	Customers are more and more interested in where their food comes from.
	Customers are interested in ethically raised meats.
	My customers come for a local, farm-to-table experience. They are moved by food chain and environmental stories.
	Our guests love a story.
	There is a high demand for local. However, it is usually not affordable for our customers (e.g., large weddings).
Not sure (47%)	The customers' concern is if the lamb is halal.
	Customers mainly care if the meat is halal.
	We are a low-end restaurant

Table 3. Would your customers be interested in purchasing local, grass-fed solar grazed lamb? Note: 6% nonresponse to the question in (A.) and 6% nonresponse to question (B.)

Solar grazing promotes our fight against climate change by offsetting carbon emissions from transportation associated with the import of lamb from Australia/New Zealand and is a benefit of siting solar facilities on agricultural land.

The survey also revealed that if the Mount Morris area lamb is channeled to the ethnic market, halal harvest is important. In general, the division between the mainstream market interest in a grass-fed, solar grazed story and ethnic market considerations will become increasingly blurred as consumer interests from the two markets are blended.

Lamb promotional efforts are targeted toward consumers, but an important first step is to gain acceptance with chefs across the U.S. If chefs appreciate

lamb's wide-ranging flavor offerings, its versatility of cuts and preparation, its availability, and importance in the farm-to-table movement, in addition to the role lamb plays in promoting renewable energy, then this helps build a story to get lamb in front of consumers.

When restaurateurs were asked "Would you be interested in purchasing local, grass-fed, solar grazed lamb if it became available," 4% reported yes, and 47% responded maybe; there was a 6% nonresponse rate. Importantly, no restaurateurs reported that they were not interested.

Table 4 reveals the importance of locally sourced proteins, but not without consideration for price competitiveness. This underscores the importance of educating consumers about the value of grass-fed, solar grazed lamb. Again,

Survey Question: **Would you be interested in purchasing local, grass-fed, solar grazed lamb if it became available?**

Survey responses	Survey responses when asked to explain further:
Yes (47%)	Always looking for local, sustainable products.
	I support local, but price needs to be competitive for customer to want it.
	Local/sustainable would make this a prize.
	We love to try most products, especially if it's produced locally.
	If the price is competitive.
Maybe (47%)	Only if halal.
	Only if halal.
	Only if halal.
	If the product is good, economic, and local. We love the idea.
	Depends on how the restaurant is doing and price.

Table 4. Would you be interested in purchasing local, grass-fed, solar grazed lamb? Note: 6% nonresponse to the question in (A.) and 33% nonresponses to question (B.)

consumers must feel that they receive a value equal to price. The survey also revealed the importance of halal harvest for expanded local lamb demand in the region.

One respondent who currently does not feature lamb has purchased it in the past and commented that lamb got too expensive and beef is the preferred customer choice. When this respondent was asked: “Would you be motivated to buy grass-fed, solar grazed lamb if the following conditions applied,” the reply was yes, if the price was right. The respondent added: “Availability of high enough volume at the right price with consistency in quality and makeup” would entice them to try lamb again.

The lamb demand survey allowed for an open-ended option for additional comments by respondents in which three restaurateurs commented as shown in Table 5.

Survey Question: Are there other comments you wish to share?

Sounds like a great opportunity. Price point is very important in the catering industry. While individual restaurant goers and households will pay a little extra for local foods, it is usually a different story when they must absorb the additional costs for another 150-200 guests.

I love lamb! Good luck!

Good luck!

Table 5 Open-Ended Comment Question

RETAILER SURVEY RESULTS

One retailer—a specialty market and deli/eatery that currently sells lamb year-round—responded to the survey. While only one respondent, the findings support continued retail lamb demand surveys and optimism for expanded lamb sales at retail in western New York.

The respondent’s lamb sales have increased over the past five years; the meat is sourced locally and primarily from the U.S. The retailer responses mirror many of those documented in the survey answers from restaurants. The retailer reported its lamb sales are less than 1% of total meat sales. The primary customers purchasing lamb from the retailer are individuals and families. The retail respondent was not sure whether customers care where the lamb is sourced or how it was raised. Beef is the protein that competes most closely with lamb. Lamb is predominately purchased frozen, and by the cut.

When asked, “What cuts of lamb meat are most popular amongst your clientele?” the respondent selected only ground lamb, among the following choices: leg, ground, kabob/stew meat, loin chops, rack, ribs, shank, shoulder and sirloin chops.

The retailer primarily purchases their lamb from a smaller distributor/meat market and revealed that there are times when they would like to purchase lamb, but it is not available.

The retailer reported that the average price for lamb purchased is \$9.99 per lb. frozen and agreed, “lamb is a good value for its price.” The retailer further confirmed that \$9.99 per lb. was the optimal price. The retailer reported that this price is “on par” with the price for other kinds of meat sold at their store.

The retailer reported that their customers would be interested in purchasing local, grass-fed, solar grazed lamb if it became available. When asked to explain further, the retailer signaled that the local, grass-fed, solar grazed lamb is similar to their current offering. When pressed further to “Would you be interested in purchasing local, grass-fed, solar grazed lamb if it became available?” the retailer again reported yes, and when asked to explain, the retailer commented that they were “interested in sustainable aspects of the product.”

DISTRIBUTOR SURVEY RESULTS

Four distributors responded to the lamb demand survey; two were usable surveys—one currently sells lamb, and one does not.

One distributor currently sells lamb. The distributor currently sells lamb year-round, and lamb represents about 5% of all meat sales. The distributor’s lamb sales have increased over the past five years, and the distributor sources lamb locally, from the U.S.

When asked, “Do your customers care where your lamb is sourced or how it was raised?” the distributor responded yes. The distributor primarily sells to fine-dining restaurants, caterers, residential/group homes, and universities/colleges. The primary competitor to lamb is beef.

Throughout the year, the distributor purchases fresh, whole lamb carcasses direct from producers. The most popular lamb cuts among the distributor’s clientele include the bone-in and boneless leg, ground lamb, kabob/stew meat, loin chop, rack, ribs, shank, shoulder, and sirloin chop.

The distributor responded that \$5 per lb. is the amount paid for lamb carcasses, a good value for the money, and high compared to other proteins purchased. The distributor then responded that \$4 per lb. would be an optimal price.

When asked, “Would your customers be interested in purchasing local, grass-fed, solar grazed lamb if it became available?” the distributor replied yes. When asked to expand on their response, the distributor commented that local, grass-fed, solar grazed lamb

is something they would try depending upon quality, size consistency, and flavor. The distributor replied maybe when asked whether they would be interested in purchasing local, grass-fed, solar grazed lamb if it became available.

One distributor currently does not sell lamb. When asked why lamb was not offered, the distributor chose, “It’s not something my customers demand” from among a

V. LIGHTWEIGHT LAMB DEMAND

An informal phone survey was conducted in July 2021 of lamb demand of lightweight lambs in the broader New York region including New Jersey and Michigan. The lightweight lamb market (about 100 lbs. liveweight) can be thought of as distinct from the mainstream market of heavier lambs (140+ lbs. liveweight). In the U.S., the largest mainstream lamb processing facilities are in California, Colorado, and Texas, but the largest uniquely lightweight lamb packers are in New Jersey and Dearborn, Michigan, home to a significant Muslim community.

The survey included four ethnic packers/packer buyers and three individuals with first-hand knowledge of the ethnic New Holland Sales Stable sheep auction in New Holland, PA. New Holland represents the second-largest sheep auction in the U.S.; the largest is in San Angelo, TX. The survey objective was to assess ethnic lamb demand in New York/New Jersey and in Michigan.

The ethnic market is very heterogeneous, and lamb promotional programs targeted to the mainstream market may not be as successful when directed to the ethnic lamb market, given customers’ diverse backgrounds and culture (Williams, et al., 2011). The Muslim market alone can be segmented into four target groups: 1.) quality-driven, 2.) price-driven, 3.) quality first, but price is important, and 4.) price first, but quality is important (Williams, et al., 2011).

Historically, wooled sheep breeds were the dominant breed at the New Holland auction; however, hair breeds began to surpass wooled breeds between 2005 and 2010. More recently, preference has swung back to wooled breeds, albeit lighter weight wooled breeds.

In 2018, an estimated 145,075 head of sheep sold at New Holland, up 33% in five years. U.S. Department of Agriculture data from New Holland is incomplete due to a transition to a new online reporting program in 2019 and COVID-19 related shutdowns in 2020. The estimate for 2018 is 60% hair breeds and 40% wooled breeds but has reportedly swung to a majority trade of wooled breeds. In 2019, 144,509 head of sheep were reported in

list of options also including source, price, and quality considerations. The distributor responded yes; they had purchased lamb in the past for the business. When pressed as to why they stopped buying lamb, the distributor responded that their customers didn’t ask for it, among a selection of possible responses.

the incomplete reporting year, down 0.4% from 2018. As prices rose at the New Holland sheep auction, it attracted wool lambs that were previously destined for mainstream markets in other parts of the country.

The objective of the informal ethnic survey was twofold:

- Determine whether ethnic demand exists for a sizable volume of lambs in October or November in Mount Morris, New York, and
- Assess whether any distinct lamb demand preferences emerge from the informal discussions.

The ethnic processors unanimously stated that lamb is in high demand. There will be no difficulty in marketing thousands of lambs during the summer and late fall from the solar facilities in the Mount Morris area, including the Morris Ridge solar site. When asked about specifics of lamb demand, such as breed of sheep and desired weight, answers varied, but settled on wooled or hair breeds less than 110 lbs.

When questioned about the preferred breed of sheep, those surveyed had differing opinions, with the dominant position that wooled breeds are currently preferred, but that securing supplies—wooled or hair breeds—can trump lamb breed. Some ethnic buyers noted a preference for a finished lamb with good fat cover from a smaller carcass.

Desirable wool breeds, according to survey respondents, are Suffolk, Hampshire, Dorset, and Suffolk-Hampshire crosses. Smaller framed wool breeds are preferred and thus crossing a larger-framed wool breed with a medium-framed Dorset is desirable. One buyer commented that the Dorset and Dorper cross is popular. Another ethnic buyer commented that he thought that wooled lambs that are raised on creep feed (grain) yield the desirable fat cover.

The wooled breeds are expected to have a good fat cover compared to hair breeds. Reportedly, wool breeds produce lamb meat that is white to pink. One ethnic buyer

reported that some hair breeds, for example, are too lean, and present undesirable, dark red lamb meat. Another processor commented that he was in the meat business, and he didn't care if the sheep were woolled or hair breeds.

Respondents agreed that different customers demand lambs of differing weights, and that there are strong markets for lambs under 110 lbs. One respondent believed the high-demand weight classes are roughly 50 to 70 lbs. and 90 to 110 lbs. One survey respondent familiar with New Holland sales observed that above 120 lbs., there is a steep discount in price.

Other lamb demand concerns included age, availability of carcasses, and consistency. One processor relayed that the only concern in purchasing lambs off a utility scale solar site is if the lambs get too old—namely, over 12 months. The ethnic trade is characterized by demand for carcasses, unlike the mainstream market in which primals and further fabricated cuts are traded by processors. Several survey respondents familiar with the ethnic trade felt that uniformity of lamb size is important. Muscling throughout the loin is also important.

Survey respondents wanted to know the price of lambs coming from the Morris Ridge site. Price will have to be competitive with purchasing lambs at the New Holland auction and buying direct from other processors or producers. In 2020 and the first-half of 2021, lamb prices at New Holland hit record highs. It is hypothesized that high lamb prices attracted woolled lambs to the New Holland auction from the Midwest, the Dakotas, and farther West.

Buyers of lightweight lambs are price sensitive: one ethnic researcher commented that New Holland sheep numbers appear to be falling in recent months, as prices rise and direct sales between producers and buyer increase, bypassing the higher-priced auction. A price premium can be realized by the Morris Ridge grazer selling a uniform class of lambs of similar age, weight, and muscling of lightweight lambs.

VI. REGIONAL LAMB PROCESSING CAPACITY

In a 2016 study the American Sheep Industry Association found that after grazing and forage management, marketing is the number two-ranked producer challenge identified by sheep producers (Miller, et al., 2016). Finding a buyer, or buyers, and perhaps also securing processing facilities may be a constraint to marketing Morris Ridge lambs. An increase in supply of lambs to western New York will require adequate federally inspected (FI) harvest capacity (and possibly fabrication facilities).

A thorough investigation of FI plants, locations, and capacity, was not conducted for this study. However, in speaking with packer-buyers of lightweight lambs it was understood that the processing capacity for the Morris Ridge project is not currently a constraint for ethnic markets. It is unknown at this time, however, if the processing capacity exists for a grass-fed, solar grazed labeled lamb processed in a non-ethnic plant. There are 40 federally inspected (FI) harvest facilities located in New York and New Jersey that process lamb (USDA). An additional 13 FI plants are located across New England. The capacity and excess capacity of these plants is unknown.

In March 2019, Cornell University investigated the state of USDA red meat harvest in New York and New England (Waro, et al., 2019). The Cornell livestock processing research was part of a larger research project, "Overcoming Supply Chain Barriers to Expanding Northeast Ruminant Meat Production." Among livestock producers in New York there is an assumption that there are not enough harvest plants in the region and animals cannot be harvested within a reasonable time frame. In New England in 2017, there were 62 USDA red meat harvest facilities, a mix of federally inspected and custom exempt facilities (harvest for own use). The study found that year-round operation is a struggle for some plants, and that labor constraints are a concern. An influx of solar grazed lambs might provide the necessary throughput to improve packer margins and expand capacity.

Future Research

The lamb demand assessment developed in this study can serve as a jumping off point for future research. As solar sites expand across the Northeast and Eastern U.S., grazing of sheep on solar sites is identified as a viable option for reducing net carbon emissions and combatting climate change, thereby justifying agrivoltaics.

Recommendations for further research include:

- Further development of marketing research and campaigns.
 - » Development of a grass-fed, solar grazed marketing campaign extolling the benefits of lamb as a premier protein and supporter of agricultural and environmental sustainability. This research begs the question of whether there are net benefits to adopting a unique solar grazed label. Investigate whether lambs from the Morris Ridge Solar Project can be registered under a broader “solar-raised” labeled.
 - » New York City is the largest lamb consuming market in the U.S. Further research could assess lamb demand for grass-fed, solar grazed lamb at retail and food service in New York City and more specifically, better understand why imports account for over half of the market’s lamb consumption.
 - » Western New York lies in close proximity to Toronto, a significant metropolitan region and potential market for U.S. grass-fed, solar grazed lamb. Assess lamb demand in Toronto.

- » Survey customers of restaurants that participated in this demand survey as follow-up research. The survey could ask customers directly if they would a) support local, grass-fed lamb, b) if they would prefer local, grass-fed lamb to a non-local, lamb product, and c) if they would pay more for such a product than imported lamb.
- » Lightweight lamb demand is complex, rapidly evolving, and growing. Comprehensive studies of this market demand in the U.S. are now dated—the last study was conducted by Texas A&M in 2010. We know that the mainstream and lightweight lamb markets are being assimilated, with boundaries between the two becoming blurred, but we do not know the extent of the blending. Further research is warranted to define the demand attributes of the lightweight lamb market.

- An ongoing collaborative effort between the ALB. and Michigan State University is currently evaluating the environmental footprint of the U.S. sheep industry. It is recommended that this research be followed closely to determine if it is possible to assess the environmental footprint of grass-fed, solar grazed sheep in Northeastern U.S.
- Lack of access to sheep harvesting facilities and marketing overall have been cited as production constraints by sheep operators. A comprehensive study of federally inspected lamb harvest facilities, capacity, and lamb demands in the northeastern U.S. could help with supply chain concerns as sheep numbers in New York expand.

VII. CONCLUSION

The successful grazing of lambs at the Morris Ridge solar site will introduce thousands of lambs to western New York, a sizable number in a region that is currently a net importer of lamb. A supply increase will have to be met with expanded demand in order to support a sustainable sheep solar grazing enterprise. Marketing expanded lamb demand can capitalize on the grass-fed, solar grazing story of local, agricultural and environmental sustainability, but can also market lamb in the important ethnic market whose customers eat lamb customarily and in observance of religious occasions.

Two lamb demand surveys were conducted: a formal lamb demand survey of the food service and retail sector in the Genesee-Finger Lakes Region and an informal ethnic lamb demand survey.

A formal survey was conducted of restaurants, distributors, and retailers in the Genesee-Finger Lakes Region in May 2021. Sufficient surveys were returned from restaurants to yield a robust analysis, but survey numbers were low and returns lacking or incomplete for distributors and retailers. The results of the survey of restaurateurs were promising for continued and expanded lamb demand in the region given that most of the restaurants surveyed already enjoyed local, U.S. lamb.

An informal lamb demand survey was conducted of four ethnic lamb packers and three individuals with first-hand knowledge of the New Holland, PA, Sales Stable sheep auction in June 2021. Overall, the responses were positive for expanded lamb demand with a caveat that lighter-weight lambs, less than 110 lbs., are preferred.

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Morris Ridge Solar Lamb Survey

Introduction

We are reaching out to the food industry to take a brief 5-10 minute survey to assess the current market penetration of lamb in the Genesee-Finger Lakes Region and see if there is interest in grass-fed lamb raised on land developed for solar facilities. All your answers will remain confidential.

This survey is part of a larger study to assess the feasibility of co-developing land for both solar photovoltaic power and conventional agriculture or "Agrivoltaics." Our hope is that this study will open new doors for local farmers and the region's growing food industry, while also optimizing the design of solar facilities for agrivoltaics. Thank you in advance for participating in this survey.

For respondents answering at least 80% of the survey, you will be entered into a gift drawing for products from industry supporters - a value of \$50.

If you have any questions please feel free to contact Nicole Manapol, Director of Letchworth Gateway Villages, at 585-237-8079.

* 1. What city / region does your business serve?

City / Region

County

State



Morris Ridge Solar Lamb Survey

Your Role in the Food Industry

* 2. Are you a ...

