Large-Scale Agrivoltaics:
Beekeeping on Utility Scale Solar Facilities in Western NY

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Introduction
Outline

What is solar beekeeping and why is it important?
What drives economic success for beekeepers?
What drives honey yields?
How do beekeepers perceive agrivoltaics?
Recommendations for solar developers
Solar Beekeeping

Definition
Solar beekeeping is an emerging agrivoltaic practice that involves siting managed honeybee colonies on solar facilities for honey production.

Motivations
As solar development drives land use changes, can these changes support insect pollinator health, beekeeping businesses, and pollination as an ecosystem service?
Economic Importance of Honeybees

Economic Value in New York State

- **Honey Production**: $11 million in 2020
- **Commercial Pollination**: $308 - $439 million
- **Crops Dependent on Insect Pollination**: $624 million

Honeybees are important to:
- Beekeepers
- Crop Producers
- Consumers

"While NYS is home to more than 400 bee species, the honeybee is the most economically important."
Motivation
Mount Morris Agrivoltaic Study: Solar Beekeeping

What do beekeepers need from solar sites?
• Understand opportunities and challenges of solar beekeeping from a beekeeper’s perspective
• Understand economics of establishing and operating an apiary on a solar site

How can we identify good apiary locations?
• Use landscape analysis tools to assess possible apiary locations within the proposed Morris Ridge Solar Development
• Provide an approach that others could use

How can solar developers attract and retain beekeepers?
• Recommend best practices for solar developers looking to recruit beekeepers and establish viable apiaries for honey production
Research Methods
Mount Morris Agrivoltaic Study: Solar Beekeeping

Beekeeper Survey
• Interviewed 5 beekeepers about production practices, honey yields, revenues and expenses, and perceptions of solar beekeeping
• Four commercial operations (400 to 1,000+ colonies); plus one sideliner (50 colonies)

Economic Model
• Developed an annual apiary budget for a representative small, medium & large apiary
• Included honey and wax revenues, operating expenses, depreciation on establishment cost, and operator labor & management fee

Landscape Analysis
• Completed a geospatial analysis using the USDA NASS Cropland Data Layer to evaluate land cover around 3 plausible apiary locations
• Compared land cover with criteria thought to support a large apiary, from literature review
Results

1. Honey yields drive economic success
2. Landscape composition drives honey yields
3. Solar apiaries are “apiaries” to a beekeeper

1. Honey Yields Drive Economic Success

- Honey is the top source of income for beekeepers in New York.
- Honey yields are highly variable across space and time.
- Assumed 60 lbs/colony honey yield for medium and large apiaries, which is higher than the NYS average.
- Assumed 110 lbs/colony honey yield for the small apiary due to higher intensity management and lower stocking rate.
- Small apiary had the highest revenues and expenses on a per colony basis.

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.
1. Honey Yields Drive Economic Success

Operating Profit Margin

- How many dollars of profit do we generate for every dollar of sales?
  - > 25% is considered strong
  - > 10% is considered stable
  - > 0% indicates a profit

- Based on our economic model, operating profit margin was:
  - -16% for the small apiary
  - 3% for the medium apiary
  - 14% for the large apiary

- What happens if honey yields change?

Operating profit margin = (net income - operator labor and management fee) \( \div \) gross revenue

<table>
<thead>
<tr>
<th>Operating Profit Margin</th>
<th>Small Apiary</th>
<th>Medium Apiary</th>
<th>Large Apiary</th>
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<tbody>
<tr>
<td>0%</td>
<td>129</td>
<td>58</td>
<td>51</td>
</tr>
<tr>
<td>10%</td>
<td>144</td>
<td>65</td>
<td>57</td>
</tr>
<tr>
<td>25%</td>
<td>175</td>
<td>79</td>
<td>70</td>
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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.
2. Landscape Composition Drives Honey Yields

- Landscape composition influences honey bee health and productivity.
- Beekeepers depend on a small number of plants for surplus honey production.
- Stationary apiaries require sufficient habitat diversity to capture honey flows in all seasons.
- Beekeepers mitigate colony health risks by minimizing exposure to pesticides used in conventional cropping systems.
- Neonicotinoids are of particular concern due to toxicity and persistence in the environment.

