Growing Agrivoltaics in New York State:

Advancing Understanding of Opportunities to Integrate Renewables into Working Landscapes

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Our Mission:

Advance clean energy innovation and investments to combat climate change, improving the health, resiliency, and prosperity of New Yorkers and delivering benefits equitably to all.

Growing Agrivoltaics in New York State:

Advancing Understanding of Opportunities to Integrate Renewables into Working Landscapes

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Notice

Abstract

This report supplements ongoing research on potential opportunities and constraints associated with the increasing uptake of agrivoltaics projects in New York State. The report outlines the results of a limited literature review to advance understanding of opportunities for agrivoltaics by reviewing New York State's current agricultural landscape; the current situation of agrivoltaics pilots and programs; and solar design considerations related to integration of agricultural activities and solar power generation. In aggregation with additional State efforts to understand land-use implications of large-scale solar (LSS) development, results inform potential future actions to provide education on best practices for implementation of agrivoltaics projects in New York State.

Keywords

Solar, agrivoltaics, agrophotovolatics, agrisolar, solar sharing, PV agriculture, agri-PV, dual use, co-utilization, co-location, agriculture

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Acronyms and Abbreviations

AGV SC	Agrivoltaics Specialist Committee
AREGCBA	Accelerated Renewable Energy Growth and Community Benefit Act
ASGA	American Solar Grazing Association
A-TWG	New York State Agricultural Technical Working Group
CAFO	concentrated animal feeding operations
Climate Act	Climate Leadership and Community Protection Act
DG	distributed generation
DOE	US Department of Energy
EPRI	Electric Power Research Institute
FARMS	Foundational Agrivoltaic Research for Megawatt Scale
GCR	ground coverage ratio
GHG	greenhouse gas
InSPIRE	Innovative Solar Practices Integrated with Rural Economies and Ecosystems Project
kWh	kilowatt-hour
kWp	kilowatt peak
LSS	large-scale solar
MA DOER	Massachusetts Department of Energy Resources
MFT	Maine Farmland Trust
MWac	A megawatt of alternating current electric energy generating capacity
MWdc	A megawatt of direct current electric energy capacity
MWhr	megawatt-hour
NASS	National Agricultural Statistics Service
NGO	nongovernmental organization
NJBPU	New Jersey Board of Public Utilities
NRCS	National Resources Conservation Service
NREL	National Renewable Energy Laboratory
NYPA	New York Power Authority
NYSAGM	New York State Department of Agriculture and Markets
NYSERDA	New York State Energy Research and Development Authority
ORES	Office of Renewable Energy Siting
PON	Program Opportunity Notice
REDC	New York Regional Economic Development Council
SETO	Solar Energy Technologies Office
SMART	Solar Massachusetts Renewable Target
USDA	United States Department of Agriculture

Executive Summary

The New York State Energy Research and Development Authority (NYSERDA) commissioned this report to identify potential opportunities and constraints associated with increasing uptake of agrivoltaic projects in the State. The focus and contents of this effort were informed through engagement with the Agrivoltaics Specialist Committee (AGV SC) of the New York State Agricultural Technical Working Group (A-TWG). NYSERDA initiated A-TWG in recognition of concerns from diverse stakeholders related to potential conflicts between solar development and agricultural lands and operations. A-TWG is an independent advisory body that informs efforts for solar development across a range of scales in a way that supports the State's agricultural operations, lands, farmers, and communities. A-TWG comprises farmers and agriculture advocates, solar developers, academic experts, nongovernmental organizations (NGOs), and State agencies. The AGV SC is a subset of A-TWG that identified the following purpose statement:

> "Given that NYS would like to advance agrivoltaics that is beneficial to farmers and their communities to encourage further development of solar while maintaining and demonstrating viable commercial agriculture operations, the AGV SC shall:
>
> - Develop a stronger understanding of the current state and potential for agrivoltaics in NYS to promote land-use efficiencies, supplement agricultural revenue streams, and minimize land use competition.
> - Identify information and knowledge needed to better understand the viability of agrivoltaics across a range of conditions in NYS.
> - Provide guidance on how policies and programs could be developed or amended to advance agrivoltaics."

Agrivoltaics is a nascent field of research and development that currently does not retain an industry-standard definition; variety in terminology and scope is common across the United States and internationally. To facilitate engagement, the AGV SC developed the working definition of agrivoltaics that is used within this report: "a simultaneous use of land for solar photovoltaic power generation and agricultural production of 'crops, livestock, and livestock products' as that phrase is defined by Agriculture & Markets Law (AML) §301(2)."

This report was developed to support the AGV SC in advancing its stated purpose and its goal to advance best practices for farmers and solar developers. To support the committee's ability to provide recommendations for best practices, identify research gaps, and make potential recommendations related to policy, WSP USA conducted a limited literature review and report designed to support:

- Understanding of New York State's agricultural landscape.
- Understanding of the current condition of agrivoltaics pilots and programs with relevancy to the State.
- Expanded understanding of opportunities and constraints related to dairy, sheep grazing, and specialty crops focus areas.
- Understanding of existing and emerging agrivoltaic solar design considerations.

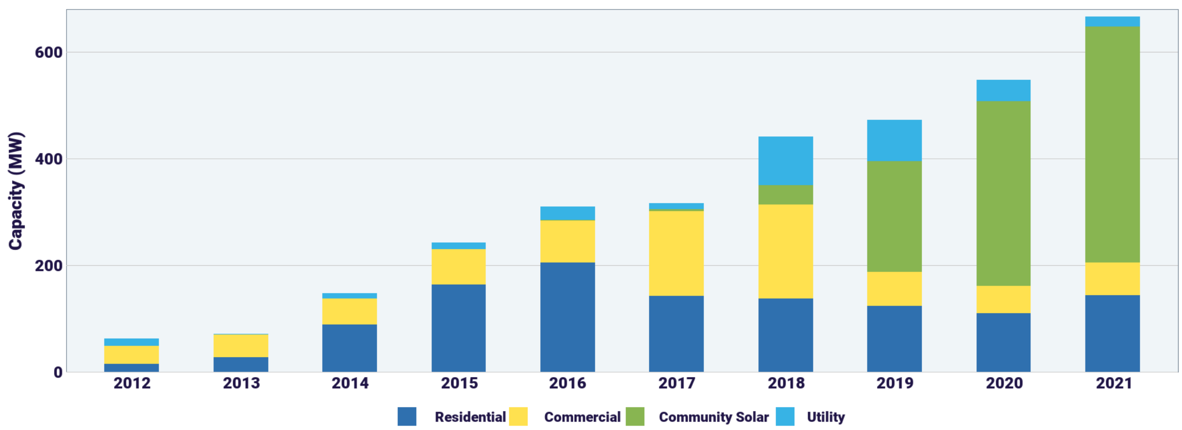
The results of this effort and A-TWG's engagement have provided key findings and recommendations for continued research and engagement. Together with additional State efforts to understand land-use implications of LSS development, the contents of this report and its recommendations inform potential future actions to investigate the opportunities and constraints associated with implementation of agrivoltaics projects, and development of education and best management practices.

1 Introduction

The Climate Leadership and Community Protection Act (Climate Act), adopted in 2019, requires that 70% of New York State's electricity come from renewable energy sources by 2030. Renewable energy accounted for 27% of the State's electricity generation in 2021 (New York State Climate Action Council Scoping Plan, 2022, p. 219). Of that 27%, solar accounted for 3% (EIA 2022); Figure 1 shows the types of solar in that mix.

Figure 1. New York Annual Solar Installations

Source: *https://www.seia.org/state-solar-policy/new-york-solar*



The Climate Act also created the Climate Action Council, a body tasked with developing a Scoping Plan for how the State will reduce greenhouse gas (GHG) emissions and achieve net-zero emissions, increase renewable energy usage, and ensure climate justice. The Climate Action Council adopted the Final Scoping Plan on December 19, 2022, which includes a key strategy to accelerate the growth of large-scale renewable energy generation. In each of the three GHG mitigation scenarios included in the Scoping Plan, significant solar power generation is required to achieve targets, with around 60 gigawatts of solar generation needed by 2050 (ibid, p. 221). Given the scale of the effort needed to achieve these goals, it is critical that New York State investigate opportunities to advance solar development across various scales in a manner that considers and supports the State's agricultural sector and communities.