- Restaurant
- Distributor
- Retailer



Morris Ridge Solar Lamb Survey

For Restaurants

3. Do you currently serve lamb on your menu?

- Yes
- No



Morris Ridge Solar Lamb Survey

For Restaurants Serving Lamb

4. Is lamb a menu item that you serve year-round?

- Yes
- No

5. If "No", when do you typically offer it?

- Special occasions/holidays
- Seasonally
- When I can find a deal
- When a customer asks for it
- Other (please specify)

6. What percentage of your total meat sales does lamb represent?

7. How has the volume of lamb sold changed over the past five years?

- Increased
- Decreased
- Not sure

8. What is the origin of your lamb? (check all that apply)

- U.S.
- U.S.-Local
- Australia/New Zealand
- Not sure

9. Do your customers care where your lamb is sourced or how it was raised?

- Yes
- No
- Not sure

10. Which protein competes most closely with lamb?

- Beef
- Pork
- Chicken
- Seafood (fish, lobster, shrimp, crab, etc.)
- Meat substitutes (e.g., Impossible Burger, Beyond Meat)
- Other (please specify)

11. How do you predominately buy your lamb?

- Live
- Fresh
- Frozen
- Fresh and Frozen

12. Does this change depending on the time of year? If yes, please explain.

13. Where do you primarily purchase your lamb?

- Livestock auction
- Direct from producers
- From a distributor/importer
- From a grocery store
- From a butcher

14. If you purchase your lamb live, how much do you pay on average? \$_____ per head.

15. If you purchase your lamb fresh, How much do you pay on average? \$_____ per lb.

16. If you purchase your lamb frozen, how much do you pay on average? \$_____ per lb.

17. Do you feel that the lamb is a good value for its price?

- Yes
- No

18. What is the optimal price per pound you would pay for lamb?

19. Is this high, low or on par with the price for other kinds of meat served at your restaurant?

- High
- Low
- On par
- Other (please specify)

20. Would your customers be interested in purchasing local, grass-fed, solar grazed lamb if it became available?

- Yes
- No
- Not sure

21. Please explain your response

22. Would you be interested in purchasing local, grass-fed, solar grazed lamb if it became available?

- Yes
- No
- Maybe

23. Please explain your response



Morris Ridge Solar Lamb Survey

For Restaurants Not Serving Lamb

24. Please indicate the reason(s) you do not offer lamb on your menu. Check all that apply:

- It's not something my customers demand
- My food distributor does not carry this product
- I am unable to purchase the quantity of product I need on a consistent basis
- It's too expensive
- The quality of the lamb is inconsistent
- I don't care for lamb meat
- I'm not familiar enough with the product to serve it on my menu
- Other (please specify)

25. If you answered, "too expensive," what is the optimal price per pound you would pay for lamb?

26. Have you ever purchased lamb in the past for your business?

- Yes
- No

27. If "Yes", Why did you stop buying lamb? (Check all that apply)

- It got too expensive
- My customers didn't demand it
- My food distributor stopped providing it
- I was unable to purchase the quantity I needed
- Other (please specify)
- I could no longer find local or U.S. lamb
- The lamb quality was not consistent
- I don't care for lamb meat

28. Which protein do your customers prefer?

- Beef
- Pork
- Chicken
- Seafood (fish, lobster, shrimp, crab, etc.)
- Meat substitutes (e.g., Impossible Burger, Beyond Meat)
- Other (please specify)

29. Would you be motivated to buy grass-fed, solar-grazed lamb if the following conditions applied? (select all that apply)

- Customers asked for it
- The price was right
- The lamb was local
- The lamb was fresh, not frozen
- The lamb was sustainably raised
- You were more familiar with how to serve it
- You were able to purchase the quantity of lamb needed on a consistent basis
- The quality of the lamb was consistent
- None of the above

30. Is there any factor that would lead you to purchase lamb for your clientele not mentioned above? Please explain.



Morris Ridge Solar Lamb Survey

For Distributors

31. Do you currently sell lamb?

- Yes
- No



Morris Ridge Solar Lamb Survey

For Distributors Selling Lamb

32. Is lamb an item that you sell year-round?

- Yes
- No

33. If "No", when do you typically offer it?

- Special occasions/holidays
- Seasonally
- When I can find a deal
- When a customer asks for it
- Other (please specify)

34. What percentage of your total meat sales does lamb represent?

35. How has the volume of lamb sold changed over the past five years?

- Increased
- Decreased
- Not sure

36. What is the origin of your lamb? (check all that apply)

- U.S.
- U.S.-Local
- Australia/New Zealand
- Not sure

37. Do your customers care where your lamb is sourced or how it was raised?

- Yes
- No
- Not sure

38. Who are your primary customers purchasing lamb? (check all that apply)

- | | |
|--|--|
| <input type="checkbox"/> Restaurants (fine-dining) | <input type="checkbox"/> Schools |
| <input type="checkbox"/> Restaurants (ethnic) | <input type="checkbox"/> Residential / group homes |
| <input type="checkbox"/> Restaurants (chain) | <input type="checkbox"/> Universities / colleges |
| <input type="checkbox"/> A meal preparation and delivery service like Blue Apron | <input type="checkbox"/> Hospitals |
| <input type="checkbox"/> Grocery Stores | <input type="checkbox"/> Soup Kitchens |
| <input type="checkbox"/> Caterers | |
| <input type="checkbox"/> Other (please specify) | |

39. Which protein competes most closely with lamb?

- Beef
- Pork
- Chicken
- Seafood (fish, lobster, shrimp, crab, etc.)
- Meat substitutes (e.g., Impossible Burger, Beyond Meat)
- Other (please specify)

40. How do you predominately buy your lamb?

- Live
- Fresh
- Frozen
- Fresh and Frozen

41. Does this change depending on the time of year? If yes, please explain.

42. Where do you primarily purchase your lamb?

- Livestock auction
- Direct from producers
- From a distributor/importer
- From a grocery store
- From a butcher

43. If you purchase your lamb live, how much do you pay on average? \$ _____ per head.

44. If you purchase lamb fresh, How much do you pay on average? \$ _____ per lb.

45. If you purchase lamb frozen, how much do you pay on average? \$ _____ per lb.

46. Do you feel that the lamb is a good value for its price?

Yes

No

47. What is the optimal price per pound you would pay for lamb?

48. Is this high, low or on par with the price for other kinds of meat sold through your business.

High

Low

On par

49. Would your customers be interested in purchasing local, grass-fed, solar grazed lamb if it became available?

Yes

No

Not sure

50. Please explain your response

51. Would you be interested in purchasing local, grass-fed, solar grazed lamb if it became available?

Yes

No

Maybe

52. Please explain your response



Morris Ridge Solar Lamb Survey

For Distributors Not Selling Lamb

53. Please indicate the reason(s) you don't currently sell lamb. Check all that apply:

- It's not something my customers demand
- It's difficult to source the quantity of product I need on a consistent basis
- It's too expensive
- The quality is inconsistent
- Other (please specify)

54. If you answered, "too expensive," what is the optimal price per pound you would pay for lamb?

55. Have you ever purchased lamb in the past for your business?

- Yes
- No

56. If "Yes", Why did you stop buying lamb? (Check all that apply)

- It got too expensive
- My customers didn't demand it
- My food distributor stopped providing it
- I was unable to purchase the quantity I needed
- Other (please specify)
- I could no longer find local or U.S. lamb
- The lamb quality was not consistent
- I don't care for lamb meat

57. Which protein do your customers prefer?

- Beef
- Pork
- Chicken
- Seafood (fish, lobster, shrimp, crab, etc.)
- Meat substitutes (e.g., Impossible Burger, Beyond Meat)
- Other (please specify)

58. Would you be motivated to buy grass-fed, solar-grazed lamb if the following conditions applied? (select all that apply)

- Customers asked for it
- It was easy to source
- The price was right
- The lamb was local
- The lamb was fresh, not frozen
- The lamb was sustainably raised
- You were able to purchase the quantity of lamb needed on a consistent basis
- The quality of the lamb was consistent
- None of the above

59. Is there any factor that would lead you to purchase lamb for your clientele not mentioned above? Please explain.



Morris Ridge Solar Lamb Survey

For Retailers

60. Do you currently sell lamb?

Yes

No



Morris Ridge Solar Lamb Survey

For Retailers Selling Lamb

61. Is lamb an item that you sell year-round?

Yes

No

62. If "No", when do you typically offer it?

Special occasions/holidays

Seasonally

When I can find a deal

When a customer asks for it

Other (please specify)

63. What percentage of your total meat sales does lamb represent?

64. How has the volume of lamb sold changed over the past five years?

Increased

Decreased

Not sure

65. What is the origin of your lamb? (check all that apply)

- U.S.
- U.S.-Local
- Australia/New Zealand
- Not sure

66. Who are your primary customers purchasing lamb? (check all that apply)

- Individuals / Families
- Restaurants
- Caterers
- Other (please specify)

67. Do your customers care where your lamb is sourced or how it was raised?

- Yes
- No
- I'm not sure

68. Which protein competes most closely with lamb?

- Beef
- Pork
- Chicken
- Seafood (fish, lobster, shrimp, crab, etc.)
- Meat substitutes (e.g., Impossible Burger, Beyond Meat)
- Other (please specify)

69. How do you predominately buy your lamb?

- Live
- Fresh
- Frozen
- Fresh and Frozen

70. Does this change depending on the time of year? If yes, please explain.

71. Where do you primarily purchase your lamb?

- From a distributor/importer
- Major national food service distributor (such as Sysco, U.S. Foods, or McLane Food service)
- Smaller distributor/meat market
- Private sheep producers (Or sheep cooperative, Farmers Market, or CSA)
- Other (please specify)

72. Are there times when you would like to purchase lamb, but it is not available?

- Yes
- No

73. If you purchase your lamb live, how much do you pay on average? \$ _____ per head.

74. If you purchase your lamb fresh, How much do you pay on average? \$ _____ per lb.

75. If you purchase your lamb frozen, How much do you pay on average? \$ _____ per lb.

76. Do you feel that the lamb is a good value for its price?

- Yes
- No
- Not sure

77. What is the optimal price per pound you would pay for lamb?

78. Is this high, low or on par with the price for other kinds of meat sold at your store?

- High
- Low
- On par

79. Would your customers be interested in purchasing local, grass-fed, solar grazed lamb if it became available?

- Yes
- No
- Not sure

80. Please explain your response

81. Would you be interested in purchasing local, grass-fed, solar grazed lamb if it became available?

- Yes
- No
- Maybe

82. Please explain your response



Morris Ridge Solar Lamb Survey

For Retailers Not Selling Lamb

83. Please indicate the reason(s) you do not sell lamb. Check all that apply:

- It's not a product my customers demand
- It's difficult to source the quantity of product I need on a consistent basis
- It's too expensive
- The quality is inconsistent
- Other (please specify)

84. If you answered, "too expensive," what is the optimal price per pound you would pay for lamb?

85. Have you ever purchased lamb in the past for your business?

Yes

No

86. If "Yes", Why did you stop buying lamb? (Check all that apply)

It got too expensive

I could no longer find local or U.S. lamb

My customers didn't demand it

The lamb quality was not consistent

My food distributor stopped providing it

I don't care for lamb meat

I was unable to purchase the quantity I needed

Other (please specify)

87. Which protein do your customers prefer?

Beef

Pork

Chicken

Seafood (fish, lobster, shrimp, crab, etc.)

Meat substitutes (e.g., Impossible Burger, Beyond Meat)

Other (please specify)

88. Would you be motivated to buy grass-fed, solar-grazed lamb if the following conditions applied? (select all that apply)

Customer demand was high enough

It was easy to source

The price was right

The lamb was local

The lamb was fresh, not frozen

The lamb was sustainably raised

You were able to purchase the quantity of lamb needed on a consistent basis

The quality of the lamb was consistent

None of the above

89. Is there any factor that would lead you to purchase lamb for your clientele not mentioned above? Please explain.



Morris Ridge Solar Lamb Survey

End of Survey

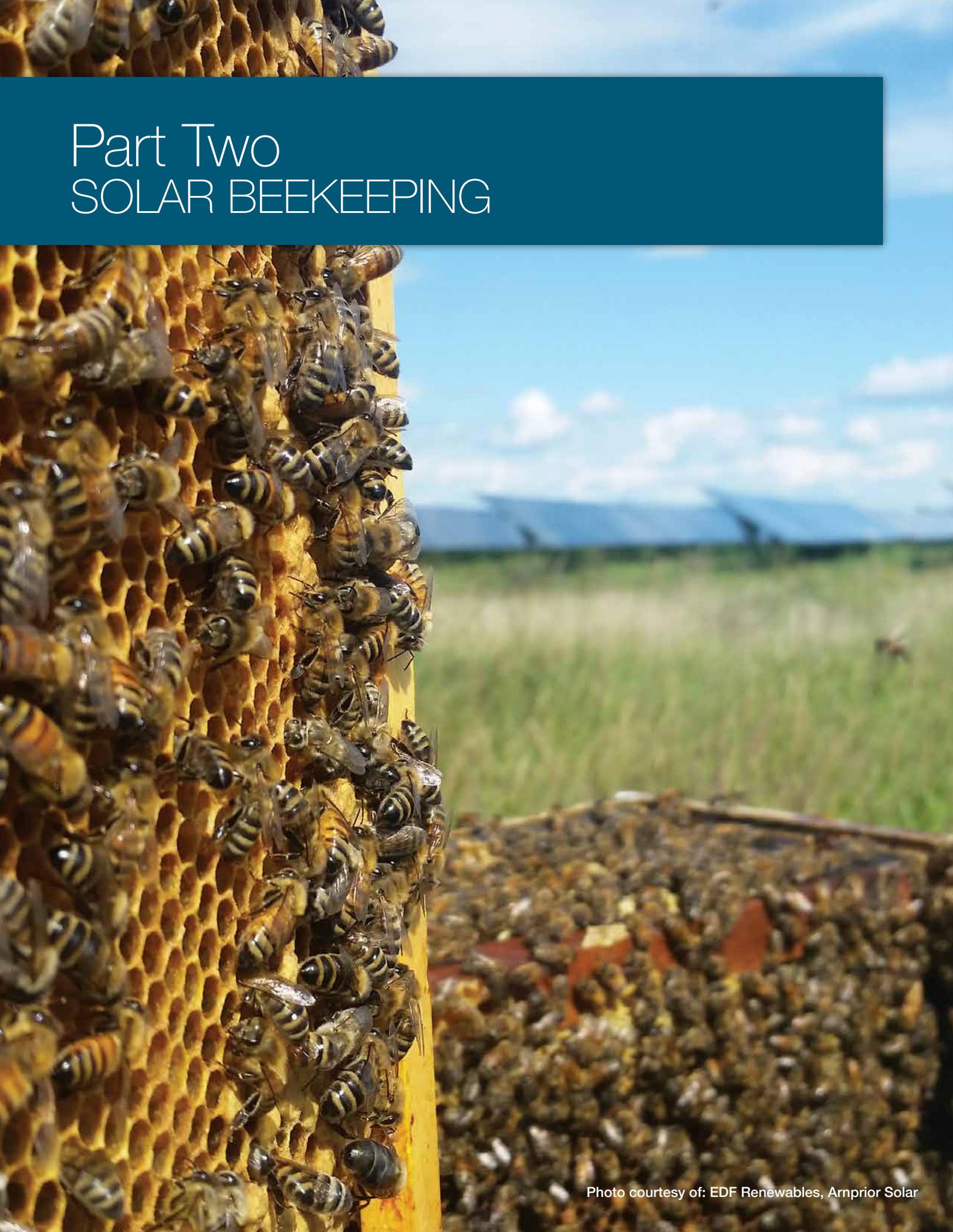
90. Are there other comments you wish to share?

91. Please add your contact details here if you would like to be entered into a gift drawing for products from industry supporters - a value of \$50.

Name	<input type="text"/>
Company	<input type="text"/>
Address	<input type="text"/>
Address 2	<input type="text"/>
City/Town	<input type="text"/>
State/Province	<input type="text" value="-- select state --"/>
ZIP/Postal Code	<input type="text"/>
Country	<input type="text"/>
Email Address	<input type="text"/>
Phone Number	<input type="text"/>

92. Do you want to stay informed about the development of solar-raised lamb in our region?

- Yes, keep me informed
- No thanks, I'm not interested at this time



Part Two SOLAR BEEKEEPING

Photo courtesy of: EDF Renewables, Arnprior Solar

Morris Ridge Solar Beekeeping Report

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Reviewed by

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I. Introduction	64
II. Beekeeper Survey	65
III. Landscape Analysis	69
IV. Economic Analysis of Apiary Budgets	74
V. Recommendations	80
References	84
Appendix	86

List of Figures

Figure 1: 2020 Value of Honey Production	64
Figure 2: New York State Annual Honey Yields	66
Figure 3: Land Cover Around Potential Apiary Sites	71
Figure 4: Land Cover at the Project, County and State Levels	72

List of Tables

Table 1: Estimated direct value of pollination services	64
Table 2: Considerations for apiary site selection and design	67
Table 3: Flowering plants and habitat types	68
Table 4: Landscape criteria used to evaluate potential apiary locations	70
Table 5: Land Cover within 1600 Meters of Proposed Apiary Locations	86
Table 6: Land Cover within 3200 Meters of Proposed Apiary Locations	73
Table 7: Apiary budget assumptions	76-77
Table 8: Annual budget for small apiary with 10 colonies	87
Table 9: Annual budget for medium apiary with 30 colonies	88
Table 10: Annual budget for large apiary with 60 colonies	89
Table 11: Comparison of annual apiary budgets	78
Table 12: Honey yield sensitivity analysis	79

I. INTRODUCTION

Wild and managed pollinators play a critical role in maintaining environmental health and agricultural productivity in New York State. Honey bees are the most prevalent of all managed pollinator species in New York, which is home to an estimated 60,000 to 80,000 colonies (Hinsley et al., 2021; NYSDAM, n.d.). With honey production in the state valued at over \$11 million, New York is the eighth largest honey producing state in the country (Figure 1). The sale of other apiary products including wax, nucleus colonies, queen bees, and value-added goods adds several million dollars in additional revenue to the total production value of New York beekeepers (Grout, et al., 2020).

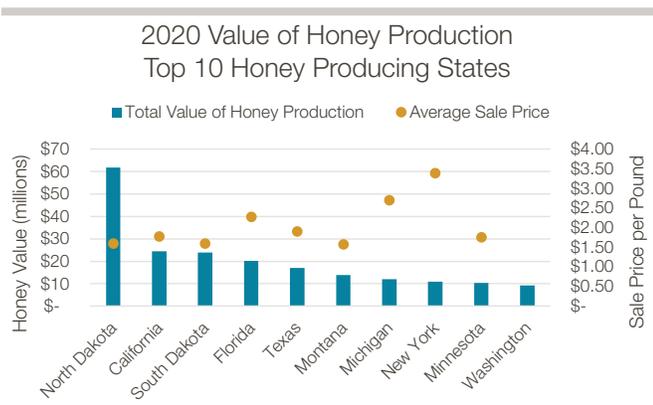


Figure 1. Total value of honey production and average honey price for the top 10 honey producing states in 2020. Source: USDA NASS Quick Stats.

Honey is a beekeeper’s primary source of income, yet the estimated value of pollination services that beekeepers provide is many times greater than the total value of honey and wax production. Every year, New York crop growers rely on thousands of honey bee colonies to pollinate crops valued at \$624 million (Grout et al., 2020). Many of the state’s top fruit and vegetable crops benefit from insect pollination, which contributes to higher yields and larger produce (Table 1). Grout et al. estimate that commercial pollination adds between \$308 million and \$439 million annually to the value of 18 New York crops. As the number one pollinator-dependent crop in New York, apples account for 68% to 73% of the total value of pollination services. Soybean is New York’s second ranked pollinator-dependent crop in terms of total production value, yet it accounts for just 3% to 10% of the direct value pollination services because it is less reliant on insect pollination compared to apples and other fruit crops.

As growth of New York’s solar industry drives land use change in rural areas, opportunities exist to conserve insect pollinators and enhance pollination services through establishment and maintenance of pollinator habitat on solar facilities (Dolezal, Torres & O’Neal, 2021). Some solar projects have already adopted this practice

with success. For example, one study of 11 solar farms that were intentionally managed for wildlife conservation in the UK revealed that the solar sites supported significantly higher bumblebee abundance, although the number of bumblebee species was similar at solar sites and control sites (Montag, Parker & Clarkson, 2016).