<table>
<thead>
<tr>
<th>Season</th>
<th>Flowering Plants</th>
<th>Habitat Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>- Black locust (Robinia pseudoacacia)</td>
<td>- Hedgerows</td>
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<tr>
<td></td>
<td>- Sumac (Rhus spp.)</td>
<td>- Forest edges</td>
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<tr>
<td>Summer</td>
<td>- Basswood (Tilia spp.)</td>
<td>- Meadows</td>
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<tr>
<td></td>
<td>- Clover (Trifolium spp.)</td>
<td>- Roadside ditches</td>
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<tr>
<td></td>
<td>- Knapweed (Centaurea spp.)</td>
<td>- Wetlands</td>
</tr>
<tr>
<td>Fall</td>
<td>- Goldenrod (Solidago spp.)</td>
<td>- Old farm fields</td>
</tr>
<tr>
<td></td>
<td>- Aster (Aster spp.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Japanese knotweed (Polygonum cuspidatum)</td>
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</tr>
</tbody>
</table>

*Table 3.* Flowering plants and habitat types valued by New York beekeepers for honey production.
2. Landscape Composition Drives Honey Yields

- Honey bee foraging area is much larger than most solar installations.
  - Typical honey bee foraging radius of 1600m covers 1,987 acres
  - Extended foraging radius of 3200m covers 7,949 acres
- Are high value habitats and honey plants present within the foraging area?
  - Grassland/pasture, shrubland, fallow land, wetlands, forest edges
- Are high risk land uses or crops present?
  - Corn, soy, alfalfa hay

Figure 3. Landscape composition around potential apiary sites. Source: USDA-NASS Cropland Data Layer.
2. Landscape Composition Drives Honey Yields

- No easy way to predict honey yields from landscape composition.
- Beekeepers expressed concern about the extent of field crops and lack of other habitat types in the project area.
- We could not identify anyone keeping bees within the project area, so local honey yields are unknown.
- Using criteria adapted from a ND study, these proposed sites met some but not all criteria to support a large apiary.
- Bee Scape Tool: [https://beescape.org/](https://beescape.org/)
2. Landscape Composition Drives Honey Yields

- Landscape composition will change over the next several years.
- Rotationally grazed pasture can provide better pollinator habitat vs. corn and soy.
- Proposed apiaries would meet study criteria after conversion of land from row crops to pasture mix with clovers and other flowering plants.
- Positive impacts for beekeepers are conditional on the establishment and ongoing maintenance of new vegetation.
- Rotational grazing offers benefits over mowing for ongoing management.
3. Solar Apiaries are "Apiaries" to a Beekeeper

- Beekeepers are accustomed to managing apiaries on private land
- Apiary selection criteria are no different for solar apiaries vs. any other apiary
- Willing to drive 25 to 50 miles to establish a new apiary
- Preference for establishing 2 to 3 bee yards in a general area to make travel more efficient
- Minimum distance of 1 to 4 miles between apiaries

<table>
<thead>
<tr>
<th>Top Criteria for Beekeepers</th>
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<tbody>
<tr>
<td>Accessibility</td>
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<tr>
<td>Landscape composition</td>
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<tr>
<td>Safety &amp; privacy</td>
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<tr>
<td>Physical site characteristics</td>
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<tr>
<td>Protection from pesticides</td>
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<tr>
<td>Property owner relations</td>
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</tbody>
</table>
3. Solar Apiaries are "Apiaries" to a Beekeeper

- 4 of 5 survey respondents expressed positive attitudes toward solar beekeeping.
- Beekeepers with retail sales saw more potential value in marketing “solar honey” compared to beekeepers with no direct sales.

**Top Criteria for Beekeepers**

- Accessibility
- Landscape composition
- Safety & privacy
- Physical site characteristics
- Protection from pesticides
- Property owner relations
Recommendations

1. Recruit and retain a good beekeeper
2. Provide sufficient access and space
3. Prioritize safety & security for people and bees
4. Manage vegetation for honey production
5. Seek input from outside experts
6. Read the Mount Morris Agrivoltaic Study!
Recruit and Retain a Good Beekeeper

- Establish clear project goals and evaluation criteria. Do you want to emphasize pollinator conservation or honey production?
- Take time to find the right fit. Look for a local, experienced beekeeper. Understand different beekeeping business models. Discuss how your goals align with the beekeeper’s management practices.
- Seek opportunities to mitigate production risk. Start small and go one year at a time in case the relationship doesn’t work out.
- Clarify expectations in writing. Most beekeepers use handshake agreements with property owners, but are open to written agreements for solar beekeeping.
Provide Sufficient Access & Space

- Beekeepers need reliable year-round access to colonies. Ensure the access route is dry and passable even in mud season.
- Provide beekeepers with a key or security code to access restricted areas.
- Provide adequate space for hives, workers, vehicles, and mowing equipment.