The New York State Energy Research and Development Authority (NYSERDA) commissioned this report to identify potential opportunities and constraints associated with increasing uptake of agrivoltaics projects. Legislation and policy demonstrate the State's commitment to development that considers co-location of solar and agricultural activities. The Accelerated Renewable Energy Growth and Community Benefit Act (AREGCBA) passed in the 2020-21 State budget adds a new section 94-c to the Executive Law, titled Major Renewable Energy Development (the "94-c Process"). The Act establishes Office of Renewable Energy Siting (ORES), housed within the Department of State, which conducts environmental review of major renewable energy facilities and provides a single forum to ensure "siting decisions are predictable, responsible, and delivered in a timely manner along with opportunities for input from local communities" (ORES n.d.-a). Exhibit 15 of the ORES regulations promulgated pursuant to Executive Law §94-c requires "Any agricultural co-utilization plan for the lifespan of the facility shall demonstrate that the proposed agricultural co-utilization will be feasible. The plan shall be assembled by a qualified or accredited third-party agricultural professional. The plan should include an itemization of the investments made by the applicant to facilitate the agricultural co-utilization (e.g., grazing plan, planting pasture species, development of watering facilities, modified access for livestock trailers, panel spacing, additional fencing, access roads, gates, housing, etc.)" (§900-2.16). The AREGCBA leaves the environmental review of facilities smaller than 25 megawatts (MW) to the State Environmental Quality Review Act, enabling local municipalities or other involved agencies to serve as the lead agency, although renewable energy facilities between 20 and 25 MW can opt into the 94-c Process. While the vast majority of MW hours produced are projected to come from major renewable energy facilities, the largest number of interconnection requests in the New York Independent System Operator (NYISO) queue are around solar projects with a nameplate capacity of 20 MWac (megawatt, alternating current) or less. In 2022, New York State adopted Chapter 629 of the Laws of 2022, which "Directs the department of agriculture and markets, in cooperation with NYSERDA, to develop and produce guidance and educational materials for farmers on the use of agrivoltaics in farming."

NYSERDA developed the New York State Solar Guidebook for Local Governments to ensure that local jurisdictions have the proper tools to understand, manage, and permit development in their communities. Resources in the guidebook underscore the State's priority to preserve agricultural lands and encourage balance between solar development and agricultural activities. The chapter "Solar Installations on Agricultural Lands" acknowledges the NYS Constitution, which holds that "[t]he policy of the State shall be to conserve and protect its natural resources and scenic beauty and encourage the development and improvement of its agricultural lands for the production of food and other agricultural products" (NYS Const. Art. XIV § 4). This exact constitutional provision also creates an inextricable link between agricultural conservation and the State's clean energy transition, noting that New York State's conservation policies must "include adequate provision for the abatement of water and air pollution," alongside "the protection of agricultural lands." NYSERDA's 2022 Renewable Energy Standard (RES) Tier 1 Renewable Energy Certificates (REC) solicitation (RESRFP) executes this policy in multiple ways:

- Appendix 2: Permitting Plan Requirements and Guidelines states, "Proposers are strongly encouraged to explore the option for co-location of solar panels and farming that results in continued agricultural production within the project site, and/or other productive uses on the site such as sheep grazing and utilizing pollinator friendly planting practices."
- The Smart Solar Siting Scorecard is a part of the RESRFP that awards additional evaluation points for projects that incorporate agricultural co-utilization activities, among other agriculture protection strategies.
- The Agricultural Mitigation Payment deferral provides a financial incentive for projects that employ accepted agricultural co-utilization activities within the Facility Area, defined as "all land area occupied during the commercial operation of the generation facility, the associated interconnection equipment and, if applicable, energy storage equipment."

The New York State Farmland Protection Working Group was formed in 2021 "to consider and recommend strategies to the State on the siting process of major renewable energy facilities and to minimize the impact of siting on productive agricultural soils on working farms" (NYSAGM n.d.-a). Strategy recommendations in the applied research/demonstrations category include furthering research related to dual use and co-utilization of agricultural production and renewable energy projects, including documenting case studies from other states, direct funding to applied research and demonstration projects, and fostering development of standards and best management practices for agricultural co-utilization related to forage, row crops, and pasture (NYSAGM February).

With respect to potential future policy, New York State also recognizes agrivoltaics as an emerging opportunity that requires greater understanding of feasibility to determine how best to foster its uptake in the State's regulatory and agricultural landscape.

A 2022 amendment to the Regional Greenhouse Gas Initiative operating plan proposes $5 million to further promote agrivoltaics through establishing a partnership between NYSERDA, New York State Department of Agriculture and Markets (NYSAGM), and academic institutions. The goal of the investment is to enable development of educational materials and guidance regarding use of agrivoltaics in New York State (NYSERDA 2022c).

Additionally, the Climate Action Council Final Scoping Plan advises that "NYSERDA and [NYSAGM] should commence a study on developing a comprehensive agrivoltaics program to research and incentivize the viability of agrivoltaics to integrate solar into the agricultural communities and provide habitat for threatened and endangered species" (E4. Support Clean Energy Siting and Community Acceptance, p. 236). NYSERDA, through the Agricultural Technical Working Group (A-TWG), is evaluating multiple federal and State legislation, programs, and pilots that support to better consider the barriers and opportunities associated with advancing agrivoltaics in the State. A-TWG is an independent advisory body that informs efforts for solar development in a way that supports the State's agricultural operations, lands, farmers, and communities. Farmers and agriculture advocates, solar developers, academic experts, nongovernmental organizations (NGOs), and State agencies comprise A-TWG. This effort aligns with the State's priority to mitigate impact from renewable energy projects on forests and agricultural lands, as expressed in the Final Scoping Plan:

> DEC and AGM should work with the New York State Energy Research and Development Authority (NYSERDA) and Office of Renewable Energy Siting (ORES) to facilitate the siting of renewable energy projects, including solar on appropriate sites, to avoid adverse impacts to New York forests and agricultural lands in order to mitigate impacts to agricultural production, and carbon storage and sequestration. In some cases, this may include rejection of a State subsidy, tax credits, and/or renewable energy credits in forests or agricultural lands with high carbon, climate, or other related benefits. This strategy should also align with the recommendations put forward by the Farmland Protection Working Group and the Agricultural Technical Working Group for further actions and research to mitigate the impact of renewable energy projects on agricultural lands (LU3. Avoid Agricultural and Forested Land Conversion, p.376).

The focus and contents of this report were informed through engagement with the Agrivoltaics Specialist Committee (AGV SC) of the A-TWG. The AGV SC identified the following purpose statement:

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To facilitate engagement, the AGV SC developed the working definition of agrivoltaics used within this report:

> A simultaneous use of land for solar photovoltaic power generation and agricultural production of "crops, livestock, and livestock products" as that phrase is defined by Agriculture & Markets Law (AML) §301(2).

This definition makes the distinction that agrivoltaics is a dual-use solar activity, but that not all dual-use solar activities are agrivoltaics. The National Renewable Energy Laboratory (NREL) defines "dual-use solar" as "the combination of solar development with land management philosophies rooted in conservation and agriculture to create a multifunctional system with a variety of ecological, agricultural, and energy benefits" (Macknick et al. 2022). Notably, dual use includes co-located activities that support or enhance ecosystem services, like providing pollinator habitat or creating new habitat designed to support biodiversity. The AGV SC recognizes the critical nature of these activities; however, the working definition limits the scope of agrivoltaics to those activities that align with agricultural production of crops, livestock, and livestock products, including field crops, fruits, vegetables, horticultural specialties, apiary products, and the additional items outlined in AML §301(2). However, through its Smart Solar Siting Scorecard Specialist Committee, A-TWG investigates the dual-use ecosystem service potential of pollinators, carbon storage, wildlife, and wildlife habitat.

This report was developed to support the AGV SC in advancing its stated purpose and goal to advance best practices for farmers and solar developers.

This report is intended to support the A-TWG's ability to provide recommendations for best practices, identify research gaps, and make potential recommendations related to policy as follows:

- Section 2 provides an overview of New York State's agricultural landscape and economy to provide context for understanding what types of agrivoltaic projects may warrant deep consideration.
- Section 3 reviews and summarizes proposed or ongoing pilot programs and projects relevant to New York State's solar regulatory and agricultural context.
- Section 4 summarizes key aspects of three types of agriculture of particular interest for fostering co-location with solar development.
- Section 5 identifies technical design characteristics for solar projects relevant to determining the most suitable design considerations for co-location with agrivoltaic systems.
- Section 6 outlines key findings and recommendations for continued research and engagement.

Together with additional State efforts to understand land-use implications of large-scale solar (LSS) development, this report informs potential future actions to investigate the opportunities and constraints associated with agrivoltaic uptake that consider New York State's agricultural landscape and provide education on best practices for implementation of agrivoltaics projects in the State.

2 New York State Agricultural Sector

2.1 Land Value

In order to identify existing and proposed pilots and programs regionally, nationally, and globally that have greatest relevance to New York State, it's important to first understand the State's agricultural sector. This review supports an understanding of current agricultural data drawing largely from the 2017 Agricultural Census. However, broader understanding of land-use trends and potential future scenarios will be important for additional context. Once the feasibility of agrivoltaic operations in New York State is understood and advanced, it will be beneficial to build on work that takes into consideration broad land- use and farmland conversion trends,[1] and determine opportunity for agrivoltaics to support resiliency in agriculture. This is particularly important in considering the land-use implications of onboarding 60 gigawatts (GW) of solar by 2050, as noted in the Integration Analysis Technical Supplement supporting the Climate Action Council Scoping Plan (New York State Climate Action Council 2022). The following section provides information to support understanding the current state of this sector, and includes information related to land value, payroll, agricultural commodity production and value, and limited information on the State's import and export market.