Habitat loss in agricultural landscapes reduces pollen and nectar availability and is a key driver of wild and managed pollinator declines (Otto et al., 2016; Gallant et al., 2014). Studies have shown that creation of pollinator habitat around agricultural fields may enhance wild pollinator communities and improve honey bee fitness (Kennedy et al., 2013; Dolezal et al., 2019). Establishment of pollinator habitat on solar farms could provide not only conservation benefits to pollinators, but also economic benefits to local fruit, vegetable and crop farmers. A 2018 study identified 2609 hectares of pollinator-dependent crops within the honey bee foraging distance from existing and proposed utility scale solar energy facilities in New York (Walston et al., 2018). Soybean fields comprised one third of this total area. Research has shown that, depending on soybean variety, insect pollination may have no yield effect at all, or it may increase soybean yields up to 18% (Klein et al., 2006; Milfont et al., 2013). Conditions in agricultural landscapes are highly complex, making it difficult to predict how pollinator plantings at a specific solar facility might affect pollination services on surrounding farms.

Solar pollinator habitat has potential to provide additional value by supporting beekeeping operations. Solar beekeeping is an emerging agrivoltaic practice that involves siting managed honey bee colonies on solar facilities for honey production (EDF Renewables, 2019). In this way, a pollinator-friendly solar farm could host a beekeeping enterprise while also enhancing pollination services to surrounding farms.

Crop	Value of NYS production ¹	Estimate 1, using Morse and Calderone [585]		Estimate 2, using Klein et al. [450]	
		EPD (%) ²	Value ³	EPD (%) ^{2,4}	Value ³
1 Apples	\$ 321,839,333	100%	\$ 321,839,333	65%	\$ 209,195,567
2 Soybeans	\$ 125,701,333	10%	\$ 12,570,133	25%	\$ 31,425,333
3 Squash	\$ 27,615,667	90%	\$ 24,854,100	95%	\$ 26,234,883
4 Cucumbers	\$ 12,184,000	90%	\$ 10,965,600	65%	\$ 7,919,600
5 Pumpkins	\$ 10,625,667	90%	\$ 9,563,100	95%	\$ 10,094,383
6 Strawberries	\$ 9,496,000	20%	\$ 1,899,200	25%	\$ 2,374,000
7 Peaches	\$ 6,698,333	60%	\$ 4,019,000	65%	\$ 4,353,917
8 Raspberries and blackberries	\$ 4,981,000	90%	\$ 4,482,900	65%	\$ 3,237,650
9 Pears	\$ 4,427,000	70%	\$ 3,098,900	65%	\$ 2,877,550
10 Blueberries	\$ 3,667,000	100%	\$ 3,667,000	65%	\$ 2,383,550
Eight other crops	\$ 92,345,489		\$ 42,170,956		\$ 8,068,972
Total	\$ 624,111,823		\$ 439,130,223		\$ 308,165,406

Notes: (1) Mean annual value of production, 2016-2018 [945]; (2) Estimated pollinator dependence (EPD) represents expected production reduction in the absence of animal pollination, based on studies by Morse and Calderone [585] and Klein et al. [450]; (3) The estimated direct value of pollination, here, is the value of NYS production multiplied by the EPD of a given crop; (4) Mean values from Klein et al. [450].

Table 1. Estimated direct value of pollination services to New York agriculture. Adapted from Grout et al., 2020, page 191.

While some solar farms have already incorporated flowering plants into their vegetation management plans, many unanswered questions remain about the logistics and economic viability of solar beekeeping. There is little empirical evidence documenting the effects of pollinator-friendly solar farms on honey bee health, foraging behavior, or productivity (Graham et al., 2021). Concerns exist about incorporating pollinator habitat in agricultural landscapes where exposure to pesticides on nearby cropland may harm pollinators (Mogren & Lundgren, 2016). Native pollinator conservation and honey production goals may be in conflict, as managed honey bees compete for resources and share pathogens with wild pollinators (Dolezal, Torres & O’Neal, 2021). Native pollinator conservation efforts tend to emphasize restoring native grasses and forbs yet New York beekeepers depend on several tree species and some invasive plant species to produce surplus honey. These considerations highlight knowledge gaps for further research and consideration by stakeholders seeking to advance solar beekeeping.

This study explores the viability of solar beekeeping and honey production in the Town of Mount Morris, NY. To accomplish this goal, we conducted a survey documenting beekeeper perspectives on the opportunities and challenges of honey production at solar facilities in general, and at the Morris Ridge Solar Project in particular. Morris Ridge is a 1000-acre utility scale ground mount solar photovoltaic facility under development in Mount Morris. The beekeeper survey collected economic data allowing us to quantify the costs and benefits of establishing and operating solar apiaries at different scales. We also performed a landscape analysis to identify and evaluate potential apiary locations within the Morris Ridge facility. Part II of this paper describes beekeeper survey methods and results, while Part III covers the landscape analysis. Part IV details the economic analysis and provides apiary enterprise budgets. We offer recommendations for solar apiary design, vegetative plantings to support honey production, and strategies for beekeeper recruitment in Part V.

II. BEEKEEPER SURVEY

BEEKEEPING IN NEW YORK STATE

Beekeeping operations in New York State exhibit diversity in size, management practices, and marketing strategies. New York beekeepers can be classified into three groups based on operation size: hobbyists (fewer than 50 colonies), sideliners (50 to 299 colonies), and commercial beekeepers (300 colonies or more) (Hinsley et al., 2021). According to the 2020 New York State Beekeeper Tech Team Report, more than 90% of New York’s estimated 3000 beekeepers are hobbyists. The state’s 109 sideliners and 59 commercial beekeepers manage the vast majority of colonies in the state. Commercial operations provide most of the contracted pollination services in New York, and often transport bees to pollinate crops and overwinter in other states (NYSDEC & NYSDAM, n.d.). Earning one’s livelihood from beekeeping typically requires at least several hundred colonies. Although hobbyists may sell honey and wax products, their beekeeping venture is rarely their sole income source.

Flowering plant species in New York number in the thousands, yet the business of honey beekeeping relies on a small number of species that yield abundant nectar and are prevalent enough in the landscape to support surplus honey production (Pellett, 1923). Historically, the most important plants for New York honey production were white clover, alsike clover, sweet clover, buckwheat, basswood, black locust, sumac, fruit trees, goldenrod, and asters (Pellett, 1923; Lovell, 1926). Today, buckwheat cultivation has declined, making this crop less important to New York beekeepers. Invasive plants including Japanese knotweed (*Reynoutria japonica*), spotted knapweed (*Centaurea stoebe*), and purple loosestrife (*Lythrum*

salicaria) have expanded their ranges in New York and become increasingly important for honey production. The productivity of honey plants varies considerably across the state, with higher nectar flows and honey yields observed in areas with high pH limestone soils. Landscape diversity is also important. Pollen and nectar resources from minor plants help to maintain strong colonies throughout the season so that bees are ready to capitalize on periodic heavy nectar flows to produce surplus honey. In particular, willow, maple, and dandelion provide early pollen sources that support colony growth in the spring (Pellett, 1923).

SURVEY METHODS

We developed a survey to evaluate the economics of establishing an apiary within a solar development, and to document beekeeper perspectives on solar beekeeping arrangements and solar honey marketing opportunities. The survey included five sections covering the following:

1. Beekeeper and operation characteristics
2. Honey yields and sales through various marketing channels
3. Beekeeper demand and preferences for new apiary locations
4. Apiary establishment and operating costs
5. Beekeeper perspectives on solar beekeeping arrangements and solar honey marketing

The survey used a phone interview format that allowed the interviewer to ask follow-up questions for clarification and additional information. Five beekeepers completed the survey between May 13 and June 29, 2021. Survey participants were selected based on the size and location of their operations. We targeted beekeepers operating in Western New York, within an hour of the Town of Mount Morris. We prioritized large commercial beekeepers and interviewed one smaller operation to capture a wider range of beekeeper perspectives. Within this sample, beekeepers reported a variety of management practices, yet they all focused on honey production as their primary enterprise.

SURVEY RESULTS

Beekeeper and Operation Characteristics

Five beekeepers completed the survey, including four commercial operations managing 300–2000 colonies each, and one sideliner operation managing 50–299 colonies. Together, these five beekeepers managed 3861 colonies in 2020. Beekeeper experience ranged from 15 to 51 years, with a total of 181 years of experience among the five survey respondents. In 2020, these beekeepers managed bees in ten New York counties: Allegany, Broome, Erie, Genesee, Livingston, Niagara, Onondaga, Ontario, Orleans, and Wyoming.

Two of the commercial operations were migratory, meaning they move their colonies between eight and twelve times a year to provide commercial pollination services, follow seasonal honey flows, and overwinter bees in southern states. The other three operations overwintered bees in New York and did not provide any commercial pollination services. Although our sample is not statistically representative of New York beekeepers, it captures important variation in size and migratory patterns, two defining characteristics of beekeeping operations. Moreover, the respondents have extensive experience managing honey bees in our Central and Western New York regions of interest.

Honey Yields and Prices

Beekeepers reported total 2020 honey yields on a per colony basis. The two migratory beekeepers excluded winter honey production from their calculations, so all yield data reflect honey produced in New York State. Three commercial operations reported harvesting 60–75 pounds per colony, and the fourth was missing 2020 yield data. However, they all considered 60 pounds per colony to be a typical yield. These reported yields are higher than the statewide average of 56 pounds per colony in 2020, and the statewide 10-year average of 54.7 pounds per colony (Figure 2).

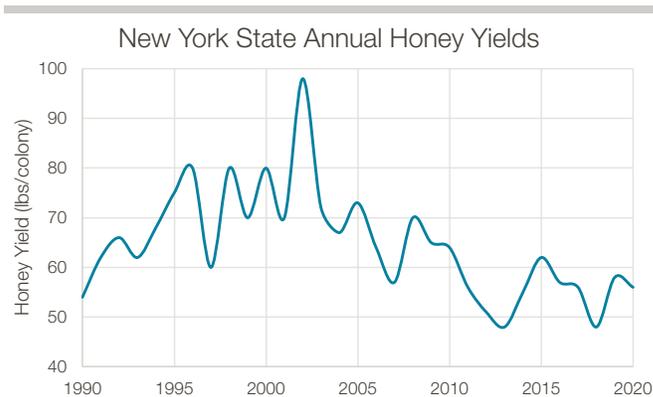


Figure 2. New York State Annual Honey Yields. Average honey yield over the past 30 years was 65.0 pounds per colony, but beekeepers have only harvested 54.7 pounds per colony, on average, over the past 10 years. Source: USDA NASS Quick Stats.

The sideliner operation reported a 2020 honey yield in excess of 100 pounds per colony, which was typical for their operation. A few possible factors may explain this relatively high yield. This beekeeper maintains apiaries in areas with abundant natural forage throughout the entire beekeeping season and minimal exposure to agricultural crops and pesticides. By maintaining a lower number of colonies per apiary, there is more forage available for each colony. In addition, this beekeeper invests significantly more time and resources per colony compared to the larger operations. The sideliner also reported consistently high colony survival rates over the winter, resulting in more mature colonies ready to start producing honey earlier in the spring.

Beekeepers in our sample used wholesale and retail channels to market their honey. The commercial operations sold nearly all of their honey wholesale, and reported minimal retail sales. In contrast, the sideliner marketed 80% of their honey directly to consumers through retail channels. Most wholesale honey was sold to packers in 55-gallon barrels with a net weight of 660 pounds per barrel. Beekeepers also marketed wholesale honey by the case to retail stores, coffee shops and restaurants, and by the bucket to commercial bakers and meaderies. One beekeeper also sold buckets of honey to small-scale beekeepers who repackage the honey for sale at local farmers markets. Beekeepers in our survey reported wholesale prices ranging from \$1.75 per pound to \$2.50 per pound for New York honey.

Beekeepers with retail sales marketed honey directly to consumers through farmers markets, farm stands, and sales to friends and family. Respondents received retail prices as low as \$4.00 per pound for honey bottled in 2.5 and 5-pound jars, and from \$6.00 to \$8.00 per pound for honey bottled in 1-pound jars. Beekeepers marketed honey with special attributes including raw, local and varietal honey. Both wholesale and retail prices may be higher for some varieties. Beekeepers with retail sales saw more potential value in marketing “solar honey” compared to beekeepers with no direct sales. In 2020,

the average sale price for New York honey was \$3.39 per pound (Figure 1). This USDA price includes retail and wholesale honey sales, so it is not directly comparable to the prices reported in our survey.

Preferences for New Apiary Locations

Beekeepers group individual colonies together into bee yards called apiaries. Apiary size varied among survey respondents, with one beekeeper managing 8 colonies per apiary, two beekeepers managing 20 to 30 colonies per apiary, and two managing 48 colonies or more per apiary. Beekeepers reported a minimum distance of one to four miles between apiary locations to ensure adequate forage availability. Respondents expressed a willingness to travel 25 to 50 miles one-way to reach a

productive apiary site. Several respondents articulated a preference for establishing a cluster of two to three apiaries a few miles apart within a new beekeeping area to make a longer drive worthwhile.

In addition to travel distance, beekeepers described a number of characteristics they look for in an ideal apiary site. Survey respondents repeatedly mentioned **six important characteristics**: accessibility, composition of vegetation in the landscape, safety and privacy, physical site characteristics, protection from agrichemicals, and the quality of their relationship with the property owner. Table 2 summarizes important considerations for each characteristic. Beekeeper survey responses were consistent with longstanding guidelines for apiary siting in New York (Morse & Dyce, 1982).

Characteristics	Considerations for Site Selection and Design
Accessibility	<ul style="list-style-type: none"> • Beekeepers require year-round access to apiary sites, ideally a gravel road or driveway and ample space for vehicles and equipment. Depending on the scale of the operation, equipment may include a standard or flatbed pickup truck, trailer, and skid steer. • The site must be well drained and dry enough to allow access in early spring when some soils become saturated from precipitation and snowmelt.
Landscape Composition	<ul style="list-style-type: none"> • Beekeepers look for abundant floral resources within a 1-mile radius of the apiary to sustain bees and achieve desired honey yields. Bees will travel several miles from their colony to forage if necessary, but adequate nectar in proximity to the hives is necessary to achieve production goals. • Diversity in plant species and habitat types is critical to provide steady nectar flows throughout the entire growing season and avoid artificial feeding. • While there are many flowering plants that bees visit to collect nectar and pollen, the number of plants that provide an abundance of nectar to support surplus honey production is relatively small.
Safety & Privacy	<ul style="list-style-type: none"> • Locate colonies at least 100 yards from solar panels and other areas where technicians work to minimize the risk of bee stings. This distance will also minimize honey bee defecation on solar panels and other equipment. • Avoid locating apiaries in close proximity to swimming pools, as bees will visit pools to drink water and may become a nuisance to the homeowner. • Beekeepers prefer to keep colonies out of public view, with a visual block separating the apiary from nearby roads and residences. • Electrified bear fencing may be necessary at some sites if colonies are located outside the perimeter fence.
Physical Characteristics	<ul style="list-style-type: none"> • Beekeepers prefer flat terrain with adequate southern or eastern exposure. • A hedgerow, tree line or other windbreak may be desirable to the north or west of an apiary site, depending on prevailing winds. • Honey bees require a nearby pond, lake, or stream to collect water for drinking and moderating temperatures within the hive. • A grassy surface is ideal for moderating heat during the summer. Avoid placing colonies on dark surfaces, such as gravel or asphalt.
Protection from Agrichemicals	<ul style="list-style-type: none"> • Beekeepers avoid siting apiaries near corn and soybean fields due to concerns about pesticide exposure, particularly exposure to neonicotinoid insecticides and glyphosate. • Beekeepers avoid apiary locations in close proximity to conventional orchards, vineyards, and vegetable farms to reduce insecticide and fungicide exposure.
Property Owner Relationships	<ul style="list-style-type: none"> • Beekeepers value and seek strong relationships with landowners to support secure long-term access to apiary sites.

Table 2. Considerations for apiary site selection and design.

In seeking locations for apiary establishment, beekeepers avoid certain land uses perceived to negatively affect honey bee performance (Otto et al., 2016). Beekeepers in our survey avoid apiary locations close to corn fields and other row crops to reduce the risk of insecticide and herbicide exposure from neonicotinoid seed treatments and glyphosate foliar sprays. Survey respondents also avoid commercial orchards and vegetable operations due to concerns about insecticide and fungicide exposure from foliar sprays. Research documents substantial risk to bees from insecticide exposures in corn and soybean fields and within apple orchards, supporting these concerns (Grout et al., 2020; McArt et al., 2017).

The honey yield potential for a given apiary site depends on floral nectar resources and, to a lesser extent, pollen resources in the landscape surrounding the apiary. Bees convert nectar into honey, a stored feed that provides a year-round source of energy for the colony, while pollen provides a protein source critical for raising brood and growing the population within a colony. Variation in the bloom timing of flowering plants causes pollen and nectar sources to change throughout the season. Except during early spring, pollen availability rarely limits honey bee productivity in New York. As a result, beekeepers tend to look for apiary locations surrounded by an abundance of specific plants and habitat types known to provide abundant nectar. Our survey respondents identified eight flowering plants and six habitat types as key resources for honey production at different times during the beekeeping season (Table 3). Research on seasonal availability of floral resources across 21 pollinator habitat types in New York reinforces the habitat types identified by beekeepers (Iverson, 2018).

Season	Flowering Plants	Habitat Type
Spring	<ul style="list-style-type: none"> Black locust (<i>Robinia pseudoacacia</i>) Sumac (<i>Rhus</i> spp.) 	<ul style="list-style-type: none"> Hedgerows Forest edges
Summer	<ul style="list-style-type: none"> Basswood (<i>Tilia</i> spp.) Clover (<i>Trifolium</i> spp.) Knapweed (<i>Centaurea</i> spp.) 	<ul style="list-style-type: none"> Meadows Roadside ditches Wetlands
Fall	<ul style="list-style-type: none"> Goldenrod (<i>Solidago</i> spp.) Aster (<i>Aster</i> spp.) Japanese knotweed (<i>Polygonum cuspidatum</i>) 	<ul style="list-style-type: none"> Old farm fields

Table 3. Flowering plants and habitat types valued by New York beekeepers for honey production.

Perspectives on Solar Beekeeping

Four of the beekeepers in our sample expressed positive attitudes toward beekeeping on solar sites in general, and showed interest in establishing apiaries on solar farms. In fact, one survey respondent was already collaborating with a solar development in Western NY. However, this positive attitude was not unanimous, as one survey respondent expressed strong skepticism about solar development and the viability of keeping bees on solar sites.

Despite their interest in solar beekeeping, two commercial beekeepers expressed strong concerns about honey bee forage availability at the Morris Ridge site. According to the Town of Mount Morris 2019 Agricultural and Farmland Protection Plan, agricultural land uses cover approximately 53% of the town's total land area. Field crops represent the most prevalent agricultural land use in the town, covering two thirds of all land used for farming in 2015. Aside from buckwheat, field crops grown in New York State do not support surplus honey production. Thus, the high prevalence of commercial agriculture in the Mount Morris area is concerning to beekeepers, who perceive a high likelihood of low honey yields in that area. The fact that we have not identified any beekeepers currently managing apiaries in Mount Morris casts further doubt on the suitability of the site for honey production. In other parts of the state, New York beekeepers face stiff competition for highly productive apiary sites.