<table>
<thead>
<tr>
<th>Apiary Size</th>
<th>Typical Layout</th>
<th># Colonies</th>
<th>Minimum Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>Single row or grid</td>
<td>10</td>
<td>1600 sq ft</td>
</tr>
<tr>
<td>Medium</td>
<td>Two rows</td>
<td>30</td>
<td>2300 sq ft</td>
</tr>
<tr>
<td>Large</td>
<td>Horseshoe</td>
<td>60</td>
<td>4600 sq ft</td>
</tr>
</tbody>
</table>
Prioritize Safety & Security for People & Bees

- Site hives out of public view using visual barriers or setbacks from roads and residential areas.
- Locate apiaries at least 100 yards from solar equipment.
- Maintain a greater distance from swimming pools or other swimming areas.
- Ensure adequate fencing is in place to deter bears (and sheep).
- Do not site apiaries near agricultural fields or orchards managed with conventional pesticides.
- Establish a pesticide-free buffer around apiaries and pollinator plantings to reduce the risk of pesticide exposure. Minimum 40 ft for ground application, 60 ft for airblast applications.
- Avoid establishing pollinator habitat on land that was treated with neonicotinoids in the previous two years (Xerces Society).
Manage Vegetation for Honey Production

- Landscape composition may trump on-site plantings; however, developers can still consider honey production when designing plantings for the site.
- Perennials may persist better over time than annuals, but may be more difficult to establish.
- Some honey plants, such as white and alsike clover, are appropriate to grow under panels.
- Sweet clover, goldenrod, and asters may be too tall for planting among the panels. Select shorter varieties or increase panel heights to avoid shading panels when flowers are blooming.
- Consider taller species, including trees and shrubs, for perimeter and buffer areas.
- Wild pollinator mixes can provide important nutrients for honey bees but may not stimulate surplus honey production.
Seek Input from Outside Experts

• Establishing pollinator plantings while meeting other solar facility design criteria requires a nuanced understanding of botany and ecology.

• Consult with regional biologists to identify vegetation suitable for honey bees and other local pollinators that can be feasibly grown among utility scale solar infrastructure.

• Protect your investment; consider third-party vegetation management and monitoring to ensure that plantings persist over time.
Read Our Study!  
Linked in the Chat

Mount Morris Agrivoltaic Study - PDF

Morris Ridge Solar Project Website – Click On 2022 Spring Newsletter to access find the link

USES USA Website – Under the Education select Ag + Solar to find the study
Thank you!

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Future Opportunities for Solar-Raised Honey

Of the lamb consumed is imported, primarily from Australia and New Zealand.

Expansion of imported lambs over the past 10 years.
### Current Demand

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<th>Businesses Interviewed</th>
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<tr>
<td>20 businesses contacted, 15 responded.</td>
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<tr>
<td>Businesses included three food manufacturers, three craft beverage producers, and nine specialty food retailers.</td>
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<tr>
<td>2 of 3 food manufacturers use honey, 1 had to discontinue due to pandemic-related supply chain disruptions.</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Retailers</th>
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<tr>
<td>Honey purchased 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.</td>
</tr>
<tr>
<td>Retail margin ranged from 33%–50%.</td>
</tr>
<tr>
<td>In high tourism areas retailers reported selling close to 200 bottles of honey per month.</td>
</tr>
<tr>
<td>Retailers most concerned about price, consistency, and where honey is sourced (must be local)</td>
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</tbody>
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<table>
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<tr>
<th>Breweries</th>
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<tbody>
<tr>
<td>2 of the 3 breweries surveyed use honey on a consistent basis.</td>
</tr>
<tr>
<td>Honey purchased in five-gallon buckets for $150/bucket and sourced locally.</td>
</tr>
<tr>
<td>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.</td>
</tr>
</tbody>
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<thead>
<tr>
<th>Food Manufacturers</th>
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<tr>
<td>2 of 3 food manufacturers use honey, 1 had to discontinue due to pandemic-related supply chain disruptions.</td>
</tr>
<tr>
<td>The volume of honey used 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.</td>
</tr>
<tr>
<td>Cost determined by kind of honey (regular, organic, or fair trade).</td>
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</table>
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

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
Key Insights and Recommendations

A need for consumer awareness and education

• Most respondents 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.

Recommendations – Prepare the Market for Solar-raised Honey

• Partnerships with New York State Ag and Market’s Taste NY program, Cornell Cooperative Extension offices, Taste NY Market locations, as well as the New York State Division of Tourism will be key for both promoting the story of solar-raised honey and educating consumers on the state’s renewable energy agenda.
Key Insights and Recommendations

Market Opportunities for Apiarists

• The top market opportunities were the Taste NY retail outlets throughout the state especially those located near tourism areas, 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.

Recommendations

• Connect apiarists with Letchworth State Park concessionaire and 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).

• Build relationships with the region’s growing food manufacturing sector, many of which currently source their honey from outside the U.S.
Thank you

www.letchworthgatewayvillages.org