Table 1 presents the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Land Values 2022 Summary published in August for farm real estate, cropland, and pasture value per acre, and the estimated value of farmland and buildings per acre compared to 2021 values. The values are all increasing in New York State, the Northeast, and nationally—although not all values in the State are increasing as significantly in comparison. In 2022, the estimated value of farmland and buildings was over $22 billion. Nearly 23% of the State's total land area is in agricultural use at 33,438 farms (USDA-NASS 2017a). As of 2020, 4.3% of farms are tenant farms, and the average farmland rental rate is $68 per acre (Acre Trader 2023).

1 See the following American Farmland Trust reports: Farms Under Threat: The State of the States; Farms Under Threat 2040: Choosing an Abundant Future; and Smart Solar Siting on Farmland: Achieving Climate Goals While Strengthening the Future for Farming in New York.

Table 1. USDA NASS Land Values 2022 Summary

Source: United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) *Land Values 2022 Summary, August 2022.*

		Farm Real Estate Average Value per Acre[a] (dollars)	Cropland Average Value per Acre (dollars)	Pasture average Value per Acre (dollars)	Estimated Value of Farmland and Buildings[b] (million dollars)	Approximate Acreage of Farmland and Buildings
New York	2021	3,270	2,910	1,580	21,735	6,646,789
	2022	3,450	3,150	1,620	22,563	6,540,000
	Percent change	**5.5**	**8.2**	**2.5**	**3.8**	
Northeast	2021	6,000	6,490	4,030	121,836	20,306,000
	2022	6,490	7,060	4,280	128,088	19,736,210
	Percent change	**8.2**	**8.8**	**6.2**	**5.1**	
United States	2021	3,380	4,420	1,480	2,733,521	808,734,024
	2022	3,800	5,050	1,650	2,916,029	767,376,053
	Percent change	**12.4**	**14.3**	**11.5**	**6.7**	

[a] Farm real estate value is a measurement of the value of all land and buildings on farms.

[b] Total value of land and buildings is derived by multiplying average value per acre of farm real estate by land in farms.

2.2 Payroll

The New York State agriculture sector produced $3.3 billion in gross domestic product and paid nearly $1 billion in wages in 2021 according to the U.S. Bureau of Labor Statistics. The average annual pay (the total annual wage divided by the average of 12 monthly employment levels) in crop production was $38,143, approximately 43% of the State average of $88,030 for all occupations reported by the Quarterly Census of Employment and Wages. The average annual pay for animal production was $43,380, approximately 49% of the State average for all occupations. Of all jobs in New York State in 2021, 11,430 related to animal production, and 12,438 related to crop production (NYS Comptroller 2022). Farm employees are also frequently compensated with non-cash incentives and benefits. For permanent, full-time employees, benefits may include paid time off or vacation time, disability insurance, farm produce (milk, meat, vegetables, etc.), clothing, housing, sick days, retirement, paid family leave, utilities, health insurance, recreational use of farm property, paid holidays, fuel, television and internet, continuing education or off-farm training, meals, transportation to work or other places, life insurance, personal use of a vehicle, and farm commodities (Stup et al. 2022).

There are numerous formal and informal training opportunities and programs for beginning farmers in the State, as well as apprenticeship programs that offer employment opportunities. These opportunities include, but are not limited to, college agricultural programs; training programs such as AgCareers, Cornell Cooperative Extension, GrowNYC Beginning Farmer Program, and Essex Farm Institute; and apprenticeships such as the Dairy Grazing Apprentice, NCAT ATTRA Sustainable Farming Internships and Apprenticeships, and Glynwood Hudson Valley Farm Business Incubator (NYSAGM 2023a).

2.3 Agricultural Products and Land Use

Table 2 summarizes the top 10 rankings for the State according to the USDA Northeastern States' Ranking in the Nation's Agriculture. Nationally, New York State ranks first for creamed cottage cheese, low-fat cottage cheese, sour cream, and yogurt, and second for maple syrup, apples, cabbage, snap beans, and vegetables based on production. Table 3 summarizes the market value of agricultural products sold in the State. The overall value of dairy products, measured as milk from cows, represents over $2.5 billion in sales and 47% of the total agricultural sales in the State on approximately 12% of the total number of farms. New York State ranked 27th overall among U.S. states in 2021, with 1.4% share of receipts for all commodities, at $5,903,803,000 (USDA-ERS 2021).

Table 2. USDA Northeastern States' Ranking in the Nation's Agriculture for New York State, 2021

Source: United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Northeastern States' Ranking in the Nation's Agriculture, 2021.

Ranking	Agricultural Commodity
1	Dairy Products (including creamed cottage cheese, low-fat cottage cheese, sour cream, and yogurt)
2	Maple Syrup, Apples, Cabbage, Snap Beans, Vegetables
3	Calves, Total Italian cheese, Squash, all
4	Milk production, Ice cream, Total Cheese, Total American cheese, Corn for silage
5	Tart cherries
6	Christmas trees
7	Sweet corn
8	Sheep and lambs, Onions, dry, Pumpkins
9	Floriculture sales
10	Oats

Table 3. Census of Agriculture 2017 Ranking of Market Value of Ag Products Sold in New York State

Source: U.S. Department of Agriculture-National Agricultural Statistics Service, Census of Agriculture. Retrieved from 2017 State and County Profiles - New York:

Item	Farms	Sales ($1,000)	Rank by Sales	Percent of Total Sales
Total sales	33,438	5,369,212	(X)	100.0
Milk from cows	3,984	2,528,282	1	47.1
Grains, oilseeds, dry beans, and dry peas	6,213	571,706	2	10.6
Cattle and calves	10,197	426,026	3	7.9
Fruits, tree nuts, and berries	3,083	399,803	4	7.4
Nursery, greenhouse, floriculture, and sod	2,118	385,792	5	7.2
Vegetables, melons, potatoes, and sweet potatoes	3,588	378,658	6	7.1
Other crops and hay	13,670	362,905	7	6.8
Poultry and eggs	4,146	194,747	8	3.6
Horses, ponies, mules, burros, and donkeys	1,591	33,727	9	0.6
Hogs and pigs	1,835	24,920	10	0.5
Other animals and other animal products	1,609	22,761	11	0.4
Sheep, goats, wool, mohair, and milk	2,235	17,575	12	0.3
Aquaculture	105	13,187	13	0.2
Cultivated Christmas trees and short rotation woody crops	763	9,122	14	0.2
Tobacco	-	-	-	-
Cotton and cottonseed	-	-	-	-

Cash receipts for agricultural commodities measure the gross income from crop, livestock, and livestock product sales by state within a calendar year (USDA-NASS 2022a). The annual receipts are based on data obtained from National Agricultural Statistics Service (NASS) sources: the annual Agricultural Resource Management Survey Phase III and USDA Farm Service Agency's Commodity Credit Corporation loan data. NASS annual crop quantities produced by each state are converted into quantities sold, which are then converted to monthly open-market cash receipts using monthly average state prices (USDA-ERS 2022a).

Figure 2 displays cash receipts by commodity, and Figure 3 summarizes the cash receipts in terms of commodity category (animals and products and crops) in 2021 (USDA 2021). "Miscellaneous crops" in Figure 4 include those for which there were insufficient data to forecast cash receipts for that commodity, including dry beans, potatoes, cauliflower, cucumbers, storage onions, peas, peppers, tomatoes, grapes, peaches, pears, blueberries, strawberries, and mushrooms.

Figure 2. New York State Cash Receipts by Commodity in 2021

Source: USDA Economic Research Service, Farm Income and Wealth Statistics, Cash receipts by commodity State Ranking.