In the words of one survey respondent, *"There's really not much there [in the Mount Morris area] for the bees. I don't think you could plant enough [bee forage] that a commercial guy wouldn't have to come in and feed. Maybe it would work for a hobbyist with a few colonies. But it would cost us time, energy and money just to say we had bees [on a solar farm] and we don't see any marketing benefit."* Another respondent expressed interest in keeping bees at the Morris Ridge site only if they could start small, with 10 to 20 colonies due to uncertainty about nectar availability and honey yields. Observing honey yields in a small apiary for one to two years could help a commercial beekeeper decide whether to establish a larger apiary at the Morris Ridge site.

Beekeepers also expressed concerns about access to the solar site. In particular, they desire assurance that they can access their apiaries at any time, including on weekends, without having to ask for permission or coordinate with solar site managers or staff. One beekeeper expressed concerns about having to move their colonies on short notice or at impractical times of year. These considerations could easily be addressed in a written apiary lease agreement. Although none of the survey respondents reported using written apiary lease agreements at any of their current apiary locations, they all expressed a willingness to work with solar developers to implement written lease agreements for apiaries on solar sites.

III. LANDSCAPE ANALYSIS

LANDSCAPE COMPOSITION AND HONEY PRODUCTION

Landscape composition directly influences honey bee health and productivity, making it a critical factor for economically viable honey production. Land use, soil type, and vegetative cover are highly variable at the local level, which explains why two apiaries situated just a few miles apart can have substantially different honey yields (Pellett, 1923). For this reason, landscape composition drives beekeeper decisions about where to place apiaries, and, ultimately, their productivity and long-term success.

As discussed in the previous section, beekeepers prefer apiary sites with abundant, high quality forage, and low agrichemical exposure (Table 2). Beekeepers observe land use practices, habitat types, and plant species around potential apiary locations to evaluate site quality. Plant species and habitat types associated with high forage availability attract beekeepers, while land use practices that involve heavy use of insecticides and fungicides repel them. Beekeepers make tradeoffs in response to this push-pull dynamic when selecting apiary sites. However, the most desirable locations provide abundant forage resources with minimal pesticide risks.

Honey bee foraging distances vary throughout the season depending on floral availability, landscape structure, and weather conditions. The average foraging radius for honey bees in New York state is 1.5 km, or just under one mile, although bees will forage up to several miles from their colonies, particularly if resources are scarce (Waddington et al., 1994; Visscher & Seeley, 1982). A 1.5 km foraging radius covers approximately 707 hectares (1747 acres) of land, so beekeepers must consider land cover patterns across a large area when deciding where to locate hives. This honey bee foraging area is much larger than most utility scale solar installations, so bees located at solar facilities will undoubtedly forage elsewhere, often far beyond the solar site. Consequently, beekeepers must consider landscape composition within and around solar developments when selecting solar apiary sites.

The criteria that beekeepers use to select apiary locations differ from criteria that developers use to determine optimal placement of utility scale solar energy facilities. Intensively managed agricultural land may offer an appealing set of site characteristics to a solar developer. Such land tends to be relatively flat and well drained with good solar exposure. However, landscapes dominated by intensive cropping systems have harmful impacts on wild and managed bees and provide low-quality pollinator habitat (Koh et al., 2015). To the extent that solar development takes place on sites surrounded by large-scale conventional farming, there may be negative consequences for honey bees located on solar sites.

Mapping and evaluating land cover patterns is helpful to understand the suitability and productive potential of apiary locations (Otto et al., 2016; Koh et al., 2015). The objective of this landscape analysis is to describe and assess the landscape composition within a typical honey bee foraging distance around several possible apiary sites at the Morris Ridge Solar Project. Both the Town of Mount Morris and the Morris Ridge Solar Project wish to incorporate and support solar beekeeping at the Morris Ridge site, yet commercial beekeepers have expressed concerns about nectar availability and agrichemical exposure (see Part II). Results from this analysis can help beekeepers decide whether the landscape composition around the Morris Ridge Solar Project meets their apiary siting criteria. More broadly, this analysis aims to identify opportunities and challenges related to solar apiary siting that will be relevant to solar developers and beekeepers across New York State.

SPATIAL ANALYSIS METHODS

To assess landscape composition around plausible solar apiary locations, we identified three potential apiary sites within the Morris Ridge Solar Project. Key considerations which informed apiary site selection were: (1) vehicle access, (2) agrichemical exposure risk, and (3) distance between sites, and (4) proximity to residential homes. Each site is located close to a public road, allowing easy and reliable access for vehicles and equipment. To minimize the risk of pesticide exposure, each site is bordered either by land controlled by the solar project or by forested land. None of the sites is directly adjacent to private farmland. Finally, the three apiary sites are located toward the outer edges of the Morris Ridge Solar Project to maximize the distance between sites, which ranges from 3.0 miles (4.9 km) to 3.8 miles (6.1 km).

We obtained spatial information on crop types surrounding each apiary location from the 2020 New York State Cropland Data Layer (CDL) produced by USDA National Agricultural Statistics Service (USDA NASS, n.d A). The CDL is a geo-referenced raster data layer that represents agricultural land cover with a ground resolution of 30 meters (USDA NASS, n.d. B). NASS generates the CDL from satellite imagery and updates it annually.

The national 2020 CDL data layer classified 133 land cover types, 69 of which were present in New York. We grouped all land cover types in our area of interest into 14 categories with different implications for honey bee health and foraging behavior. These 14 categories included seven crop categories (corn, soybeans, small grains, alfalfa hay, grass hay, fruits and vegetables, and Christmas trees), four grassland categories (grassland/pasture, fallow cropland, shrubland, and clover/wildflowers), and three other categories (forest, wetlands,

and developed land). We report the land area covered by each category, and we report sub-totals for row crops (corn, soybeans, small grains), hay crops (alfalfa hay, grass hay), all crops, and all grassland cover types.

Using GIS mapping software, we measured the total area occupied by each land cover category around each apiary site. The analysis used two different foraging areas, one based on a 1600 meter (1 mile) foraging distance and the other using a 3200 meter (2 mile) foraging distance. We defined a circular buffer around each apiary site using the foraging distance as the radius. The 1600-meter radius approximates the average foraging distance for honey bees in New York state, and the associated foraging area covers roughly 804 hectares (1987 acres). While a honey bee typically forages within a mile of her hive, beekeepers tend to evaluate forage quality and availability within two miles of potential apiary sites, as honey bees will travel two miles or more to collect food at times (Gallant, Euliss Jr & Browning, 2014). Thus, the circles defined by a 3200-meter radius may better reflect the area of interest to beekeepers. Doubling the radius of a circle quadruples its area, so the foraging area within 3200 meters of an apiary covers four times as much land, approximately 3217 hectares (7949 acres). We report land cover results for each individual apiary buffer and for the three sites combined. Because the 3200 meter circular buffers surrounding our apiary locations overlap, we merged the three buffers to create a single shape with a total area of 8584 hectares for the combined analysis.

Based on research and interviews with beekeepers, we consider row crops (corn, soybeans, small grains) to be the most undesirable land cover for beekeepers. We consider hay crops (alfalfa hay, grass hay) to be a relatively neutral land cover type. Grass hay does not provide significant floral resources for bees (Iverson, 2018), and, while alfalfa is a major honey crop in western states where the arid climate stimulates nectar production, it is not a reliable nectar producer in New York's humid climate (Pellett, 1923). We consider grassland cover types (grassland/

pasture, fallow cropland, shrubland, clover/wildflowers) and wetlands to be the most desirable land cover classifications. Forested land provides important nectar and pollen resources for bees, particularly along hedgerows and forest edges, yet this land cover is so prevalent across the combined foraging area that the total amount of forested land is less likely to influence beekeeper site preferences. Thus, we expect beekeepers to prefer sites with higher proportions of grassland and wetland cover, and lower proportions of row crop cover.

In their 2014 paper, authors Gallant, Euliss Jr, and Browning describe a methodology for mapping honey bee habitat and evaluating potential apiary sites according to honey bee nutritional needs and landscape composition. Using a honey bee foraging area of 3255 hectares, they identify local landscape criteria for siting commercial apiaries in the Northern Great Plains, based on industry standards used by professional beekeepers in that region (Table 4). They select criteria that would support apiaries of 100 colonies, even though most commercial apiaries in their region have about half that number of colonies. The authors adopt conservative criteria because competition for apiary locations in their area is high, and beekeepers commonly place apiaries within overlapping forage ranges.

We lack comparable published landscape criteria for New York State, so we adapted the North Dakota apiary siting criteria to reflect crop types and land use patterns in New York. Table 4 presents the original published criteria and our revised criteria. The revised criteria include at least 65 hectares of forested land, at least 260 hectares of grassland cover types (grassland/pasture, fallow cropland, shrubland, and clover/wildflowers), and the presence of wetlands within a 3200-meter radius of an apiary site. The North Dakota criteria also included land devoted to crops known to provide abundant nectar to bees. However, with the limited exception of buckwheat, field crops in New York State and in the Mount Morris area are not a significant source of nectar for honey bees

Land Cover	Site Criteria for North Dakota (Gallant, Euliss Jr & Browning, 2014)	Site Criteria Adapted for New York
Forest	≥65 hectares deciduous trees/shrubs	≥65 hectares forest
Grassland	≥130 hectares Conservation Reserve Program (CRP) grassland or comparable mixed grass/forb cover	≥260 hectares any combination of grassland/pasture, fallow cropland, shrubland, and clover/wildflowers ¹
Cropland	≥130 hectares any combination of alfalfa, oilseed sunflowers, and canola	n/a
Wetland	Surface water present	Wetland present

Table 4. Landscape criteria used to evaluate potential apiary locations for adequate pollen and nectar resources to support honey bee colonies throughout the growing season in New York State.

¹We double the grassland requirement for New York State and dropped the cropland requirement because cropland in New York generally does not provide a significant source of feed for bees relative to alfalfa, sunflower and canola fields in North Dakota (Iverson, 2018; Pellett, 1923).

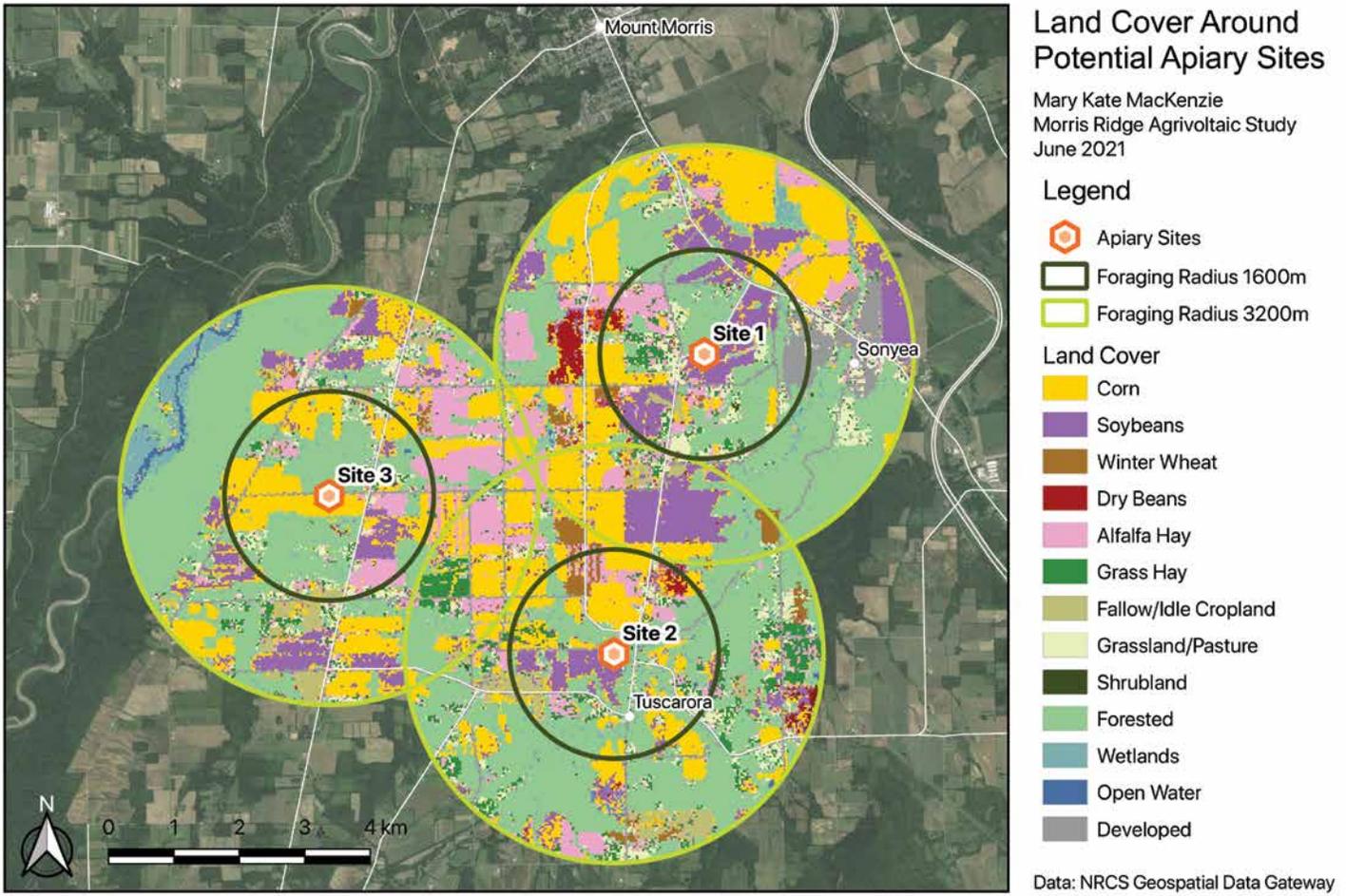


Figure 3. Landscape composition around potential apiary sites. Source: USDA NASS Cropland Data Layer.

(Iverson, 2018; Pellett, 1923). Following methods outlined by Gallant, Euliss Jr, and Browning (2014), we used these criteria to evaluate the landscape composition around each proposed apiary at the Morris Ridge Solar Project.

LANDSCAPE COMPOSITION RESULTS

The apiary sites selected for the landscape analysis were located at the following coordinates: Site 1 (42.68023, -77.85442); Site 2 (42.63835, -77.87189); and Site 3 (42.65965, -77.92341) (Figure 3). Relative to the center of the Morris Ridge Solar Project, Site 1 was located to the northeast, Site 2 was located to the southeast, and Site 3 was located to the west. Site 1 was the closest site to the Village of Mount Morris, Site 2 was closer to Tuscarora, and Site 3 was nearest to the Genesee River

and Letchworth Gorge. Each site represents a viable apiary location according to our three selection criteria: allow vehicle access, minimize pesticide exposure, and maximize distance between sites.

Figure 3 illustrates a one-mile (1600 meter) and two-mile (3200 meter) radius around each apiary site, and shows land cover classifications surrounding each site. Figure 4 illustrates the land cover breakdown for our combined 8584 hectare area of interest at the Morris Ridge Solar Project compared to Livingston County and New York State. Land use patterns surrounding apiary locations at the Morris Ridge site were very similar to land use patterns throughout Livingston County. Compared to land use patterns across New York State, Morris Ridge and Livingston County had relatively more land allocated to crops, about the same to grassland, and less to forest, wetlands, and development.

Land Cover at the Project, County, and State Levels

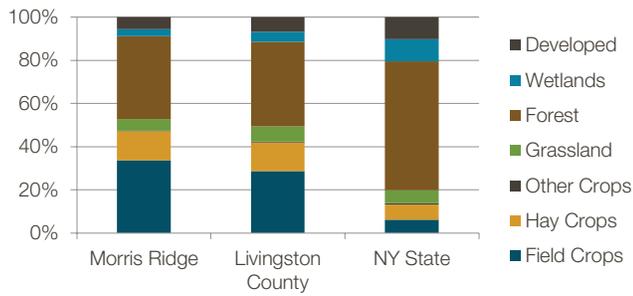


Figure 4. Land Cover at the Project, County, and State Levels. This figure shows land cover for the 8584 hectare area of interest at the Morris Ridge Solar Project compared to land cover across Livingston County and New York State.

Table 5 (page 86) presents total area (hectares) and relative area (percent) for each land cover class within 1600 meters of each apiary site, and combined total. The combined total land area equaled the sum of the three 1600-meter radius foraging areas, as there was no overlap between the three circular buffers. Across the combined area, crops occupied 47% of the land, followed by forest (36%), grassland (8%), developed land (6%), and wetlands (2%). Corn and soybeans were the most prevalent crops, covering 21% and 11% of the total land area, respectively, followed by alfalfa hay (9%), grass hay (4%), and small grains (2%).

Table 6 (page 73) presents total area (hectares) and relative area (percent) for each land cover class within 3200 meters of each apiary site, and combined total. At this scale, the combined total land area was less than the sum of the three apiary foraging areas due to the overlap among foraging ranges. The distribution of land cover types was very similar across the combined 3200-meter radius foraging area compared to the combined 1600-meter radius foraging area. Crops occupied 47% of the land, followed by forest (38%), grasslands (6%), developed land (6%), and wetlands (3%). Corn and soybeans were the most prevalent crop types, covering 22% and 10% of the total land area, respectively, followed by alfalfa hay (9%), grass hay (4%) and small grains (2%).

EVALUATION OF PROPOSED APIARY SITES

The landscape analysis reveals some differences among the three apiary sites, yet those relationships change depending on the size of the foraging area under consideration. Within the 1600 meter foraging radius, Site 1 had the lowest proportion of land devoted to row crops (30%) and all crops (45%), and the highest proportion of land devoted to grassland cover types (11%). In contrast, Site 2 had the highest proportion of land devoted to row crops (39%) and all crops (50%), and the lowest proportion of land devoted to grasslands (6%). All three sites had significant forest cover and some wetlands. Given these data, it

is tempting to rank Site 1 as the best site for beekeepers in terms of landscape composition, and Site 2 as the worst.

However, within the 3200 meter foraging radius, Site 1 had the highest proportion of land devoted to row crops (41%) and all crops (53%), and the lowest proportion of land devoted to grassland cover types (7%). At the larger scale, Site 3 had the lowest proportion of land devoted to row crops (29%) and all crops (45%), and the highest proportion of land devoted to wetlands (5%). Site 2 and Site 3 each had similar proportions of land devoted to grasslands (8%). Considering this larger foraging radius, most beekeepers would likely prefer Site 3 and rank Site 1 last in terms of land cover. This example illustrates the importance of scale in evaluating landscape composition around potential apiary locations.

A comparison of site criteria in Table 4 with land cover results in Table 6 indicates that all three apiary sites met some, but not all, of the landscape criteria to support a large commercial apiary. Within a 3200-meter radius, each proposed apiary location had more than 65 hectares of forested land and some wetlands present. In fact, across our three sites, forested land ranged from 977 hectares to 1242 hectares and wetlands ranged from 44 hectares to 167 hectares (Table 6). However, none of the apiary locations had 260 hectares of grassland cover within the 3200-meter radius foraging area. The foraging area around Site 1 had the lowest amount of grassland cover, with 216 hectares, followed by Site 3 (242 hectares). Site 2 was the closest to meeting all three selection criteria, with 255 hectares of grassland and associated cover types within its foraging area. According to this methodology, none of our three sites met the landscape criteria to support a large commercial apiary. This finding helps to explain the skeptical attitude regarding forage availability in the Mount Morris area expressed by several beekeepers in our survey (Part II).

There is one important caveat to interpreting these data. Landscape composition will change over the next several years as the Morris Ridge Solar Project is constructed on 1000 acres (roughly 400 hectares) of private land. The solar development intends to establish a pasture mix including clover and other flowering plants under the panels, with the goal of attracting a sheep producer to manage that vegetation through rotational grazing. Compared to corn, soybean and small grain fields, rotationally grazed pasture can provide better pollinator habitat (Montag, Parker & Clarkson, 2016). The solar project will also establish perennial flowering plants in buffer areas. The conversion of land within the solar development from row crops to pasture or wildflower plantings would increase the grassland cover around all three potential apiary sites such that they would likely meet the criteria to support a commercial apiary. However, the expected positive impact for pollinators of this land use change is conditional on not only the

LAND COVER WITHIN 3200 METERS

Land Cover Class	Site 1		Site 2		Site 3		Combined	
	Hectares	%	Hectares	%	Hectares	%	Hectares	%
Corn	766.0	23.8%	661.3	20.6%	695.1	21.6%	1852.3	21.6%
Soybeans	458.9	14.3%	276.7	8.6%	223.5	6.9%	819.3	9.5%
Small Grains	98.4	3.1%	107.2	3.3%	28.1	0.9%	212.9	2.5%
Row Crops Subtotal	1323.3	41.1%	1045.2	32.5%	946.6	29.4%	2884.4	33.6%
Alfalfa Hay	285.7	8.9%	273.3	8.5%	383.2	11.9%	813.1	9.5%
Grass Hay	85.7	2.7%	202.0	6.3%	116.5	3.6%	351.4	4.1%
Hay Crops Subtotal	371.4	11.5%	475.3	14.8%	499.7	15.5%	1164.5	13.6%
Fruits & Vegetables	2.0	0.1%	7.9	0.2%	2.1	0.1%	11.6	0.1%
Christmas Trees	0.7	0.0%	0.6	0.0%	0.2	0.0%	1.4	0.0%
All Crops Subtotal	1697.4	52.8%	1529.0	47.5%	1448.6	45.0%	4061.8	47.3%
Grassland/Pasture	172.7	5.4%	139.0	4.3%	140.0	4.4%	242.4	2.8%
Fallow Cropland	38.6	1.2%	108.8	3.4%	95.9	3.0%	218.8	2.5%
Shrubland	3.3	0.1%	4.3	0.1%	3.2	0.1%	10.2	0.1%
Clover/Wildflowers	1.2	0.0%	2.7	0.1%	2.7	0.1%	6.2	0.1%
Grassland Subtotal	215.8	6.7%	254.8	7.9%	241.8	7.5%	477.7	5.6%
Forest	977.3	30.4%	1242.3	38.6%	1240.6	38.6%	3291.5	38.3%
Wetlands	59.5	1.8%	43.8	1.4%	167.2	5.2%	264.6	3.1%
Developed	267.4	8.3%	147.4	4.6%	119.3	3.7%	488.7	5.7%
TOTAL	3217.5	100.0%	3217.2	100.0%	3217.4	100.0%	8584.2	100.0%

Table 6. Land Cover within 3200 Meters of Proposed Apiary Locations (percentages rounded to nearest whole number).

successful establishment of new vegetation, but also the ongoing maintenance to ensure that flowering plants persist in the landscape.

Our landscape analysis suggests that, after establishment of new vegetative plantings, the Morris Ridge Solar Project could support one or more commercial apiaries. However, there are some important limitations to our methodology. First, our adapted criteria from the North Dakota study have not been formally validated for New York State. Nectar availability per acre for the same land cover types could differ by region. The North Dakota evaluation criteria reflect the importance of field crops for honey production in the Great Plains Region. In contrast, while honey bees may collect pollen from corn and soybean fields, field crops contribute minimally to honey production in New York. Thus, further validation of apiary siting criteria by beekeepers and researchers is needed to clarify the relationship between landscape composition and honey producing potential in New York State.

Second, the resolution of the Cropland Data Layer may lack sufficient local accuracy to identify key nectar resources for surplus honey production. For example, hedgerows and forest edges are two of the most

important forest habitat types for bees. Yet our dataset does not have enough resolution to distinguish these habitat types from other forest habitats. Beekeepers use an even finer resolution to select apiary sites, seeking out locust and basswood trees within hedgerows and forest edges. While unpublished data illustrate relationships between habitat types and floral resource availability in New York (Iverson, 2018), there is no empirical formula to predict honey yields from landscape composition. Mapping land cover types is helpful for analyzing potential apiary locations, yet apiary siting decisions ultimately rely on beekeeper experience and observation of local vegetation and forage resources.

Finally, the presence of good pollinator habitat in the landscape does not eliminate beekeeper concerns about the prevalence of land cover types known to have negative impacts on bees. Row crops were the second most prevalent land cover type in our 3200-meter radius combined foraging area, covering 34% of the landscape or 2884 hectares. This land use pattern may deter some beekeepers from siting apiaries in the Mount Morris area. The establishment of the Morris Ridge Solar Project has the potential to convert up to 1000 acres (approximately

400 ha) of cropland to pastureland and other pollinator-friendly habitat types. However, pastureland alone may not support high honey yields, particularly for a large apiary. Including vegetative species with high honey yield potential in buffer zones could further enhance the site's appeal to beekeepers.

The three potential apiary locations identified in our analysis are not the only, nor necessarily the best, apiary locations within the Morris Ridge Solar Project.

Beekeepers and site managers must consider additional logistical and social design issues when finalizing site selection. For instance, apiaries could be set back farther from public roads if gravel access roads are available once the project is developed. If project plantings provide natural buffers between apiaries and neighboring crop fields, more locations for apiary siting may become available. Site planners should consider neighbor relations and other social factors in final siting decisions.

IV. ECONOMIC ANALYSIS OF APIARY BUDGETS

ECONOMIC ANALYSIS METHODS

To understand the economic viability of solar beekeeping, we collected apiary management and financial data through our beekeeper survey. These data allow us to quantify the costs and benefits of establishing and operating solar apiaries at different scales. The economic analysis uses annual apiary enterprise budgets to evaluate establishment costs, operating costs, revenues, and profits for a small (10 colony), medium (30 colony), and large (60 colony) apiary.

Enterprise budgets typically evaluate enterprises at the farm level. However, we selected the apiary as our unit of analysis to identify costs and revenues that established beekeepers could expect to incur from adding one or more new apiaries on a solar site. The budgets rely on assumptions about colony management strategies, honey and wax yields and prices, supply and equipment costs, operator and unpaid family labor hours, the value of labor, and depreciation rates (Table 7, page 76). Assumptions are based primarily on survey data that we collected during beekeeper interviews, supported by additional production data from USDA NASS QuickStats (USDA, n.d. C), colony loss data from the Bee Informed Partnership Winter Loss Survey (Steinhauer et al., 2021), and cost data from the Mann Lake and Datant websites. Assumptions reflect typical management employed by experienced New York beekeepers.

Management Assumptions

All three model apiaries are assumed to be permanent, year-round apiaries with colonies overwintering in New York. Colonies are assumed to be stationary, meaning they are not transported off site or utilized for commercial pollination. Honey bee colonies are housed in standard 10-frame wooden Langstroth hives with two deep brood boxes, three medium honey supers, bottom boards, and covers. Colonies are set on hive stands that raise them up off the ground. The small apiary operator uses hive stands constructed from pressure treated decking with two colonies per stand. The medium and large apiary operators place colonies on top of recovered wooden pallets with 3 or 4 colonies per pallet.

We include electric fencing and a fence charger in the budget for each apiary. Beekeepers use electric fencing to protect honey bee colonies from predation by black bears in most parts of New York. If the apiary is located inside a solar facility's perimeter fence, bear fencing may not be necessary. However, if honey bee colonies are located in an area where grazing takes place, fencing is critical to protect hives from being knocked over by sheep or other livestock.

We consider purchase of hive woodenware, hive stands, and fencing to be apiary establishment costs. Additional establishment costs include expenses associated with generating honey bee colonies (splits) to populate the new apiary; site work, delivery and setup; and a one-time fee to add a new apiary location to a farm insurance policy. We annualize the cost of apiary establishment by calculating depreciation at a rate of 10%, which reflects a 10-year depreciation period with no salvage value.

Beekeepers in our survey do not feed any pollen or nectar, so the amount budgeted for feed is zero. We assume that the small apiary operator replaces 10% of queens and 20% of colonies per year, while the medium and large apiary operators replace 30% of queens and 40% of colonies annually. The small apiary operator uses FormicPro and Apivar treatments to control Varroa mites, while the medium and large apiary operators use oxalic acid and thymol treatments. None of the beekeepers budgeted for treatments to address any other colony health issues.

We budget for replacing 5% of brood frames per year for all apiaries, and we estimate a fixed value for consumable supplies (smoker fuel, paint, hive repair supplies, etc.). Apiary rent is calculated by multiplying the amount of honey given in trade to property owners by the market value of that honey. For the small apiary operator, we estimate five pounds of honey valued at \$8.00 per pound for an annual apiary rent of \$40. We estimate 30 pounds of honey valued at \$4.00 per pound totaling \$120 in annual apiary rent for the medium and large apiaries.

To estimate vehicle costs associated with travel to and from each apiary, we multiply the 2020 IRS federal mileage reimbursement rate (\$0.56/mile) by the estimated round trip mileage and the number of trips per year. We estimate a beekeeper visits the small apiary 35 times per year with a round trip distance of 30 miles for a total of 1050 miles. Operators of the medium and large apiaries each make 12 trips per year with a round trip distance of 50 miles for a total of 600 miles annually. The travel cost per apiary would be lower if beekeepers visited multiple apiaries per trip.

None of the beekeepers in our survey reported using any hired labor for beekeeping. We therefore consider all beekeeping labor to be contributed by operators and unpaid family members. To estimate the number of beekeeping labor hours, we multiply the average number of apiary workers by the annual number of visits to the apiary by the average duration of each visit. For the small apiary, we estimated one worker, 35 visits, and three hours of beekeeping labor plus 0.75 hours of travel time per visit for a total of 131 labor hours per season. The medium apiary had 1.5 workers, 12 visits, and three hours of beekeeping labor plus 1.5 hours of travel time totaling 81 annual labor hours. The large apiary had two workers, 12 visits, and four hours of beekeeping labor per visit for 132 annual labor hours. We used an hourly rate of \$17.25 to value all beekeeping labor. This rate comes from the U.S. Bureau of Labor Statistics May 2020 mean hourly wage estimate for New York State farmworkers employed in livestock operations (occupation code 45-2093) (U.S. Bureau of Labor Statistics, 2021).

Yield and Price Assumptions

Beekeeper survey data provided the basis for our honey yield and price assumptions. We assumed an annual honey yield of 110 pounds per colony for the small apiary, resulting in 1100 total pounds per apiary. This yield reflects the small apiary's relatively higher management intensity and lower stocking rate. We assumed honey yields of 60 pounds per colony for the medium and large apiaries, resulting in total honey yields of 1500 pounds per apiary and 3000 pounds per apiary, respectively. The commercial beekeepers we surveyed consider 60 pounds to be a typical honey yield for Western New York, which is 10% higher than the 10-year statewide average of 54.7 pounds per colony reported by USDA (Figure 2).

The difference in honey yields reported by the four commercial beekeepers in our survey and the beekeepers reporting yield data to USDA may reflect variation in operation size, management practices, beekeeper experience, or regional nectar availability. New York beekeepers experience high variability in honey yields over space and time, with large potential yield differences from one year to the next or between apiary locations in the same year. Our yield assumptions provide an estimate of what could happen in a typical

year, assuming that solar apiary sites perform as well as other sites in Western NY where our survey respondents currently manage bees.

We assume that beekeepers use modern extraction equipment to harvest honey and wax cappings, with wax yields estimated to be 2% of total honey yields. The beekeeper survey did not attempt to quantify honey extraction costs for individual beekeepers. Instead, we use a custom extraction rate of \$100 per 55-gallon barrel. A barrel of honey has a net weight of 640 pounds, resulting in an extraction cost of \$0.156 per pound. This custom extraction rate does not include costs associated with bottling and labeling honey for retail sale.

We use wholesale honey prices from beekeeper interviews, crosschecked against USDA price data, to estimate honey revenues. Honey from the small apiary is valued at \$3.00 per pound, while honey from the medium and large apiaries is valued at \$2.50 per pound. These prices are at the high end of prices reported by our survey respondents, yet they all fall below the average 2020 sale price for New York honey (Figure 1). A wholesale beeswax price of \$8.00 per pound is used for all three apiary models.

Wholesale pricing is appropriate for the medium and large apiaries, as operations of that scale primarily sell honey through wholesale channels. Retail pricing could be more appropriate for the small apiary, as operations of that scale usually sell honey through retail channels. However, it is difficult to estimate the additional cost of materials and labor associated with bottling and marketing honey. Although the smallest operation would likely take additional steps to add value and direct market their product, we use wholesale pricing in our analysis to build comparable budgets across the three model apiaries.

Profitability Analysis

Net farm income is the most common indicator of farm profit, as it represents the total value of production minus the total cost of production. Cost of production includes operating expenses and depreciation, but does not include the value of operator labor and management or unpaid family labor. We calculate the annual net income at the apiary level, rather than the farm level, by subtracting the total apiary cost of production from the total apiary income. We report net income per apiary, per colony, and per pound of honey.

Return to equity capital is a second indicator of farm profit. This metric reflects the financial return after accounting for the value of operator and unpaid family labor. None of our survey respondents used any hired labor in their bee yards, so our budgets assume that all beekeeping labor is operator and unpaid family labor. We calculate the return to equity capital at the apiary level by subtracting the value of operator and unpaid family labor from net apiary income.

Operating profit margin ratio is a third profitability indicator representing the return per dollar of gross revenue. To calculate operating profit margin at the apiary level, we divide the return to equity capital by gross apiary revenue. Benchmark data for the agricultural industry provide standards for comparison. An operating profit margin over 25% is considered strong, 10% to 25% is considered stable, and less than 10% is considered weak (Kohl and Blonde, 2009).

After calculating budgets and profits based on our starting honey yield assumptions, we conduct a yield sensitivity analysis. We use the economic model to determine the required honey yield for each apiary size to achieve an operating profit margin of 0%, 10%, and 25%. This analysis illustrates honey yields needed to attain economic viability and various levels of profitability at different production scales.

APIARY BUDGET ASSUMPTIONS

Production Metrics	Small Apiary	Medium Apiary	Large Apiary
Number of colonies ¹	10	30	60
Honey yield (pounds per colony) ^{1,2}	110	60	60
Honey price (\$ per pound) ^{1,2}	\$3.00	\$2.50	\$2.50
Wax yield (% of honey yield) ³	2%	2%	2%
Wax price (\$ per pound) ^{2,4}	\$8.00	\$8.00	\$8.00
Apiary Establishment	Small Apiary	Medium Apiary	Large Apiary
Hive equipment description ¹	10-frame colonies with 2 deep & 3 medium boxes, assembled and painted with frames, bottom boards & covers		
Hive equipment (cost per colony) ^{1,4}	\$400	\$350	\$350
Pallets/hive stand ¹	2' x 6' PT decking	Recycled pallets	Recycled pallets
Colonies per pallet/hive stand ¹	2	3	4
Hive stand cost (\$ per pallet/stand)	\$60	\$0	\$0
New colony value (cost to make a split) ³	\$50	\$50	\$50
Cost of electric fencing and charger ¹	\$500	\$400	\$400
Increase to insurance premium (one-time) ³	\$50	\$50	\$50
Cost of site work, delivery, other setup ¹	\$70	\$100	\$100
Depreciation (% of total establishment cost) ³	10%	10%	10%
Management Assumptions	Small Apiary	Medium Apiary	Large Apiary
Feed (\$ per colony) ¹	\$0.00	\$0.00	\$0.00
Percentage of queens replaced per year ¹	10%	30%	30%
Cost of purchased queens ¹	\$25.00	\$25.00	\$25.00
Percentage of colonies replaced per year ^{1,5}	20%	40%	40%
Replacement colony value ³	\$50.00	\$50.00	\$50.00
Varroa treatment ¹	Apivar & FormicPro	Oxalic Acid & Thymol	Oxalic Acid & Thymol
Cost of Varroa treatment (\$ per colony) ⁴	\$21.20	\$7.50	\$7.50
Other colony health treatments ¹	None	None	None
Cost of other treatments (\$ per colony) ¹	\$0.00	\$0.00	\$0.00
Total brood frames (# per colony)	20	20	20
Replacement brood frames (% per colony) ¹	5%	5%	5%
Brood frame cost (\$ per frame) ^{1,4}	\$4.80	\$4.35	\$4.35
Supplies - consumable items (\$ per apiary) ¹	\$50	\$60	\$100

Management Assumptions <i>(continued)</i>	Small Apiary	Medium Apiary	Large Apiary
Apiary rent (honey lbs per apiary) ¹	5	30	30
Honey value (\$ per lb) ¹	\$8.00	\$4.00	\$4.00
Vehicle mileage rate ⁶	\$0.56	\$0.56	\$0.56
Round trip miles ¹	30	50	50
Trips per year ¹	35	12	12
Annual miles ¹	1050	600	600
Honey extraction cost (\$ per lb) ¹	\$0.156	\$0.156	\$0.156
Unpaid Operator & Family Labor	Small Apiary	Medium Apiary	Large Apiary
Number of operator/family apiary workers ¹	1	1.5	2
Trips to the apiary per year ¹	35	12	12
Beekeeping labor per trip (hrs) ¹	3	3	4
Travel time per trip (hrs) ¹	0.75	1.5	1.5
Total beekeeping & travel labor hours ¹	131	81	132
Hourly rate for beekeeping labor ⁷	\$17.25	\$17.25	\$17.25
Total operator and unpaid family labor	\$2,264	\$1,397	\$2,277

¹Beekeeper interviews

²USDA NASS QuickStats

³Author's estimate

⁴Mann Lake and Dadant websites

⁵Bee Informed Partnership Winter Loss Survey: <https://beeinformed.org/category/winter-loss-survey/>

⁶IRS 2021 federal reimbursement rate

⁷U.S. Bureau of Labor Statistics May 2020 State Occupational Employment and Wage Estimates for New York.

Mean wage for occupation code 45-2093 Farmworkers, Farm, Ranch, and Aquacultural Animals: https://www.bls.gov/oes/current/oes_ny.htm

Table 7. Apiary budget assumptions.

RESULTS FROM APIARY BUDGETS

Based on our assumptions, gross annual apiary income was \$3476 for the small apiary, \$4788 for the medium apiary, and \$9576 for the large apiary (Tables 8, 9, 10, pages 87-89). The small apiary had the highest gross income on a per colony basis, with \$348 per colony compared to \$160 per colony for the medium and large apiaries (Table 11). This difference reflects the small apiary's higher honey yield per colony and higher honey price per pound compared to the larger apiaries.

Apiary establishment cost represents a one-time startup investment to set up a new apiary. This cost was \$5420 for the small apiary, \$12,550 for the medium apiary, and \$24,550 for the large apiary. Apiary establishment cost per colony was highest for the small apiary, which spent \$542 per colony compared to \$418 per colony for the medium apiary and \$409 per colony for the large apiary. These differences reflect economies of scale, with larger beekeeping operations able to purchase hive equipment in bulk at a lower cost and spread fixed costs such as fencing and insurance over a larger number of colonies.