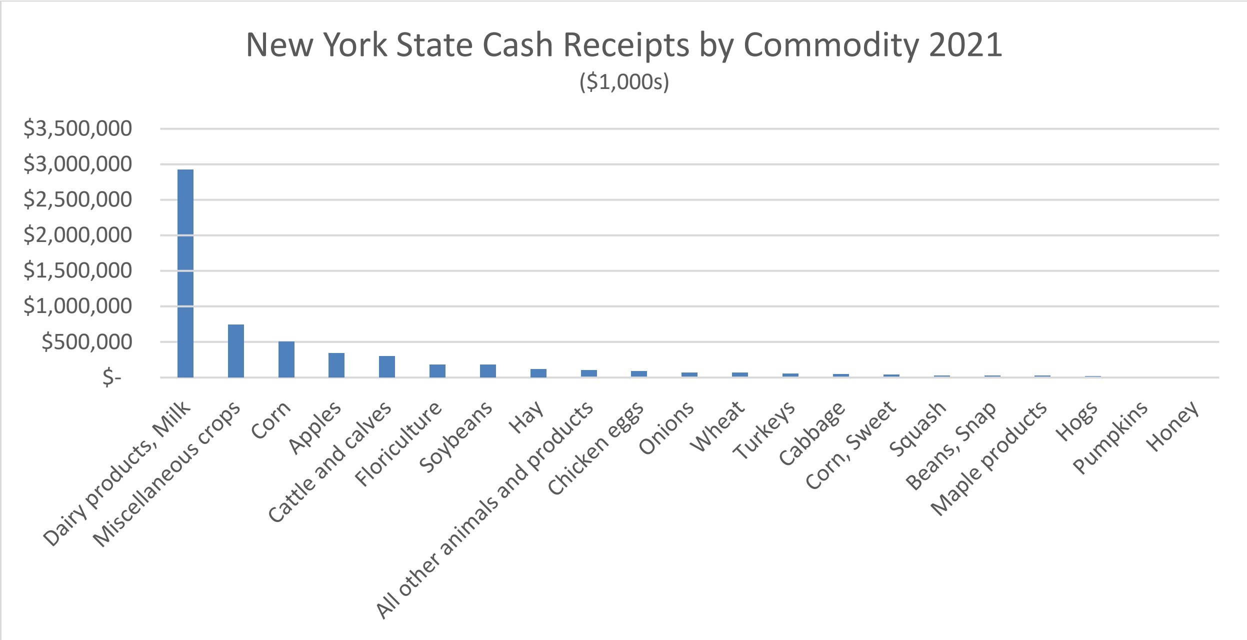

Figure 3. New York State Cash Receipts by Commodity in 2021

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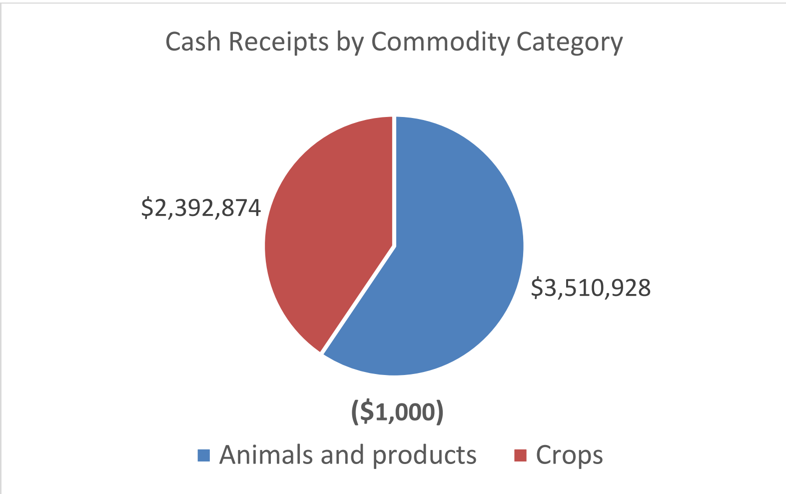
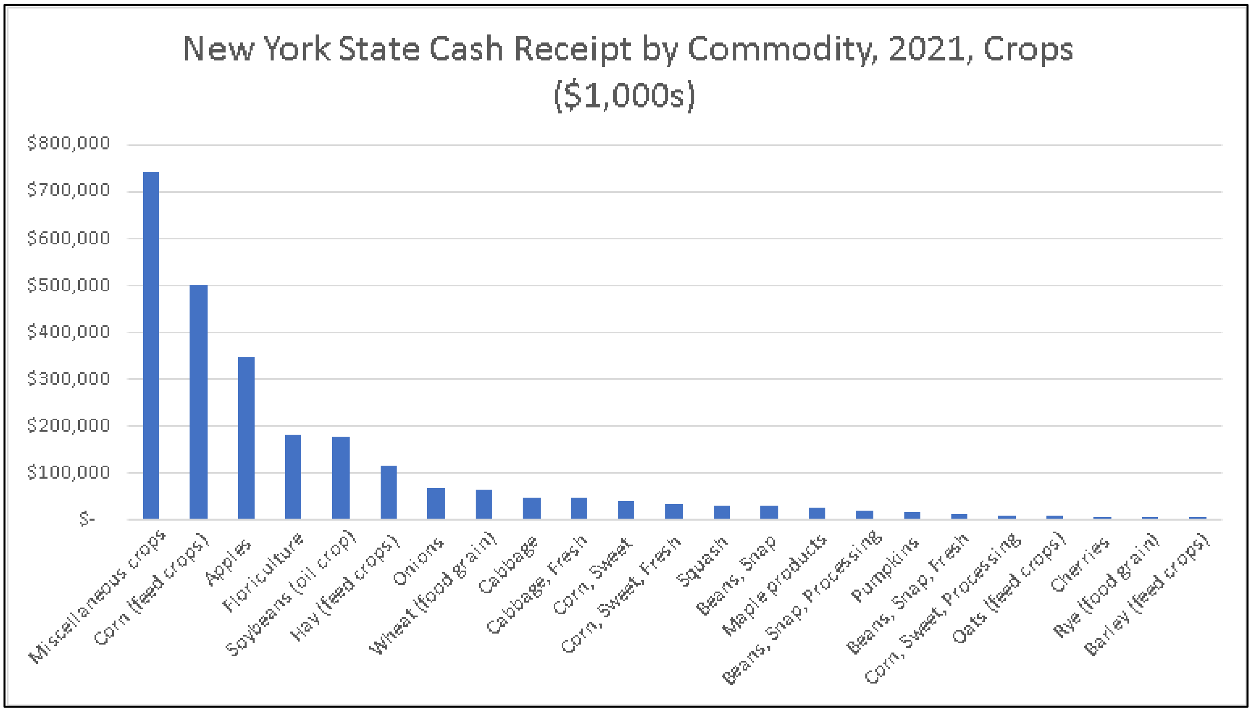


Figure 4. 2021 Cash Receipts by Commodity for Crops Category ($1,000s)



The USDA-NASS 2017 Census of Agriculture provides data on farmland, crop sales, and livestock, poultry, and products sales by New York County (USDA-NASS 2017a). Figure 5 illustrates the total land area in acres per New York Regional Economic Development Council (REDC) retrieved from the 2020 Census Bureau data, and the 2017 total farmland in acres per REDC in descending order of the percentage of farmland by the total land area per REDC. The REDCs with the greatest proportion of farmland per total land area are the Finger Lakes region at 47.8%, the Central New York region at 33.1%, and the Southern Tier region at 27.9%. The North Country, Southern Tier, and Finger Lakes regions have the most land in farms, and North Country, Southern Tier, and the Capital Region have the most land area by county.

Figure 6 depicts the total agricultural sales per REDC according to the 2017 Census. The Finger Lakes region has the most land in acres by farm and also retains the highest in agricultural sales by a significant margin, with over $600,000 more in sales than the second highest region, the North Country. The Southern Tier—in spite of having more land in farms than Western and Central New York—received less sales revenue comparatively. Conversely, while Long Island has comparatively small acreage in farms it achieves similar sales revenue to the Mid-Hudson region, which has over 275,000 more acres in farms.

In 2017, the top 10 counties driving agricultural sales in order were Wyoming (Finger Lakes), Cayuga (Central), Genesee (Finger Lakes), Suffolk (Long Island), Wayne (Finger Lakes), Ontario (Finger Lakes), Steuben (Southern Tier), St. Lawrence (North Country), Livingston (Finger Lakes), and Onondaga (Central), ranging from $307,521,000 to $178,409,000 in sales.