The annual depreciation expense associated with apiary establishment was \$542 for the small apiary, \$1255 for the medium apiary, and \$2455 for the large apiary.

Total apiary operating expense (before depreciation) was \$1235 for the small apiary, \$1977 for the medium apiary, and \$3479 for the large apiary. The top two operating expenses for the small apiary were vehicle expense (\$588) and Varroa treatments (\$212). The small apiary's cost structure reflects a higher number of beekeeper visits to the apiary per year and a Varroa control strategy that utilizes more expensive treatments. The top two operating expenses for the medium apiary were replacement colonies (\$600), and vehicle expense (\$336), while the top two operating expenses for the large apiary were replacement colonies (\$1200), and honey extraction (\$562). The cost structure for the two larger apiaries reflects a higher colony loss rate compared to the small apiary. However, on a per colony basis, the small apiary had the highest operating expense, spending \$123 per colony compared to \$66 per colony for the medium apiary and \$58 per colony for the large apiary.

APIARY BUDGET COMPARISON

Apiary Income	Small Apiary	Medium Apiary	Large Apiary
Honey	\$330	\$150	\$150
Wax	\$18	\$10	\$10
Gross Revenue	\$348	\$160	\$160
Apiary Establishment Cost <i>(One-Time Investment)</i>			
Hive equipment	\$400	\$350	\$350
Pallets/hive stand	\$30		
Bees	\$50	\$50	\$50
Electric fencing & charger	\$50	\$13	\$7
Insurance	\$5	\$2	\$1
Other (site work, delivery)	\$7	\$3	\$2
Total Apiary Establishment Cost	\$542	\$418	\$409
Apiary Operating Expense <i>(Variable Costs)</i>			
Purchased queens	\$3	\$8	\$8
Replacement colonies	\$10	\$20	\$20
Varroa control & treatment	\$21	\$8	\$8
Frames and foundation	\$5	\$4	\$4
Smoker fuel, paint, consumable supplies	\$5	\$2	\$2
Apiary rent	\$4	\$4	\$2
Vehicle expense	\$59	\$11	\$6
Honey extraction	\$17	\$9	\$9
Total Operating Expenses	\$123	\$66	\$58

Net Income <i>(Return to Operator Labor, Management and Equity Capital)</i>	Small Apiary	Medium Apiary	Large Apiary
Net Cash Income (gross revenue - operating expense)	\$224	\$94	\$102
- Depreciation	\$54	\$42	\$41
Net Income (net cash income - depreciation)	\$170	\$52	\$61
Honey Yield (pounds per colony)	110	60	60
Net Income per Pound of Honey	\$1.54	\$0.86	\$1.01

Return to Equity Capital	Small Apiary	Medium Apiary	Large Apiary
Net Income	\$170	\$52	\$61
- Operator & Unpaid Family Labor	\$226	\$47	\$38
Return to Equity Capital	\$(56)	\$5	\$23
Operating Profit Margin [(net income - operator & unpaid family labor) / gross revenue]	-16%	3%	14%

Table 11. Comparison of annual apiary budgets for non-migratory bee yards in New York State. Costs and revenues reported on a per-colony basis.

The small apiary showed a net income (after depreciation) of \$1699, which translates to profits of \$170 per colony and \$1.54 per pound of honey. The medium apiary had a net income of \$1556, with a profit of \$52 per colony and \$0.86 per pound of honey. The large apiary showed a net income of \$3642, with a profit of \$61 per colony and \$1.01 per pound. Thus, while the large apiary had the highest total net income, the small apiary had higher profit per colony and per pound.

The small apiary appears to be profitable before we account for labor. Yet when we subtract the value of operator and unpaid family labor, its financial performance is less impressive. The value of operator and unpaid family labor for the small apiary was higher than the net income, resulting in a negative return to equity capital of -\$565 per apiary or -\$56 per colony (Table 11). In other words, the small apiary's profit was not sufficient to cover the economic value of operator labor.

In contrast, the two larger apiaries both produced positive returns after accounting for the true value of operator and unpaid family labor. The medium and large apiaries recorded returns to equity capital of \$158 and \$1365 per apiary, respectively, or \$5 and \$23 per colony. A positive return to equity capital is important for the long-term viability of any business, especially if operators rely on the business as a primary source of income.

The operating profit margin also accounts for the value of operator and unpaid family labor. The small apiary recorded an operating profit margin of -16%, indicating an economic loss of \$0.16 for every dollar of gross revenue it generates. The small apiary operator can make up for this loss by subsidizing the business enterprise with their own unpaid labor. While this may be appropriate for a hobby, this level of economic performance is not sustainable over time for a business. The medium apiary recorded a relatively weak operating profit margin of 3%, indicating that every dollar of gross revenue generates a true economic return of \$0.03. The large apiary recorded a stable operating profit margin of 14%, reflecting an economic return of \$0.14 per dollar of gross revenue.

The sensitivity analysis shows the minimum honey yield necessary to achieve an operating profit margin of 0%, 10% and 25% for each apiary size (Table 12). The small apiary required the highest honey yield to break even, with 129 pounds per colony needed to achieve a positive operating profit margin. Without changing any other assumptions in the model, the honey yields that the small apiary would have to produce in order to achieve a stable or strong operating profit margin are unrealistically high.

Operating Profit Margin	Small Apiary	Medium Apiary	Large Apiary
0%	129	58	51
10%	144	65	57
25%	175	79	70

Table 12. Honey yield sensitivity analysis. This table presents the minimum honey yield in pounds per colony required to achieve an operating profit margin of 0%, 10% and 25% for each apiary size, holding all else constant

The large apiary had the lowest breakeven honey yield, with 51 pounds per colony required for a positive operating profit margin, compared to 58 pounds per colony for the medium apiary. To achieve a stable operating profit margin above 10%, the large apiary needs to produce just 57 pounds per colony, while the medium apiary requires a honey yield of 65 pounds per colony. A honey yield per colony of 70 pounds for the large apiary and 79 pounds for the medium apiary will result in a strong operating profit margin in excess of 25%.

APIARY ECONOMIC VIABILITY

Our economic analysis demonstrates plausible production costs and returns for small, medium and large non-migratory apiaries. The economic model relies on management, yield, and price assumptions drawn from interviews with five beekeepers. While the sample size is small, the data quality is high, ensuring that the model reflects current economic realities facing beekeepers. Survey respondents did not report any expected management differences for apiaries on solar sites, so we interpret the results as being broadly applicable to beekeeping in Central and Western New York, including on solar sites.

Results from the beekeeper survey and the economic analysis suggest that medium and large apiaries can be economically viable at a honey yield of 60 pounds per colony per year. However, the economic returns reported in this study reflect individual apiary budgets, not overall farm enterprise budgets. In addition to apiary management costs, beekeeping operations incur farm overhead costs that must be covered by apiary profits. These fixed costs may include insurance, office and administrative costs, and costs associated with the home facility (utilities, repairs, property taxes, and depreciation of vehicles, equipment, and buildings). Overhead costs can vary greatly across operations, and our survey did not attempt to capture overhead expenses. Thus, net income and return to equity capital, our two indicators of profit, must be interpreted conservatively as apiary profits rather than whole farm profits.

Differences across the three apiary budgets reflect key differences in management practices, honey yields, and prices. Economic outcomes for the small apiary reflect higher levels of operator labor, management, and

investment per colony, as well as a higher honey yield and price. Compared to the two larger apiaries, the small apiary has the highest net income per colony, yet it is the only apiary with a negative return to equity capital. Thus, the small apiary appears profitable only if we do not account for the value of operator and unpaid family labor.

For the medium and large apiaries, we assumed similar management practices and identical honey yields and prices. Thus, the differences in profit per colony and per pound between the medium and large apiaries primarily reflect differences in scale. The large apiary achieves greater efficiencies by spreading fixed costs over a greater number of productive units.

However, due to its size, we would expect the large apiary to face greater production risk. Its higher colony density means that the large apiary could require roughly twice as much nectar and pollen to produce the same honey yield as the medium apiary. This nutritional requirement may be met at a highly productive site or in highly productive years, but not all locations in New York have the landscape composition to consistently support a productive apiary of this scale. Furthermore, bees in the large apiary may have to travel farther to collect food, potentially reducing colony productivity and increasing agrichemical exposure. In addition, risks associated with disease transmission may be higher in larger apiaries, with negative implications for productivity and colony survival (Dynes et al., 2019). We may be overly optimistic to assume that the large apiary would have the same honey yield and colony loss rate as the medium apiary.

Profit margins were modest and sensitive to changes in honey yields. Given our starting assumptions, the small apiary had a negative operating profit margin. To achieve a positive margin, the small apiary would need to produce 129 pounds of honey per colony, more than double the honey yield modeled for the two larger apiaries. Even with exceptional management and abundant nectar and pollen resources, it would be extremely difficult to achieve a honey yield of 129 pounds per colony with consistency.

The large apiary had a stable operating profit margin of 14% and a breakeven honey yield of 51 pounds per colony. The average New York State honey yield dipped below 51 pounds per colony in two out of the past ten years. In contrast, the medium apiary had a relatively weak operating profit margin of 3%. Its breakeven honey yield of 58 pounds per colony is higher than the New York State 10-year average honey yield of 54.7 pounds per colony. In fact, the average New York honey dropped below 58 pounds per colony in eight of the last ten years.

Although the large apiary may face greater production risk, the medium apiary appears to be more financially vulnerable to variation in honey yields. Yields at individual apiaries are more variable than statewide averages, and a drop in yield at one apiary could wipe out profits from that location for the year. Our economic model illustrates the tight profit margins and high sensitivity to variable honey yields that influence beekeeper management decisions. These results suggest that beekeepers should be attuned to landscape composition and other external factors that influence honey yields, including vegetation quality, nectar availability, and agrichemical exposure, when considering a new apiary site.

V. RECOMMENDATIONS

BEEKEEPER RECRUITMENT

Beekeepers are accustomed to working with landowners to set up apiaries on private land. Relationships between beekeepers and landowners are critical for the long-term viability of any apiary location. Beekeepers take great pride in maintaining landowner relationships over many years, and, in some cases, over multiple generations. Accordingly, the success of a solar beekeeping venture will depend on a solid, mutually beneficial relationship between the beekeeper and the solar project. The following recommendations support best practices to establish a positive working relationship between a commercial beekeeper and a solar site.

Establish Clear Goals and Monitoring Procedures

Solar developers and community stakeholders should define clear objectives for any pollinator program. It is critical to establish the relative value of various pollinator goals to the solar project, which may include conserving

wild pollinators, achieving a pollinator-friendly certification, hosting a commercial beekeeper, maximizing honey yields, or providing pollination services to nearby farms. Some solar projects may wish to incorporate pollinator education, honey marketing, or other related objectives.

Strategies to support pollinators may differ depending on the project's objectives. While some goals may be mutually supportive, others may conflict. For instance, hosting a large commercial apiary may produce greater economic benefits for the beekeeper and for some pollinator-dependent crops, but could detract from wild pollinator conservation efforts (Alaux, Le Conte and Decourtye, 2019). On the other hand, emphasizing native plantings for pollinator conservation may not produce the highest possible honey yields. Developers seeking to achieve pollinator benefits should be aware of potential trade-offs between wild and managed pollinators, and work with community partners to identify clear priorities.

Solar projects must also establish robust mechanisms for monitoring progress toward achieving pollinator goals to ensure success over time (Dolezal, Torres and O’Neal, 2021).

Take Time to Find the Right Fit

Beekeeping management practices vary, and some management choices may be a better fit for a particular solar site. Solar developers should become familiar with different types of beekeeping operations and determine which management strategies would best match the project’s goals. For instance, if on-site honey production is a top priority, the solar project may prefer a beekeeper willing to establish a year-round apiary that will produce honey throughout the spring, summer, and fall, and then overwinter on the site. Alternatively, if working with a large commercial beekeeper is the top priority, the project may need to accommodate a migratory beekeeper who moves colonies frequently to provide commercial pollination services and capture nectar flows in different locations.

Communicating project objectives and expectations through outreach to individual beekeepers and local beekeeping organizations may help to identify beekeepers with compatible goals. Most beekeepers will not travel more than an hour to establish a new apiary site, so outreach efforts should target beekeepers within about an hour drive of the solar project. Outreach activities should provide information about the project layout, construction timeline, vegetation management plan, and surrounding landscape composition, if available. Address beekeeper concerns about forage availability by providing tours of the solar site and the surrounding landscape during spring and fall when major honey plants are blooming.

Seek Opportunities to Mitigate Production Risk

Beekeepers constantly face production risk, which refers to the possibility that honey yields will be of lower volume or quality than expected. Production risk emerges from some factors within a beekeeper’s control (e.g. colony health inspections and treatments) and many factors outside a beekeeper’s control (e.g. weather, forage availability). Beekeepers have strategies to mitigate some risk factors, including disease transmission and agrichemical exposure, even if they cannot eliminate them. One of the most important management decisions that influences production risk is apiary site selection. The following section (page 82) provides detailed recommendations for apiary site selection and design to reduce production risk while meeting the logistical needs of beekeepers and their colonies.

When honey yields are unknown, one strategy to mitigate production risk is to start small. Establishing a large apiary in an area with uncertain honey yield potential risks low productivity due to resource competition between colonies. Most beekeepers take two or three years to assess the productivity of a new apiary site to avoid

overstocking. Consider inviting a beekeeper to test a solar site by establishing one or more apiaries of 10 to 20 colonies for a period of one to three years, even if the long-term goal is to support more colonies. If honey yields are too low or another production problem arises, the cost to the beekeeper will be much lower if the problem affects 10 colonies rather than 60. Once the beekeeper is confident they understand the productivity potential of the new site, they can add additional colonies as warranted, as long as the solar project has allocated space for a larger apiary.

Another strategy to mitigate production risk is to provide financial incentives to offset low honey yields. This approach recognizes the value that beekeepers provide to a property owner by managing bees on their land. Beekeepers who provide commercial pollination services are familiar with this model. Moving colonies into fruit and nut orchards or vegetable fields generally reduces honey production and exposes bees to additional stressors. However, beekeepers receive a payment from the crop grower that compensates them for the costs of moving bees into pollination and any losses in productivity. Solar developers might consider offering beekeepers a payment to support apiary establishment, particularly if honey yields are unknown or beekeeper interest is lacking. This payment would recognize the value the beekeeper provides to the solar project and compensate them for sacrificing potential honey yields. However, if a beekeeper determines that a solar site does not have the forage availability to meet the nutritional needs of honey bees throughout the beekeeping season, then the project might consider emphasizing wild pollinator conservation goals rather than honey production.

Clarify Expectations in Writing

Most beekeepers rely on handshake agreements with landowners and are unfamiliar with written apiary lease agreements. However, our survey respondents were willing to enter into a written contract in order to secure an apiary location on a solar farm. Consider using the Solar Beekeeping Agreement Template developed by the Food and Beverage Law Clinic at Pace University under the guidance and direction of the American Solar Grazing Association as a starting point for a comprehensive lease agreement (Sioufas and Lita, 2021). The agreement should set clear expectations for a mutually beneficial relationship and protect the interests of both parties. A representative of the solar project should explain the lease terms, allow time for questions and discussion, and address any beekeeper concerns. Beekeepers should ensure that any expectations outlined in the contract are reasonable and achievable. Beekeepers may wish to have an attorney or other advisor review the contract to help identify and resolve potential issues before signing.

APIARY SITE SELECTION AND DESIGN

Consider Physical Site Characteristics

An ideal apiary site will maximize sun exposure and avoid excessive shading. The site should be dry all year, with good air and water drainage to avoid the buildup of moisture and cold air. A grassy surface under the hives is ideal for moderating heat in the summer. Avoid placing colonies on dark surfaces, such as gravel or asphalt. Beekeepers prefer a site that is flat or gently sloping to the south or east. A tree line or hedgerow to the north or west may be useful as a windbreak, depending on prevailing winds. Honey bees require a nearby water source for drinking and moderating temperatures within the hive. If the solar project intends to establish multiple apiaries, they should be located 2 to 4 miles apart. Apiary spacing depends on the number of colonies per apiary and landscape composition, with more space recommended between larger apiaries and in areas with lower forage availability.

Ensure Adequate Access

Easy and reliable vehicle access is a top priority for beekeepers, who must be able to reach their colonies as needed, year round. A gravel road or driveway is ideal. The access route should be dry and well drained to avoid damage or stuck vehicles during periods of heavy precipitation. The access route and the apiary site itself should allow sufficient space for vehicles and equipment to move freely around the bees. Depending on the scale of the beekeeping operation, equipment may include a standard or flatbed pickup truck, trailer, and skid steer. Beekeepers prefer unrestricted access to their apiary locations. Solar sites should provide a key or security code to the site so beekeepers do not have to coordinate their visits with project staff or rely on other people to let them in.

Allow Plenty of Space

An apiary requires adequate space not only for the hives, but also for the workers, vehicles, and mowing equipment. Spacing pallets or hive stands too close together could hinder beekeepers and make vegetation control more difficult. Leaving space around the perimeter of the hives allows for convenient vehicle access and mowing.

The spatial pattern of hives in an apiary depends on the size and shape of the available land. Beekeepers often arrange large apiaries in a horseshoe shape for maximum efficiency. The beekeeper can park a vehicle in the center of the horseshoe and move equipment easily between the vehicle and the hives. A large apiary with 60 colonies on 15 pallets arranged in a horseshoe pattern could take up an area of 4600 square feet or more. A medium apiary of 30 colonies might consist of two rows of pallets with space to drive between them, requiring around 2300 square feet. A small apiary with 10 colonies could be laid out in a single row or in a grid pattern, and might take up 1600 square feet.

Prioritize Safety and Security for People and Bees

Apiary site selection and design should consider features that protect bees from people, predators, and pesticides. Privacy can provide security for honey bee colonies, so beekeepers prefer to keep apiaries out of public view. Bee yards may be sited away from public roads or with a visual block separating the apiary from nearby roads and residences. For predator protection, surrounding apiaries with electrified fencing is recommended in areas with permanent or seasonal bear populations. However, privacy and electrified fencing may be less important for apiaries located within a solar project's perimeter fence.

When selecting apiary locations, special care should be taken to reduce the risk of direct agrichemical exposure from pesticide spraying and drift. Apiaries should not be sited in close proximity to agricultural fields or orchards managed with conventional pesticides. Beekeepers are particularly concerned about chemical exposure in corn, soybean, and vegetable fields and fruit orchards. Look for apiary locations that provide a natural buffer between hives and farm fields, such as forested land or a dense hedgerow. If no natural buffer is available, allow more space or consider planting a vegetated buffer strip.

Beekeepers with apiaries in close proximity to crop fields have limited options to reduce pesticide risk during intensive pesticide applications. One practice to avoid acute pesticide poisoning involves relocating colonies for a period of 48 to 72 hours to a holding yard at least four miles away from crops being treated with chemicals that are highly toxic to bees (Hooven et al., 2013). If moving bees is not possible, beekeepers may wrap colonies with wet burlap the night before a nearby crop is treated with a hazardous insecticide, keeping the covers in place as long as feasible. Both of these management strategies are laborious and depend on advance knowledge of when growers plan to apply insecticides. Selecting apiary sites that are protected from crop fields by distance or adequate buffers is the best way to reduce the risk of acute pesticide poisoning events.