Figure 5. Land Area (Acres) by REDCs and Land in Farms (Acres) by REDCs

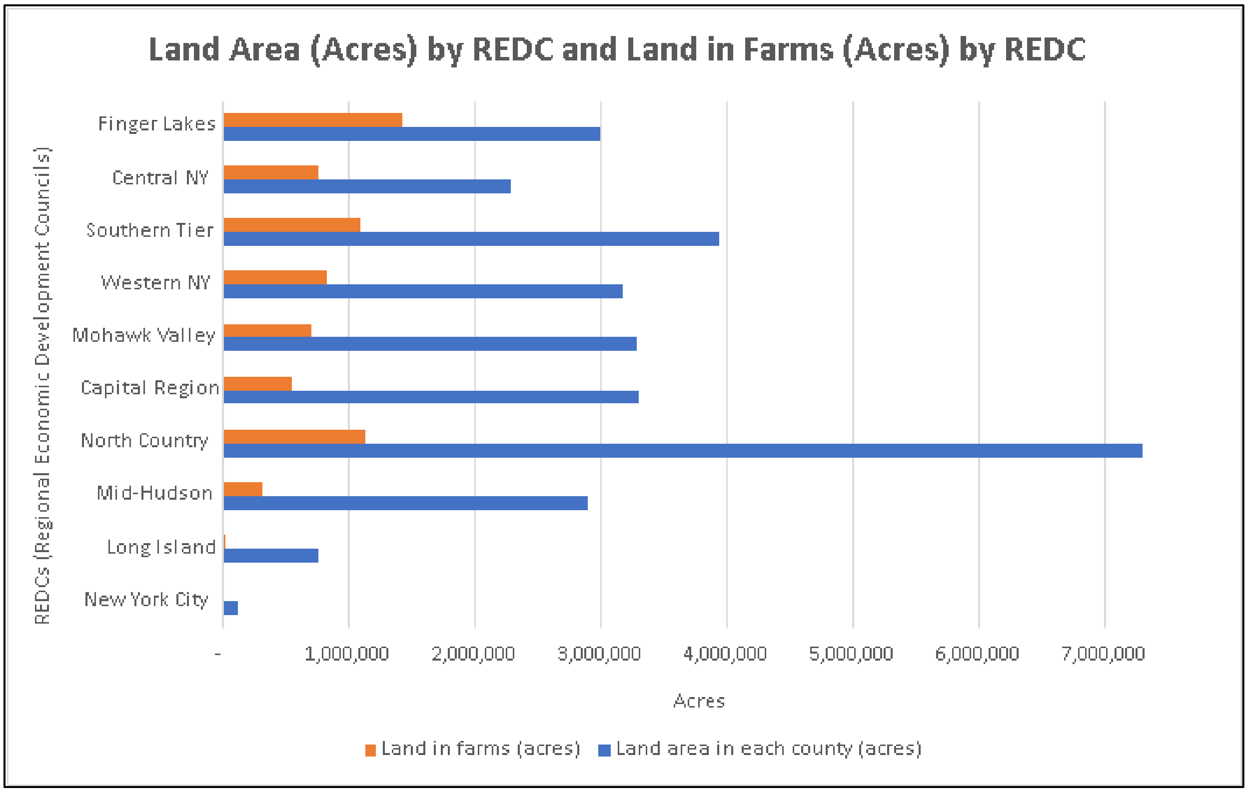


Figure 6. Total Agriculture Sales ($1,000) by REDCs, 2017

Total agricultural sales include crops such as grains, oilseeds, dry beans, and dry peas; tobacco; cotton and cottonseed; vegetables, melons, potatoes, and sweet potatoes; fruits, tree nuts, and berries; nursery, greenhouse, floriculture, and sod; cultivated Christmas trees and short rotation woody crops; other crops and hay and livestock, poultry, and products such as poultry and eggs; cattle and calves; milk and cows; hogs and pigs; sheep, goats, wool, mohair, and goat milk; horses, ponies, mules, burros, and donkeys; aquaculture; and other animals and animal products.

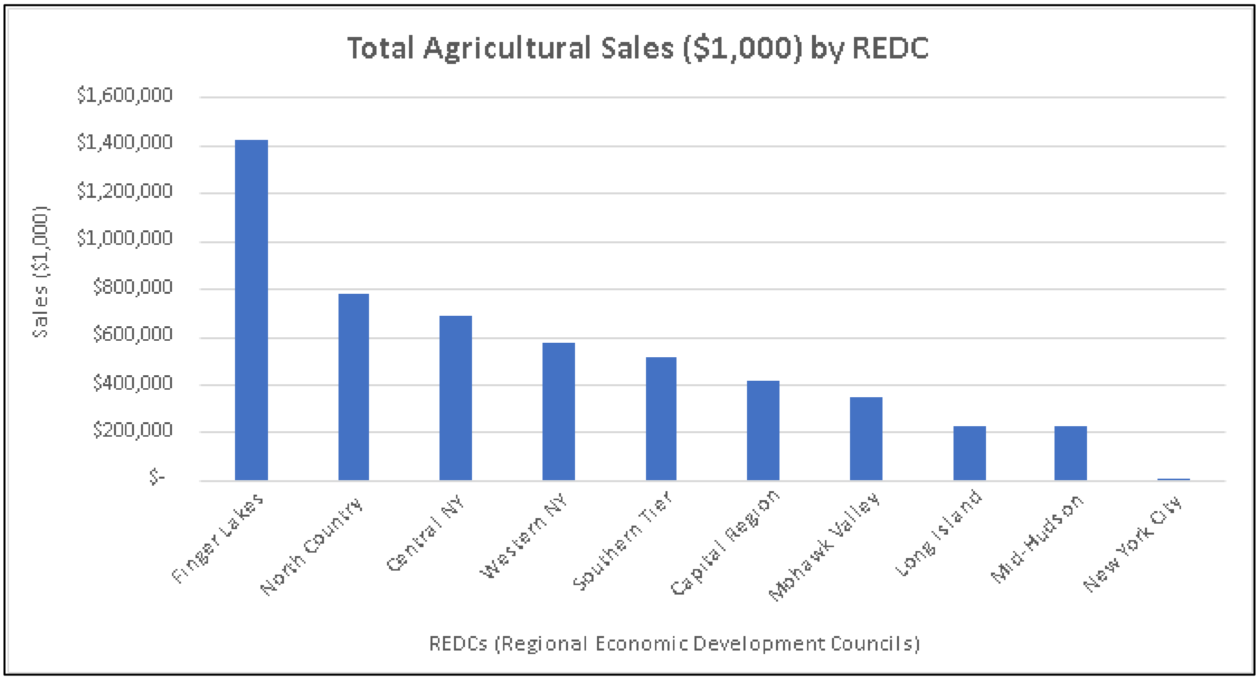


Figure 7 depicts sales related to other crops and hay as well as milk from cows because the category other crops and hay contain crops that are frequently grown in support of the dairy industry. The Finger Lakes, North Country, and Central New York lead on dairy sales. As depicted in Figure 8, the Finger Lakes leads in vegetables, melons, potatoes, and sweet potatoes sales, with over three times as many sales as in the Mid-Hudson region, which had the second most sales for that category. Figure 9 demonstrates that the Finger Lakes and Southern Tier lead in sales for sheep, goats, and affiliated products. Sales from cow's milk far exceed sales across other agricultural commodities. Figure 10 illustrates that the Finger Lakes is the predominant market for fruits, tree nuts, and berry sales with over $180 million in sales in 2017.

Figure 7. Total Other Crops and Hay and Milk from Cows Sales ($1,000) by REDCs, 2017

"Other crops and hay" category includes crops such as grass seed, hay and grass silage, haylage, greenchop, hops, maple syrup, mint for oil, peanuts, sugarcane, and sugar beets.

Source: U.S. Department of Agriculture-National Agricultural Statistics Service, Census of Agriculture. Retrieved from 2017 State and County Profiles – New York:

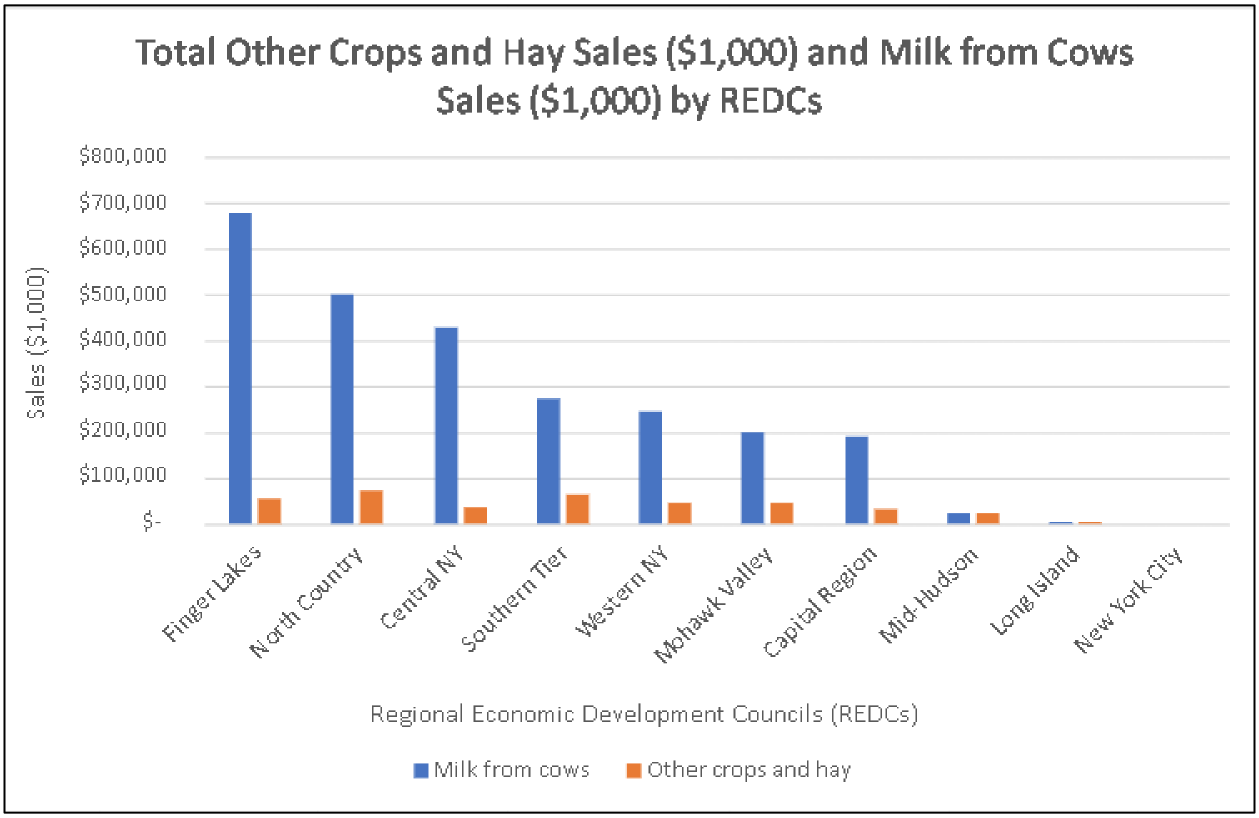


Figure 8. Total Vegetables, Melons, Potatoes, and Sweet Potatoes Sales ($1,000) by REDCs, 2017