Neonicotinoids are a specific class of chemical insecticides that can be highly toxic to bees and extremely persistent in the environment (see sidebar). Locating apiaries on land that was previously treated with neonicotinoids poses health risks to bees. If a solar development is installed on land previously used to grow treated corn or soybeans, the soils and new vegetation on that property may be contaminated with neonicotinoids. The Bee Better Certified program advises waiting at least two years before establishing pollinator habitat on sites previously treated with neonicotinoid insecticides, and it would be wise to apply that same recommendation to the establishment of honey bee apiaries. Solar developers may also consider testing soils for neonicotinoid residues as part of the apiary site selection process.

Understanding Neonicotinoids

Neonicotinoid insecticides are widely used in agricultural and urban settings. Released in the mid-1990s as an alternative to older organophosphate and carbamate insecticides, neonicotinoid insecticides are highly toxic to many invertebrates, including bees. They are systemic, meaning they are absorbed and retained in plant tissues, making all parts of the plant toxic to insects. Even very small concentrations of these insecticides found in the pollen and nectar of treated plants can be harmful to pollinators (for a review of recent research, see the Xerces Society report, *How Neonicotinoids Can Kill Bees*).

What's more, most neonicotinoids are highly persistent, sometimes remaining at harmful levels in woody plants and soil for months to years after they were applied (Jones et al., 2014). Untreated plants sown in areas formerly treated with neonicotinoids, such as cover crops that follow a rotation of treated corn or soybeans, can pick up residues from these prior applications (Bonmatin et al., 2005). In addition, neonicotinoids applied to crops can contaminate plants in surrounding areas, which poses risk to the bees that visit these plants for pollen and nectar (Botías et al., 2015; Mogren and Lundgren, 2016).

Source: Bee Better Certified
<https://beebettercertified.org/unpacking-standards-neonicotinoids>

Honey bees can be a nuisance when their natural behaviors interfere with human activities. To protect people, beekeepers prefer to locate apiaries a minimum of 100 yards from areas with regular human activity. Placing apiaries at least 100 yards away from solar panels and other solar equipment will protect maintenance technicians and minimize honey bee defecation on solar panels and other equipment. It is advisable to keep an even greater distance between bee yards and swimming pools or other swimming areas that would attract bees seeking water. Within the apiary, arrange hives so that the path of bees entering and leaving their hives does not intersect with human traffic.

MANAGE VEGETATION FOR HONEY PRODUCTION

Invest in Ongoing Vegetation Management

Beekeepers look for abundant floral resources surrounding apiary sites to sustain bees and achieve desired honey yields. While there are many flowering plants that bees visit to collect nectar and pollen, the number of plants that

provide an abundance of nectar to support surplus honey production is small. Vegetation mixes intended to support wild pollinators can provide important nutrients for honey bees throughout the growing season, but may not stimulate abundant honey production.

Solar developments that intend to host beekeepers should consider honey production when designing plantings for the site. Some important New York honey plants, such as white clover and alsike clover, are appropriate to grow under solar panels. Perennial plant species such as these will have greater utility in a solar setting, as they should persist over time better than annual plants such as buckwheat and crimson clover. Other valuable honey plants, including sweet clover, goldenrod, and asters, may be too tall for planting among the panels. Select shorter varieties of these plants or increase panel heights to avoid shading panels when flowers are blooming. Alternatively, consider using these species in perimeter and buffer areas. Honey producing trees including black locust, basswood, and sumac may also be appropriate for some buffer plantings. Willow and maple trees may also be included as early season pollen sources.

The Xerces Society for Invertebrate Conservation's Bee Better Certified program provides recommendations for protecting pollinators from neonicotinoid exposure when establishing pollinator plantings (May, n.d.). Solar developers should avoid establishing pollinator habitat on land that was treated with neonicotinoids in the previous two years. A pesticide-free buffer is necessary not only around apiaries but also around permanent pollinator habitat. Spatial buffers should be at least 40 feet wide to protect plantings from ground-based pesticide applications, and at least 60 feet wide for airblast applications.

Two articles published since 2018 recommend additional best practices for establishing flowering vegetation that will promote pollinator conservation and honey production on solar sites. Walston et al. (2018) suggest that "project developers should consult with regional biologists to identify the appropriate vegetation suitable for the local insect pollinator community that can be feasibly grown among the [utility scale solar energy] infrastructure." Dolzeal, Torres and O'Neal (2021) stress the importance of ongoing vegetation management and third-party monitoring to ensure that pollinator plantings are fully established and that they persist over time. Establishing vegetative plantings to support pollinators while meeting other solar facility design criteria requires a nuanced understanding of botany and ecology. Solar developers should seek input from outside experts to ensure that resources devoted to the design, establishment, and management of pollinator plantings are deployed effectively to achieve desired results.

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LAND COVER WITHIN 1600 METERS

Land Cover Class	Site 1		Site 2		Site 3		Combined	
	Hectares	%	Hectares	%	Hectares	%	Hectares	%
Corn	83.20	10.3%	202.51	25.2%	226.92	28.2%	512.63	21.3%
Soybeans	138.34	17.2%	80.19	10.0%	45.85	5.7%	264.38	11.0%
Small Grains	16.01	2.0%	28.65	3.6%	6.66	0.8%	51.32	2.1%
Row Crops Subtotal	237.55	29.5%	311.35	38.8%	279.43	34.7%	828.33	34.3%
Alfalfa Hay	78.71	9.8%	59.61	7.4%	74.61	9.3%	212.93	8.8%
Grass Hay	46.50	5.8%	32.24	4.0%	20.28	2.5%	99.02	4.1%
Hay Crops Subtotal	125.21	15.6%	91.85	11.4%	94.89	11.8%	311.95	12.9%
Fruits & Vegetables	0.27	0.0%	0.38	0.0%	0.87	0.1%	1.52	0.1%
Christmas Trees	0.27	0.0%	0.25	0.0%	0.09	0.0%	0.61	0.0%
All Crops Subtotal	363.30	45.2%	403.83	50.3%	375.28	46.6%	1142.41	47.4%
Grassland/Pasture	76.01	9.5%	22.63	2.8%	45.60	5.7%	144.24	6.0%
Fallow Cropland	12.41	1.5%	19.78	2.5%	14.93	1.9%	47.12	2.0%
Shrubland	1.26	0.2%	1.54	0.2%	0.58	0.1%	3.38	0.1%
Clover/Wildflowers	0.72	0.1%	1.36	0.2%	0.83	0.1%	2.91	0.1%
Grassland Subtotal	90.40	11.2%	45.31	5.6%	61.94	7.7%	197.65	8.2%
Forest	258.06	32.1%	294.90	36.7%	325.80	40.5%	878.76	36.4%
Wetlands	10.34	1.3%	15.33	1.9%	13.98	1.7%	39.65	1.6%
Developed	81.94	10.2%	43.80	5.5%	27.65	3.4%	153.39	6.4%
TOTAL	804.04	100.0%	803.17	100.0%	804.65	100.0%	2411.86	100.0%

Table 5. Land Cover within 1600 Meters of Proposed Apiary Locations (percentages rounded to nearest whole number).

SMALL APIARY BUDGET

Income	Number	Units	\$ Per Unit	Total
Honey	1100	lbs	\$3.00	\$3300
Wax (assume 2% of honey yield)	22	lbs	\$8.00	\$176
Gross Revenue				\$3,476
Establishment Cost <i>(One-Time Investment)</i>	Number	Units	\$ Per Unit	Total
Hive equipment	10	colony	\$400.00	\$4000
Pallets/hive stand	5	each	\$60.00	\$300
Bees	10	colony	\$50.00	\$500
Electric fencing & charger	1	apiary	\$500.00	\$500
Insurance	1	apiary	\$50.00	\$50
Other (site work, delivery)	1	apiary	\$70.00	\$70
Total Apiary Establishment Cost				\$5,420
Operating Expense <i>(Variable Costs)</i>	Number	Units	\$ Per Unit	Total
Feed	10	colony		
Purchased queens	1	colony	\$25.00	\$25
Replacement colonies	2	colony	\$50.00	\$100
Varroa control & treatment	10	colony	\$21.20	\$212
Other colony health treatment	10	colony		
Frames and foundation	10	frames	\$4.80	\$48
Smoker fuel, paint, consumable supplies	1	apiary	\$50.00	\$50
Apiary rent	1	apiary	\$40.00	\$40
Vehicle expense	1050	miles	\$0.56	\$588
Honey extraction	1100	lbs	\$0.156	\$172
Total Operating Expenses				\$1,235
Net Income (return to operator labor, management and equity capital)				
Net Cash Income (gross revenue - operating expense)				\$2241
- Depreciation				\$542
Net Income (net cash income - depreciation)				\$1699
Net Income per Colony				\$169.94
Net Income per Pound of Honey				\$1.54
Return to Equity Capital				
Net Income				\$1699
- Operator & Unpaid Family Labor				\$2264
Return to Equity Capital				\$(565)

Table 8. Annual budget for small apiary with 10 colonies.

MEDIUM APIARY BUDGET

Income	Number	Units	\$ Per Unit	Total
Honey	1800	lbs	\$2.50	\$4500
Wax (assume 2% of honey yield)	36	lbs	\$8.00	\$288
Gross Revenue				\$4,788
Establishment Cost <i>(One-Time Investment)</i>	Number	Units	\$ Per Unit	Total
Hive equipment	30	colony	\$350.00	\$10,500
Pallets/hive stand	10	each	\$-	\$-
Bees	30	colony	\$50.00	\$1500
Electric fencing & charger	1	apiary	\$400.00	\$400
Insurance	1	apiary	\$50.00	\$50
Other (site work, delivery)	1	apiary	\$100.00	\$100
Total Apiary Establishment Cost				\$12,550
Operating Expense <i>(Variable Costs)</i>	Number	Units	\$ Per Unit	Total
Feed	30	colony		
Purchased queens	9	colony	\$25.00	\$225
Replacement colonies	12	colony	\$50.00	\$600
Varroa control & treatment	30	colony	\$7.50	\$225
Other colony health treatment	30	colony		
Frames and foundation	30	colony	\$4.35	\$131
Smoker fuel, paint, consumable supplies	1	apiary	\$60.00	\$60
Apiary rent	1	apiary	\$120.00	\$120
Vehicle expense	600	miles	\$0.56	\$336
Honey extraction	1800	lbs	\$0.156	\$281
Total Operating Expenses				\$1,977
Net Income (return to operator labor, management and equity capital)				
Net Cash Income (gross revenue - operating expense)				\$2811
- Depreciation				\$1255
Net Income (net cash income - depreciation)				\$1556
Net Income per Colony				\$51.86
Net Income per Pound of Honey				\$0.86
Return to Equity Capital				
Net Income				\$1556
- Operator & Unpaid Family Labor				\$1397
Return to Equity Capital				\$158

Table 9. Annual budget for medium apiary with 30 colonies.

LARGE APIARY BUDGET

Income	Number	Units	\$ Per Unit	Total
Honey	3600	lbs	\$2.50	\$9000
Wax (assume 2% of honey yield)	72	lbs	\$8.00	\$576
Gross Revenue				\$9,576
Establishment Cost <i>(One-Time Investment)</i>	Number	Units	\$ Per Unit	Total
Hive equipment	60	colony	\$350.00	\$21,000
Pallets/hive stand	15	each		
Bees	60	colony	\$50.00	\$3000
Electric fencing & charger	1	apiary	\$400.00	\$400
Insurance	1	apiary	\$50.00	\$50
Other (site work, delivery)	1	apiary	\$100.00	\$100
Total Apiary Establishment Cost				\$24,550
Operating Expense <i>(Variable Costs)</i>	Number	Units	\$ Per Unit	Total
Feed	60	colony		
Purchased queens	18	colony	\$25.00	\$450
Replacement colonies	24	colony	\$50.00	\$1,200
Varroa control & treatment	60	colony	\$7.50	\$450
Other colony health treatment	60	colony		
Frames and foundation	60	colony	\$4.35	\$261
Smoker fuel, paint, consumable supplies	1	apiary	\$100.00	\$100
Apiary rent	1	apiary	\$120.00	\$120
Vehicle expense	600	miles	\$0.56	\$336
Honey extraction	3600	lbs	\$0.156	\$562
Total Operating Expenses				\$3,479
Net Income (return to operator labor, management and equity capital)				
Net Cash Income (gross revenue - operating expense)				\$6097
- Depreciation				\$2455
Net Income (net cash income - depreciation)				\$3642
Net Income per Colony				\$60.71
Net Income per Pound of Honey				\$1.01
Return to Equity Capital				
Net Income				\$3642
- Operator & Unpaid Family Labor				\$2277
Return to Equity Capital				\$1365

Table 10. Annual budget for large apiary with 60 colonies.

Mount Morris Agrivoltaic Study

Beekeeper Survey

Overview

My name is Mary Kate MacKenzie and I am an independent consultant working on the Mount Morris Agrivoltaic Study, a research project commissioned by the Town of Mount Morris.

The Town of Mount Morris is working with EDF Renewables to plan and implement a solar photovoltaic facility called the Morris Ridge Solar Energy Center. The facility will consist of hundreds of thousands of solar panels sited on approximately 1,000 acres of leased private land. One goal of the project is to encourage co-location of agricultural enterprises within the solar development.

This beekeeper survey is part of a broader study designed to evaluate opportunities for integrating farming activities within the Morris Ridge Solar Energy Center. I will be interviewing a small sample of commercial beekeepers in New York State to understand characteristics of their operations, costs to establish a new apiary location, and interest in beekeeping on solar sites. Obtaining feedback from beekeepers is vital to ensure the project team considers beekeeper needs during the planning process.

This interview will take approximately 45 minutes to complete. Upon completing the beekeeper survey, you will receive a \$100 gift card to a beekeeping supplier of your choice.

Participation is voluntary and confidential. You may choose to skip any questions that you do not wish to answer. Responses will not be identified by individual. All responses will be aggregated and analyzed as a group.

Results from this study will be shared in reports that will be available to the project team and to the public. We anticipate that our results will help the project team support solar beekeeping at the Morris Ridge Solar Energy Center, and may inform similar arrangements at other solar developments across the country.

Upon completion of this study, we will be happy to send you a copy of the report documenting our findings.

Mount Morris Agrivoltaic Study Beekeeper Survey

Beekeeper & Operation Characteristics

1	Farm/Business Name:
2	Operator Name:
3	Address:
4	Phone number:
5	Email:
6	Operator years of beekeeping experience:
7	Total number of workers in bee yards in 2020, including operator(s):
8	In which NY counties do you keep bees:
9	In which states do you keep bees:
10	Total number of colonies on April 1, 2020:
11	Total number of colonies on April 1, 2020 that spent time in NY in summer2020:
12	Total number of apiaries in NY in 2020 (excluding commercial pollination sites):
13	Number of colonies from which you harvested honey in 2020:
14	Number of colonies used in commercial pollination in 2020:
15	Number of colonies used to produce queens/nucs/packages for sale in 2020:
16	Total number of colonies on October 1, 2020:
17	Number of colonies on October 1, 2020 that you overwintered in NY state from 2020 - 2021:
18	Total number of colonies on April 1, 2021:
19	Number of colonies died from October 1, 2020 - March 31, 2021:
20	Primary cause of winter colony loss:

Mount Morris Agrivoltaic Study
Beekeeper Survey

Operation Yields

21	Total honey production in 2020 (lbs):
22	How do you market honey? <ul style="list-style-type: none"> • Wholesale • Retail (direct to consumer) • Other:
23	Total honey sold wholesale in 2020 (lbs):
24	Primary buyers/market channels for wholesale honey:
25	Average price per pound received for wholesale honey in 2020:
26	Total honey sold retail in 2020 (lbs):
27	Primary market channels for retail honey sales:
28	Average price per pound received for retail honey in 2020:
29	Total wax production in 2020 (lbs):
30	Total wax used in the business in 2020 (lbs):
31	How do you market wax? <ul style="list-style-type: none"> • Wholesale • Retail (direct to consumer) • Other:
32	Total wax sold wholesale in 2020 (lbs)
33	Primary buyers/market channels for wholesale wax:
34	Average price per pound received for wholesale wax:
35	Total wax sold retail in 2020 (lbs):
36	Primary buyers/market channels for retail wax:
37	Average price per pound received for retail wax:

Mount Morris Agrivoltaic Study Beekeeper Survey

Demand for New Apiary Locations

38	What is your ideal number of colonies per apiary site in NY:
39	How many of your apiaries currently have more than this ideal number of colonies:
40	What is the minimum distance you have between apiary locations (miles):
41	Where is your NY beekeeping headquarters located (address):
42	What is the farthest distance (miles) you currently travel to get to an apiary site in NY, excluding pollination sites:
43	How far would you be willing to travel to establish a new apiary site in NY (miles):
44	Do you intend to grow your beekeeping operation in the next 3 years:
45	How many total colonies do you expect to have three years from now (April 1, 2024):
46	How many new colonies will you keep in NY three years from now (April 1, 2024):
47	How many new apiary sites in NY will you need to accommodate this growth:
48	How many of your current apiary locations are on land that you own:
49	How many of your current apiary locations are on land owned by someone else:
50	For how many of your apiary locations do you have a written rental/lease agreement:
51	How do you compensate landowners for rented apiary locations: <ul style="list-style-type: none"> • Cash • Trade • Other:
52	What is your average rental rate for rented apiary locations:
53	Which of the following characteristics do you consider important when selecting an apiary location (1 = not at all important; 2 = low importance; 3 = neutral; 4 = important; 5 = very important) <ul style="list-style-type: none"> • Vehicle access • Forage availability • Forage diversity • Water availability • Southern exposure • Flat slope • Presence of shade <ul style="list-style-type: none"> • Protection from wind • Protection from noise • Protection from agrichemical exposure • Privacy/protection from human interference • Other(s):

Mount Morris Agrivoltaic Study Beekeeper Survey

Apiary Establishment & Operating Costs

Imagine you are setting up a new apiary this year in NY with ___ colonies (use ideal # from previous page). Estimate your one-time costs to establish the apiary and your annual expenses to operate it.

Apiary Establishment Costs

	Cost Category	Cost per Unit	# Units	Total Cost
54	Hive equipment			
55	Hive stands			
56	Bees (expansion colonies)			
57	Electric fencing & charger			
58	Other:			

Annual Operating Costs

	Cost Category	Cost per Unit	# Units	Total Cost
59	Feed (syrup, sugar water, honey, pollen, etc.)			
60	Varroa control & treatment			
61	Costs to manage other colony health issues			
62	Purchased queens			
63	Purchased bees (replacement colonies)			
64	Frames & foundation			
65	Smoker fuel, paint, other consumable supplies			
66	Apiary rental expense			
67	Increase to farm insurance expense			
68	Vehicle expense	Federal rate:	Miles:	Total cost:
69	Beekeeping labor, excluding travel	Hourly rate:	Labor hours:	Total cost:
70	Labor cost associated with travel to and from the site	Hourly rate:	Labor hours:	Total cost:

Solar Beekeeping

Mount Morris Agrivoltaic Study Beekeeper Survey

As described above, the Morris Ridge Solar Energy Center is a proposed solar photovoltaic facility that will be sited on approximately 1,000 acres of leased private land in the Town of Mount Morris, Livingston County.