Source: U.S. Department of Agriculture-National Agricultural Statistics Service, Census of Agriculture. Retrieved from 2017 State and County Profiles – New York:

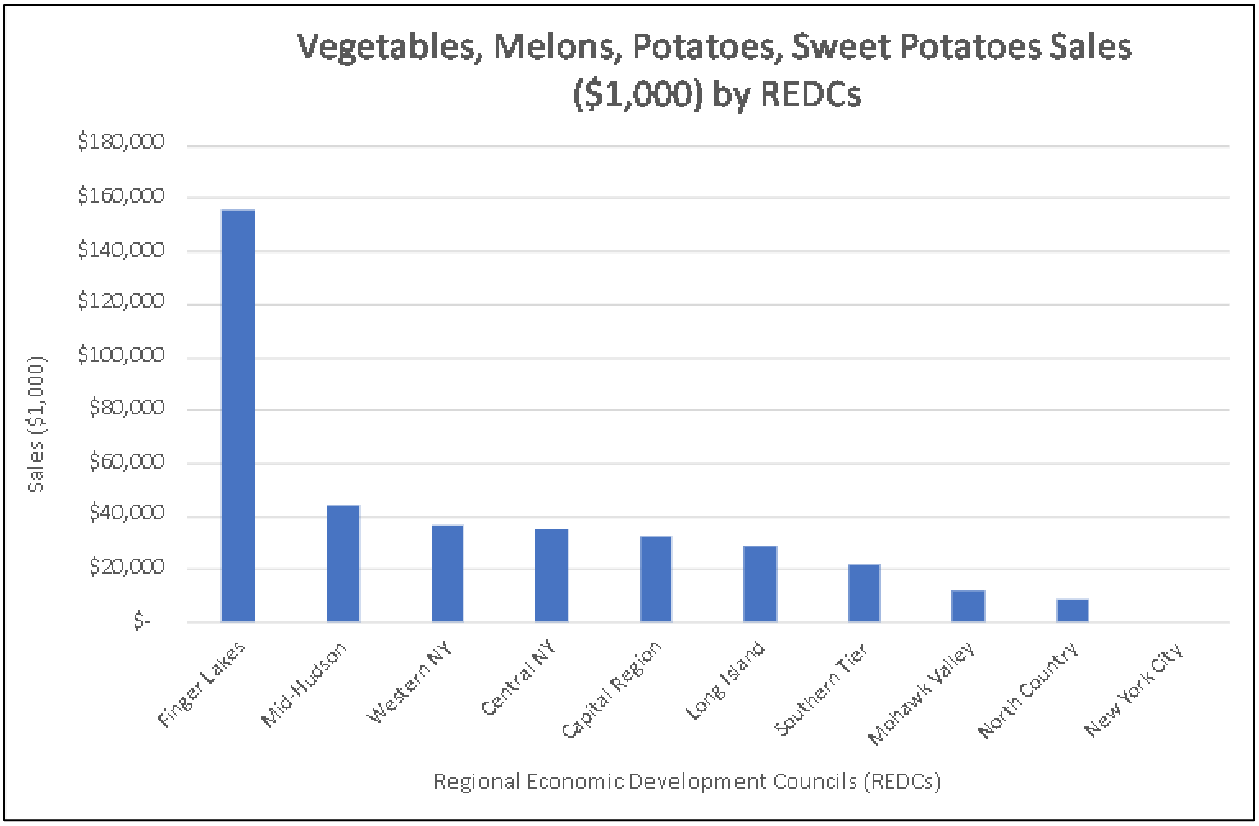


Figure 9. Total Sheep, Goats, Wool, Mohair, and Goat Milk Sales ($1,000) by REDCs, 2017

Source: U.S. Department of Agriculture-National Agricultural Statistics Service, Census of Agriculture. Retrieved from 2017 State and County Profiles – New York:

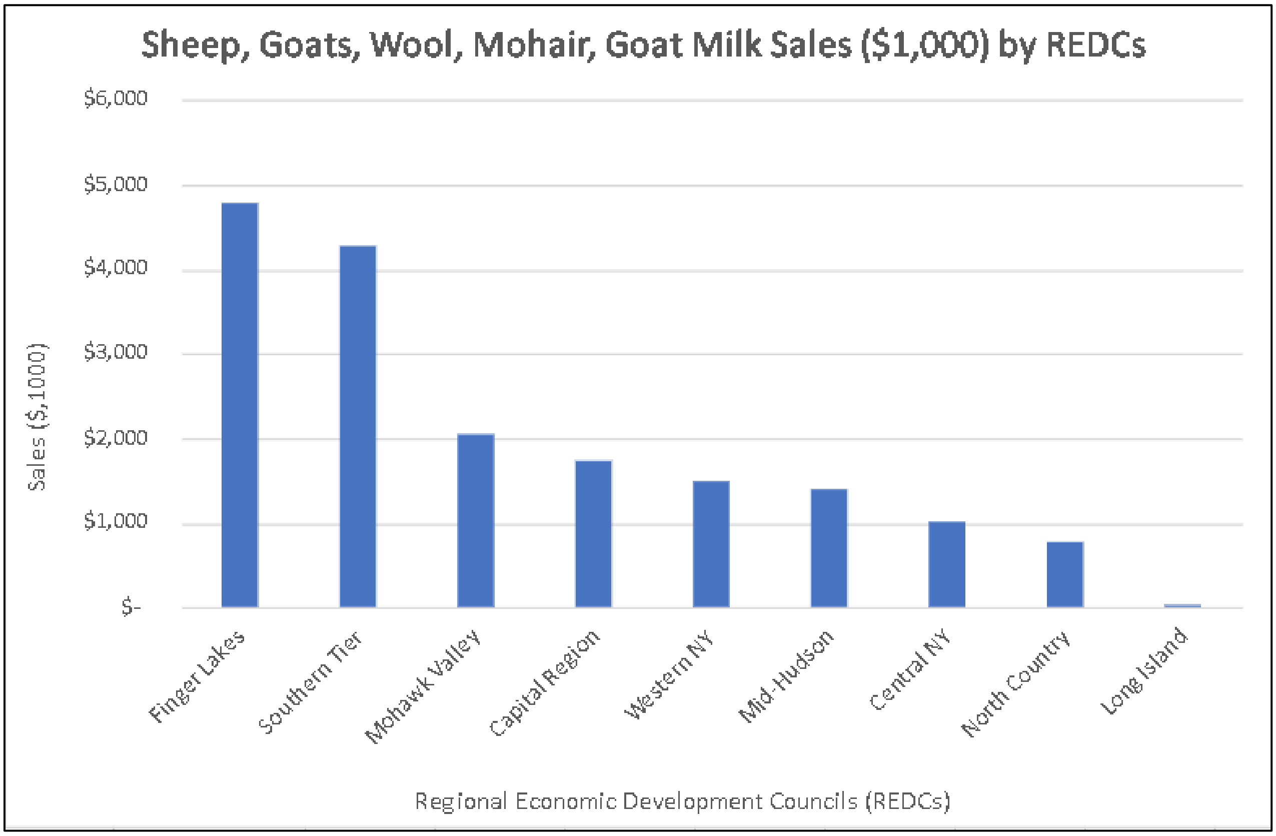


Figure 10. Total Fruits, Tree Nuts, Berries Sales ($1,000) by REDCs, 2017

Source: U.S. Department of Agriculture-National Agricultural Statistics Service, Census of Agriculture. Retrieved from 2017 State and County Profiles - New York:

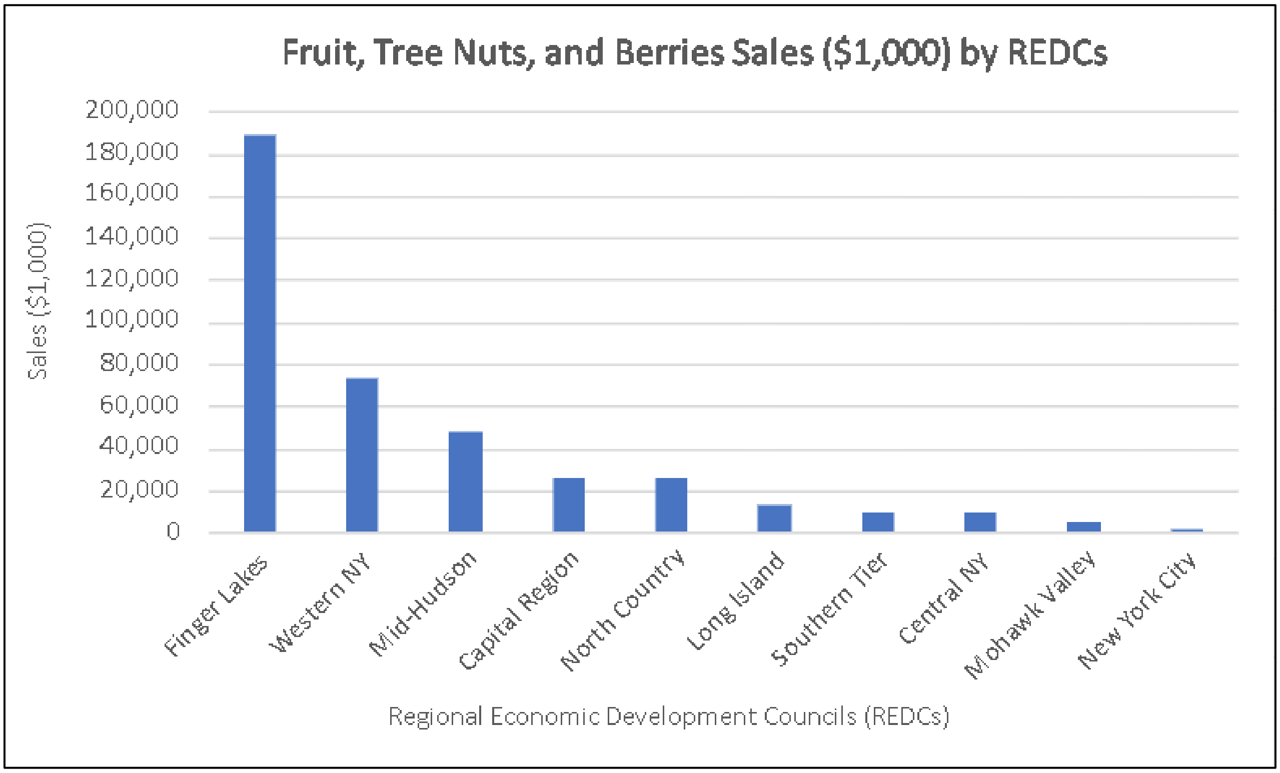
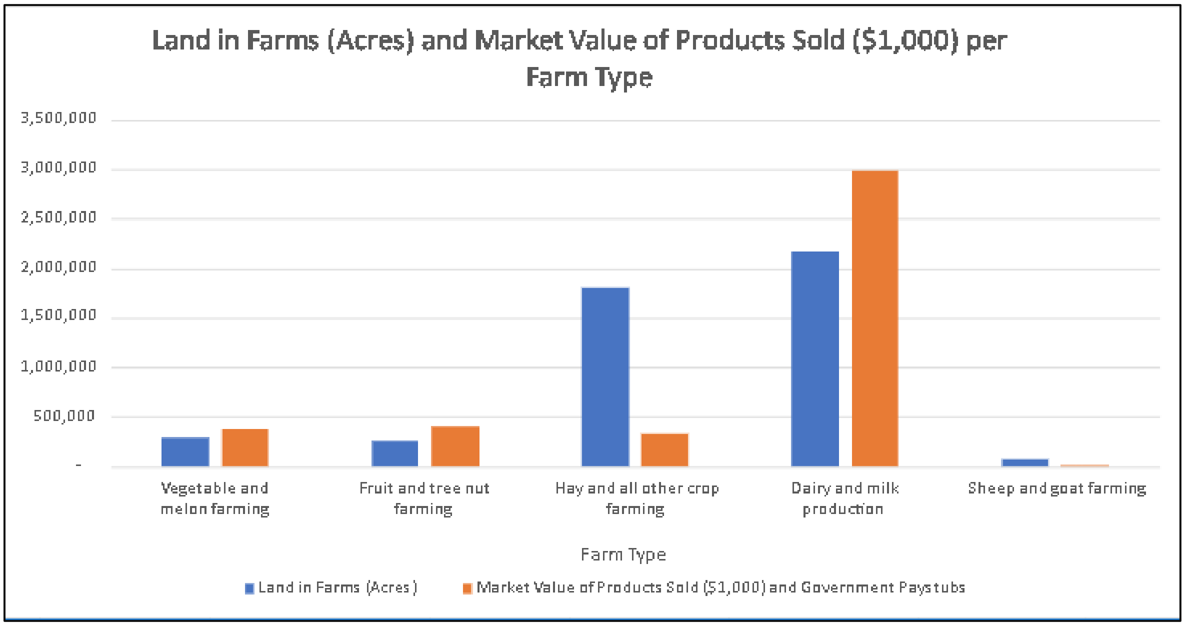


Figure 11 provides select 2017 agricultural census data included in the 2022 New York State Food Supply Resiliency Report. It illustrates the farmland acreage and market value of agricultural commodities sold ($1,000) and government paystubs for select farm types in New York State. Dairy and milk production farms far exceed the other farm types in farmland acreage and sales, with over 2 million acres in farmland and approximately $3 billion sales in 2017. Sheep and goat farming had the smallest amount of farmland acreage and sales with approximately 65,000 acres in farmland and $15 million in sales in 2017. Hay and all other crop farms had the greatest variance between land in farms and sales with approximately 1.8 million acres in farmland and over $335 million in sales in 2017. This is likely due to the fact that hay and forage crops are largely grown for silage to support dairy in concentrated animal feeding operations (CAFOs), rather than for sale.

Figure 11. Land in Farms (Acres) and Market Value of Products Sold ($1,000) per Farm Type in New York State, 2017

Source: New York State Department of Agriculture and Markets. Retrieved from 2022 New York State Food Supply Resiliency Report:



2.4 Exports and Imports

New York State ranks 30th in agricultural exports of U.S. states (USDA-NASS 2017a). In 2017, the State shipped $1.4 billion in domestic agricultural exports abroad (United States Trade Representative 2022). In 2021, the top three export commodities in the State were other plant products (listed as including sweeteners and products, other horticultural products, planting seeds, cocoa, coffee, and other processed foods) with a total value of $581.4 million, dairy products with a total value of $533.1 million, and corn with a total value of $130.9 million. Soybeans reached $98.4 million, feeds and other feed grains (including processed feeds, fodder, barley, oats, rye, and sorghum) was $86.6 million, and other livestock products (including nonpoultry meats, animal fat, live farm animals, and other animal parts) was $84 million (USDA-ERS 2022b). There is not currently a cash receipts-based method providing a similar estimate of foreign imports at the State level (USDA-ERS 2022b).

The New York/New Jersey port is the East Coast's largest port (by volume) and handles about a fifth of U.S. agricultural imports annually. In 2017, the New York/New Jersey port was the number one U.S. waterborne agricultural importer, moving over 8.8 million metric tons of agricultural products. The top crop commodities imported through New York State were coffee at a total of 435,169 metric tons, vegetables at a total of 411,637 metric tons, and rice at a total of 299,275 metric tons (USDA-AMS 2017). The type of vegetable is not specified.

3 Agrivoltaics Programs and Pilots

In the United States, less than 2% of solar energy projects are co-located with crops or pollinator habitats as of 2022 (DOE 2022a). However, this percentage is expected to increase significantly as the United States Department of Energy (DOE), United States Department of Agriculture (USDA), NYSERDA, land grant institutions, solar developers, clean energy nonprofits, and other solar industry stakeholders invest in agrivoltaics and continue to advance understanding of how to co-locate agricultural and solar activities. These efforts are intended to support rural economies and continued agricultural production, while advancing renewable energy to mitigate the impacts of climate change. This section reviews and summarizes proposed or ongoing pilot programs and projects relevant to New York State's solar regulatory activities and programs relating to agrivoltaics and recognizing the importance of a resilient food supply (NYSAGM 2022).

While there is a growing body of international agrivoltaics research focused on design and crop suitability, ecological impacts, and crop yields, current geographically relevant research gaps impede development of resources that will lower the barriers of entry to the adoption of agrivoltaics in the State.

There is a significant gap in research and demonstration necessary to support broad agrivoltaics commercialization. This gap may narrow in the coming years as major pilot projects come online and researchers begin to share early results of the first round of U.S.-based agrivoltaics projects aimed specifically at producing decision support tools for energy and agriculture regulators, solar developers, farmers, tax and finance professionals, and host communities. These tools may help overcome barriers related to informing solar photovoltaic (PV) project infrastructure and site design considerations, understanding farmer willingness and workforce availability to engage in agrivoltaics, assessing agrivoltaics' impact on solar project costs, and model any impacts on the projected cost of electricity to ratepayers. For example, it will be important to better understand the relationships between agrivoltaic integration into project design; cost implications for project development, energy generation, and cost of electricity; and agricultural considerations for yield and overarching farm economics.