71	Would you be interested in establishing an apiary location at the Morris Ridge Solar Energy Center in the Town of Mount Morris?
72	If no, why not?
73	If no, would you be interested if the Project was able to pay a pollination service fee?
74	What rate (\$/colony) would you be willing to accept to set up and maintain an apiary at the Morris Ridge Solar Energy Center in the Town of Mount Morris?
75	If yes, what type of apiary would you be interested in establishing at this site? <ul style="list-style-type: none"> • Year round • Seasonal • Other/it depends:
76	What is the ideal number of colonies you would want to keep at this apiary location?
77	What is the minimum number of colonies you would need to keep at this apiary location to make it a worthwhile undertaking?
78	How frequently would you need to access the apiary in the summer season, between April 1 and September 30?
79	How frequently would you need to access the apiary in the winter season, between October 1 and March 31?
80 81	What type of infrastructure would you require/prefer at the apiary site? (1 = not necessary; 2 = preferred; 3 required) <ul style="list-style-type: none"> • Road access • Electricity • Running water • Equipment storage space <ul style="list-style-type: none"> • Permanent fencing • Pollinator-friendly plantings • Other:
82	Would you be willing to work with the Project to develop a written apiary lease agreement?
	What questions would you like answered about the Project and/or about solar beekeeping?
83	Would you be interested in marketing “solar honey” to your existing customers?
84	Would you be interested in marketing “solar honey” to EDF Renewables?
85	Are there any other business arrangements you would be interested to explore with the EDF Renewables and the Morris Ridge Solar Energy Center?
86	Thank you for your time! Can you recommend any other beekeepers who might be willing to participate in this study?



Photos courtesy of: Scott Land Yard Group

Future Market Opportunities for Solar-Raised Honey

Nicole Manapol, Lead Strategist
Letchworth Gateway Villages Municipal Consortium

I. Background	98
II. Summary of Findings	98
III. Methods	98
IV. Current Demand	99
V. Perspectives on Solar-raised Honey	100
VI. Key Insights	101
Appendix	102

List of Tables

Table 1: Honey cost data provided by survey respondents	100
Table 2: List of Businesses Interviewed & Profiles	102-103

I. BACKGROUND

As a part of the agrivoltaics study for the Town of Mount Morris, NY, and solar developer EDF Renewables, Letchworth Gateway Villages conducted interviews with 15 local food manufacturers, craft beverage producers, and retailers to assess the current market demand for solar-raised honey in the Genesee-Finger Lakes Region. Our main goal with these interviews was to provide a snapshot of the current demand for honey in the region, and to

evaluate whether there were future market opportunities for local apiarists producing solar-raised honey. Additionally, we wanted to understand current perceptions of solar-raised honey, whether honey marketed as “solar raised” mattered to consumers and businesses, and whether businesses saw this as an added value that could give their products a competitive market advantage.

II. SUMMARY OF FINDINGS

Due to COVID-19, many of the businesses interviewed had difficulty providing data for the last 18 months due to disruptions in supply chains, lockdowns, and capacity limitations. Therefore, most data provided in the following report is pre-2020. Overall, the most important considerations for wholesale honey buyers were price, consistency, quality of the product, and where the honey was produced. Taste and product diversity were also important factors for food manufacturers and retailers. Only two respondents indicated that solar-raised honey provided any sort of market differentiation advantage. Most respondents indicated that they did not know enough about solar-raised honey to say whether their customers would buy solar-raised over other types of locally raised or organic honey. Additionally, there were a lot of questions regarding whether solar-raised honey had a different flavor or added health benefits to non-solar-raised honey. All respondents said they would be interested in learning more about solar-raised honey as it develops in the region and would consider buying it if the price were comparable to the honey, they currently source locally/regionally.

In terms of future market opportunities for apiarists producing solar-raised honey, the most promising were the Taste NY Market retail locations across the state,

three of which cover the Genesee Valley region (Southern Tier Welcome Center, Western NY Welcome Center, and the Finger Lakes Welcome Center). As the official “eat-local, drink-local” program for New York State, Taste NY is designed to create new opportunities for producers through events, retail locations, and partnerships (<https://taste.ny.gov/>). Given New York State’s push for renewable energy and its strength as the top honey producer in the Northeast, promoting the story of solar-raised honey and educating consumers about the product, would be a natural fit for the Taste NY program and a unique product to market in the Taste NY visitor centers across New York State and online (<https://taste.ny.gov/>).

Other potential markets include food manufacturers in the region. Food manufacturing is a major part of the local agriculture industry in the Genesee-Finger Lakes Region and the Genesee Valley boasts several successful food companies with national and global market reach (Upstate Revitalization Plan, 2015). All food manufacturers interviewed indicated that they would be interested in finding a local source of honey that aligned with their sustainability goals, provided it could compete on price, quality, and consistent supply.

III. METHODS

Through a combination of phone interviews and email correspondence, respondents were asked to provide information about their business (e.g., customer base, main products, and geographic market reach), their current demand for honey, the cost of the honey they purchase, and retail margin on the honey sold. Additionally, businesses were asked whether, from a marketing standpoint, solar-raised honey would be more attractive to their customer base, and whether they had an interest in solar-raised honey in the future. See appendix for the full list of survey questions.

BUSINESSES INTERVIEWED

The businesses interviewed were selected to provide a representative sample of potential markets for future solar-raised honey produced in the region. These included retailers located at major tourist attractions in the Genesee Valley, like Letchworth State Park, which attracts nearly 1 million visitors per year, and the Taste NY Market retail locations located at major Thruway stops and visitor centers across New York State (NYS Parks, Recreation, and Historic Preservation). Interviews were also conducted with major food manufacturers in western New York and

craft beverage producers and specialty food retailers in the area's largest main street districts Geneseo (Livingston County) and Perry (Wyoming County).

SURVEY FINDINGS

Of the 20 businesses contacted, 15 responded. Businesses included three food manufacturers, three craft beverage producers, and nine specialty food retailers.

IV. CURRENT DEMAND

Of the 15 businesses surveyed, only three businesses indicated they did not currently use or sell honey. Two of these three businesses had previously sold honey but stopped during the pandemic, due to disrupted supply chains and capacity limitations. Both would like to go back to selling honey in the future, provided they can find a reliable source that meets their company's needs. Only one business surveyed (a craft brewery) indicated that they had never purchased honey to use in their products and did not plan to do so in the future.

RETAILERS

Of the nine retailers surveyed, only two indicated that honey sales were slower than other products and that they were considering discontinuing the sale of honey products in their stores. One major retailer indicated that they would like to sell honey in their retail locations at Letchworth State Park; however, they had not been able to find a local producer to supply them with the quantity they needed during the last 18 months of the pandemic.

Overall, retailers indicated that there is a strong market for locally produced honey, though demand can vary throughout the year, as can the availability of local honey. Five out of the nine retailers surveyed must reorder their supply once or twice each month. In the downstate area around New York City and nearby tourist destinations like the Catskills, retailers reported selling close to 200 bottles of honey per month, while in more rural areas in the Genesee Valley retailers sell that quantity over the course of a year.

Most retailers purchased honey by the case in 8–24 oz. retail bottles, with the average cost ranging anywhere from \$3–\$15/bottle or \$2–\$4/lb. for unbottled honey in a bucket (Table 1). The retail margin on honey reported by these businesses ranged from 33%–50%, with the

Apart from the six Taste NY Market retail locations, most businesses surveyed were in the Genesee Valley region of western New York (Table 2).

Businesses were asked to provide information on their current demand for honey, what drives their buying decisions, and what their perspectives were on solar-raised honey.

average being 42%. The main consideration for retailers when purchasing honey was where the honey was sourced. Customers want to buy honey from the local area. One retailer located in the New York City area stopped carrying honey produced in Upstate New York because customers did not consider Upstate honey “local,” and would only buy honey produced nearby in Long Island.

CRAFT BEVERAGE PRODUCERS

Two of the three craft beverage producers surveyed use honey in their craft beverage products. Of these two only one, a cidery, uses it on a regular basis. Both purchase their honey in five-gallon buckets for \$150/bucket and source their honey locally. Price, locally raised, and taste/flavor profile of the honey were the main considerations when buying and sourcing honey for the two craft beverage producers.

FOOD MANUFACTURERS

Two of the three local food manufacturers surveyed use honey in their food products. The one food manufacturer who is not currently using honey had a whole honey product line prior to the pandemic, but had to discontinue it given the difficulty in sourcing organic honey, all of which came from countries outside the U.S. The volume of honey used by each of these food manufacturers ranged from 65 lb. buckets procured four times per year at a rate of \$150/bucket (or \$2.30/lb.), to 650 lb. metal drums and 3000 lb. totes purchased monthly, at a rate of \$1.50–\$3.25/lb., depending on the kind of honey (e.g., regular, organic, or fair trade). Food manufacturing is a major part of the local agriculture industry in the Genesee-Finger Lakes Region, and as can be seen from this one example, a potentially significant market for solar-raised honey in the future.

V. PERSPECTIVES ON SOLAR-RAISED HONEY

Businesses were asked four questions related to solar-raised honey:

- From a marketing standpoint would solar-raised honey be more attractive to your customer base? (Why or why not?)
- Would you be able to charge a higher price for solar-raised honey over other types of local honey?
- From a business perspective would you be more inclined to buy solar-raised honey over other types of local honey? (Why or why not?)
- Would you be interested in learning more about solar-raised honey when it becomes available?

While most businesses surveyed were enthusiastic about the idea of solar-raised honey, few felt that honey marketed as “solar raised” would be more attractive to their customer base, without a significant amount of education and coaching for businesses on how to effectively market or communicate the value add to customers. From the business perspective, all respondents indicated that price would be the main determinant for them in choosing to buy solar-raised honey over other types of local honey. Solar-raised honey would have to compete on price with the local honey they currently use. For large-scale food manufacturers and higher volume retail locations, being able to source a consistent and quality product was another key factor in their decision-making process.

Overall respondents did not feel like they knew enough about solar-raised honey to say whether they or their customers would be more inclined to buy solar-raised honey over other local honey. Taste NY Market retailers, many of which are run by Cornell Cooperative Extension offices and people with deeper, technical knowledge

“ I would be intrigued by it [solar-raised honey]. I am not quite sure it would make me more inclined to buy it. I would have to have more information on the details and the pros and cons in comparison to traditional methods.

~ Taste NY Market Retailer

of locally sourced products, wanted to know about the nutritional/health attributes of solar-raised honey. *Is there actually something different about solar-raised honey from a nutritional standpoint? How does raising honey under solar arrays impact the taste or the integrity of the honey?*

For two out of the three food manufacturers they immediately saw the benefit of being able to market local honey as “solar raised.” They saw this as a competitive market differentiator for their products in a similar way as organic.

What mattered to businesses

- Cost
- Ease of procuring the product and consistent quality
- Where the honey was produced (hyper local was most important)
- Taste, flavor profile

Across the board, the top consideration for businesses when buying honey is cost, followed by the quality and consistency of the product, and where the honey was sourced. The cost of honey purchased depended on the variation, where it was sourced, and quantity. The table below summarizes the cost data provided by respondents.

Unit	Average cost per unit (pound, case, bucket, etc.)	Location Honey was Sourced
Case (8 oz.–16 oz.) 5 Gallon Bucket (60 lbs.)	\$8.00/unit \$150–\$250/bucket or \$3.89–\$4/lb.	Genesee Valley
Case (12 bottles) 5-Gallon Bucket (60 lbs.)	\$5.20/16 oz. bottle \$138/bucket or \$2.30 / lb.	Finger Lakes (Geneva and Watkins Glen)
Case (12 bottles)	\$12–\$15/16 oz. bottle	Hudson Valley
Case (12 bottles)	\$3.00/8 oz. bottle	Mohawk Valley
Case (8 oz.–24 oz. bottles)	\$9.04/ unit	Dutchess County
Case (12 bottles)	\$6.00/16 oz. bottle	North Country
Case (8 oz.–16 oz. bottles)	\$8.50/16 oz. bottle	Long Island
650 lb. metal drums and 3000 lb. totes	\$1.50–\$3.25/lb. depending on type: regular, organic, or fair trade	Multiple Locations (U.S. + International)

Table 1. Honey cost data provided by survey respondents.

VI. KEY INSIGHTS

PREPARING THE MARKET FOR SOLAR-RAISED HONEY

As can be seen from most responses from businesses, people do not yet know enough about solar-raised honey for it to impact their buying decisions. A significant amount of investment will need to go into creating demand for solar-raised honey both locally and across New York State through education and awareness-raising campaigns. Key partners in this work will be New York State Ag and Market's Taste NY program, a statewide food certification program to promote quality, locally grown products and to strengthen confidence in New York agriculture; research and technical assistance providers like Cornell Cooperative Extension offices which also manage many of the Taste NY Market locations, as well as the New York State Division of Tourism, which jointly oversee the state's major visitor centers. Building relationships now with these organizations and educating them on the potential of solar-raised honey in the state will help open future markets for apiarists, as well as help inform honey producers on the products consumers seek at these locations.

OPPORTUNITIES FOR APIARISTS

From the businesses surveyed the top markets for solar-raised honey include Taste NY Market retail locations across the state where solar is being implemented, Letchworth State Park concessions, and local food manufacturers. While highlighting solar-raised honey in local food and drink is an important part of creating visibility for the product, the low and inconsistent demand for honey among craft beverage producers does not represent a strong market opportunity at this time, when considering the amount of time and effort required on behalf of the apiarist to produce and supply such a variable amount of honey at various times.

Taste NY Market retail locations, in particular those covering the Genesee Valley region (Southern Tier Welcome Center, Western NY Welcome Center, and the Finger Lakes Welcome Center), are a strategic fit for both promoting the story of solar-raised honey and educating consumers on the state's renewable energy agenda. As the official "eat-local, drink-local" program for New York State, Taste NY is designed to create new opportunities for producers through events, retail locations, and partnerships (<https://taste.ny.gov/>).

Taste NY Market retail locations operate independently and are each responsible for sourcing their market's local products. As the potential for solar-raised honey develops alongside solar projects in the area, establishing relationships with the Taste NY Market locations in the area and Cornell Cooperative Extension offices will be key moving forward. Additionally there is the opportunity to market and sell products online through Taste NY's online platform: <https://shoptasteny.com>, which would extend the market reach of many local honey producers and support repeat buying amongst visitors to our region who want to continue buying the product when they return home.

Other potential markets include food manufacturers in the region. Food manufacturing is a major part of the local agriculture industry in the Genesee-Finger Lakes Region and the Genesee Valley boasts several successful food companies with national and global market reach. All food manufacturers interviewed indicated that they would be interested in finding a local source of honey that aligned with their sustainability goals, provided it could compete on price and quality. As global supply chains continue to be disrupted by the COVID-19 pandemic, building a significant source of honey locally for food manufacturers based in the region could be a major "win-win" for companies, honey producers, and the state's climate agenda—in particular, the reduction of carbon emissions.

In summary, this snapshot of the current local and New York State market for locally raised honey suggests that locally raised "solar" honey would perform equally well, if not better, if cost, consistency, and quality remain competitive with current options, at least in the short-term. As consumers and businesses become more educated about the benefits of solar-raised honey in meeting our climate goals it is possible that consumers and businesses would be willing to pay more for the product, especially if there are any real differences in the health benefits/nutritional value of solar-raised honey compared to other locally raised options. Likewise, the growth of food manufacturing in our region presents one of the more lucrative opportunities for honey producers able to produce the quantities of honey needed at a competitive price.



Yes, we are always looking for sustainable, ethically raised ingredients for our products. Solar-raised honey could be a good market differentiator, like organic. We would definitely be interested in learning more.

~ Local Food Manufacturer

INTERVIEW QUESTIONS FOR BUSINESSES

About the Business

- What kind of business?
- Products?
- Customers?
- Geographic location and market reach?

Do you currently buy/sell/use honey?

If so, how much do you typically buy?

- 55-gallon barrels
- 5-gallon buckets
- Retail bottled honey by the pallet/case

What is the cost of the current honey you purchase?

- What is your average cost per unit (lb., case, bucket, etc.)?
- What is your average sale price per unit?
- What is your retail margin on honey?

On average, how long does it take you to get through your supply?

Solar-raised Honey

- From a marketing standpoint, would solar-raised honey be more attractive to your customer base? (Why or why not?)
- Would you be able to charge a higher price for solar-raised honey over other types of local honey?
- From a business perspective would you be more inclined to buy solar-raised honey over other types of local honey? (Why or why not?)
- Would you be interested in learning more about solar-raised honey when it becomes available?

What questions do you have for us?

Business Name	Type of Business	Profile
Letchworth State Park Concessionaire	Retail/Gift Shop, Food and Beverage *Not currently selling honey but would like to	(7) Locations: Letchworth State Park (Wyoming + Livingston Counties) Employees < 10 Customers: nearly 1 million visitors/year (residents, NYS, U.S. and international)
Honey Girl Gourmet	Retail/Specialty Food Products Focus on local and NYS products	(1) location in Geneseo, NY (Livingston County) Employees < 10 Customers: residents, SUNY Geneseo college students, and online
Butter Meat Co.	Retail/Specialty Food Products Focus on local and NYS products	(1) location in Perry, NY (Wyoming County) Employees < 10 Customers: residents, summer lake residents, tourists, and online

OSB Cider	Craft Cider	(2) locations: Lakeville, NY (Livingston County) and Buffalo, NY (Erie County) Employees < 25 Customers: residents, summer lake residents, tourists, Rochester and Buffalo-based food and beverage establishments
Silver Lake Brewing Project	Craft Beer	(1) location: Perry, NY (Wyoming County) Employees < 10 Customers: residents, summer lake residents, tourists to Letchworth State Park
Dublin Corners Farm Brewery	Craft Beer	(2) locations: Linwood and Geneseo, NY (Livingston County) Employees < 25 Customers: residents, summer lake residents, SUNY Geneseo, tourists, local restaurants, and bars
Taste NY Visitor Centers (11) Adirondacks Welcome Center Capital Region Welcome Center Central NY Welcome Center Finger Lakes Welcome Center Hudson Valley Catskills Welcome Center Long Island Welcome Center Mohawk Valley Welcome Center North County Welcome Center Southern Tier Welcome Center Western NY Welcome Center Taste NY at Todd Hill (Dutchess County)	Retail stores at major NYS Thruways and Visitor Centers throughout NYS	(11) Locations throughout NYS Employees < 50 employees Customers: tourists, residents, and online
Once Again Nut Butter	Food Manufacturer *Recently discontinued line of honey products due to disruptions in global supply chains	Location: Nunda, NY (Livingston County) Employees: < 100 Customers / Market Reach: Local, U.S.
Nunda Mustard	Food Manufacturer	Location: Nunda, NY (Livingston County) Employees: < 25 Customers / Market Reach: Available in over 100 retail locations, on-line, and Finger Lakes region festivals.
Creative Foods	Food Manufacturer	Location: Perry, NY (Wyoming County) Employees: > 200

Table 2. List of Businesses Interviewed & Profiles

ABOUT LETCHWORTH GATEWAY VILLAGES

Letchworth Gateway Villages is a municipal alliance committed to advancing rural development in the Genesee Valley. Through network-building, technical assistance, and research, LGV serves as a vehicle for cultivating the regional partnerships needed to build a 21st century rural economy.



Mount Morris Agrivoltaic Study
Co-locating Solar and Agriculture at the Morris Ridge Solar Energy Center