This section summarizes existing programs, pilots, and associated deliverables primarily in New York State and the Northeast, with a few other national and global sources. Additional detail is provided for State policies that support agriculture more broadly and may support agrivoltaic activities or uptake. Table 4 summarizes select agrivoltaics initiatives described in section 4 in the order in which they appear below and their applicability and relevance to New York State. Projects that are undertaking or have proposed to undertake agrivoltaic activities are identified as “pilot programs” within the table.

Table 4. Summary of Select Agrivoltaic Programs and Pilots with Relevance to New York State

Name/Location	Type of Approach	Description	Relevance to New York State	References
New York				
Boralex Greens Corners Solar Facility: Dairy and Solar Co-Location Pilot	Pilot Program	The project aims to co-locate farming activities that typically support dairy operations (such as alfalfa cultivation) and to conduct a Dairy and Solar Co-location Pilot featuring agricultural production of haylage in conjunction with manure injection. This project has been initiated and is currently in development.	Projects that intersect with the dairy industry are of particular interest to New York to support understanding of potential opportunities for scale, given the size of NY's dairy industry and supporting agricultural activities. Alfalfa hay production in 2021 in New York State was valued at $125,928,000 (USDA-NASS 2021-2022).	Boralex. (n.d.) Green Corners Solar Project. https://www.boralex.com/projects/greens-corners/Boralex. (2022, January). Agricultural Multi-Use Plan. Greens Corners Solar. Revision 2. https://d25qbug6mu3tt7.cloudfront.net/janupdatemultiuse.pdf USDA-NASS. (2021-2022). Agricultural Statistics Annual Bulletin - New York. Retrieved from New York Agricultural Statistics: https://www.nass.usda.gov/Statistics_by_State/New_York/Publications/Annual_Statistical_Bulletin/2022/2021-2022_NY_Annual_Bulletin.pdf
Morris Ridge Solar Project	Pilot Program	Rotational sheep grazing at utility-scale solar facility. This project is planned.	This project offers understanding of opportunities and constraints associated with implementing sheep grazing at a utility-scale site.	https://ores.ny.gov/permit-applicationshttps://towno/ https://www.townofmtmorris.com/_files/ugd/80e0ed_36a07f0b842e4c62b658293ea8c84e8f.pdf
Moraine Solar Project	Pilot Program	Rotational sheep grazing at utility-scale solar facility. This project is planned.	This project offers understanding of opportunities and constraints associated with implementing sheep grazing at a utility-scale site.	https://ores.ny.gov/permit-applications
Horseshoe Solar	Pilot Program	Rotational sheep grazing at utility-scale solar facility. This project is planned.	This project offers understanding of opportunities and constraints associated with implementing sheep grazing at a utility-scale site.	https://ores.ny.gov/permit-applications

Table 4 continued

Name/Location	Type of Approach	Description	Relevance to New York State	References
Empire State Development Pre-Seed and Seed Matching Fund Program	Program	$30 million Pre-Seed and Seed Matching Fund Program that will grant early-stage start-up companies $50,000 to $250,000 in growth assistance, which they will match with funds from private sector co-investors. This program has been initiated and is ongoing.	Continued monitoring of the program will be required to identify how relevant investments are for supporting farm viability and potential intersection with agrivoltaics.	New York State. (2023, January 5). Governor Hochul Announces Launch of $30 Million Pre-seed and Seed Matching Fund Program. Retrieved from Governor Kathy Hochul: https://www.governor.ny.gov/news/governor-hochul-announces-launch-30-million-pre-seed-and-seed-matching-fund-program
New York State Agricultural Assessment	Law	Under the New York Agricultural Districts Law (enacted in 1971), landowners with qualifying properties are allowed reduced property tax bills for land in agricultural production through "limiting the property tax assessment of such land to its prescribed agricultural assessment value."	At present there is no language that considers potential for land integrating agrivoltaic systems to retain an agricultural assessment.	New York State Department of Taxation and Finance. (2021). Agricultural assessment program: overview. https://www.tax.ny.gov/research/property/assess/valuation/ag_overview.htm
NY Farm Viability Institute	Program	Provides grant money to fund agricultural research and education projects that will improve economic viability of NY farmer. This program has been initiated and is ongoing.	Continued monitoring of the program will be required to identify how relevant investments are for supporting intersection with agrivoltaics.	NY Farm Viability Institute. (n.d.). What We’re About. https://nyfvi.org/what-were-about/

Table 4 continued

Name/Location	Type of Approach	Description	Relevance to New York State	References
NYPA: Sustainable Land Practices Integrating Co-Located Agricultural Land and Solar Power Generation	Research	Awarded $102,000 by the American Public Power Association in 2022 to study sustainable land practices integrating co-located agricultural land and solar power generation.	NYPA released a NY-focused report in February 2023 with recommendations for additional research on agrivoltaics, including need for comparative cost information and need for understanding of how to better connect interested farmers and developers.	American Public Power Association. (2022, March 14). APPA Awards NYPA $102,000 Grant For Agriculture And Solar Energy Production Study. https://www.publicpower.org/periodical/article/appa-awards-nypa-102000-grant-agriculture-and-solar-energy-production-study New York Power Authority and Electric Power Research Institute, Inc. (NYPA-EPRI). 2023. Agrivoltaic Leading Practices. https://info.nypa.gov/Health/Agrivoltaics23.pdf
NYSAGM Programs	Program	NYSAGM features several programs related to farming viability, adaptation to climate change, and soil health. Examples include the Beginning Farmers Grant Program, Economically Disadvantaged Farmers Grant Program, Climate Resilient Farming Program, and New York State Soil Health Initiative. These programs have been initiated and are ongoing.	Continued monitoring of the programs will be required to identify how relevant investments are for supporting farm viability and potential intersection with agrivoltaics.	NYSAGM. (2023). State Agriculture Department Seeking Program Administrators to Manage Two New Grant Funds. January 30, 2023. https://agriculture.ny.gov/news/state-agriculture-department-seeking-program-administrators-manage-two-new-grant-funds. https://agriculture.ny.gov/soil-and-water/climate-resilient-farming New York Soil Health. (n.d.). About New York Soil Health Initiative. https://www.newyorksoilhealth.org/about/

Table 4 continued

Name/Location	Type of Approach	Description	Relevance to New York State	References
NYSERDA: NY-Sun Program	Program	Solar program that provides New York State with multiple resources to enable solar energy uptake in homes, businesses, and communities while lowering energy costs. This program has been initiated and is ongoing.	Key program to continue to review for applications to distributed generation scale agrivoltaic applications.	New York State Public Service Commission (NYSDPS). (2022, April 14). Order Expanding NY-Sun Program. Retrieved From State Of New York Public Service Commission: https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={498EE5D6-6211-4721-BA98-AF40EF3F620C}
NYSERDA: Environmental Research – PON 4270 PV Site Design, Info Gaps and Mitigation Opportunities	Research	The Environmental Research Program has competitively funded six research projects that are currently underway and producing data on crop and grazing potential, environmental and species use and mitigation opportunities, and optimal siting design considerations for large, solar PV projects.	Key initiatives to continue to review to integrate lessons learned from ongoing research.	NYSERDA. (2022, April). Policy & Science Advisor UPDATE Environmental Research Q1 2022 [PowerPoint slides]. https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Environmental-Research/Q1-2022-Environmental-Research-Policy--Science-Advisor-Newsletter.pdf
NYSERDA: Renewable Energy Standard Large-Scale Renewable (LSR) Tier 1 Program	Program	The Large-Scale Renewables Program supports the Clean Energy Standard by supporting New York's renewable energy resources. This program has been initiated and is ongoing.	The land-based Tier-1 program's Smart Solar Siting Scorecard and Agricultural Mitigation Payment Deferral mechanism provide market signals to the solar industry that encourage co-utilization and agrivoltaic initiatives in the development of renewable energy projects.	https://www.nyserda.ny.gov/all-programs/clean-energy-standard/renewable-generators-and-developers/res-tier-one-eligibility/solicitations-for-long-term-contracts

Table 4 continued

Name/Location	Type of Approach	Description	Relevance to New York State	References
Northeast States				
Maine Agricultural Solar Stakeholder Group	Research	Created to make policy recommendations to balance the need to protect Maine's current and future farmland against the need to develop sources of renewable solar energy. Released report based on research and discussions with seven recommendations.	Recommend continued monitoring for relevance to NYS.	State of Maine. (2021). Agricultural Solar Stakeholder Group Past Meetings. Maine, USA. https://www.maine.gov/energy/studies-reports-working-groups/current-studies-working-groups/agricultural-solar-stakeholder-group/past-meetings State of Maine. (2022). Final Report of the Agricultural Solar. Maine Governor's Energy Office. https://www.maine.gov/energy/studies-reports-working-groups/current-studies-working-groups/agricultural-solar-stakeholder-group/past-meetings
Solar Massachusetts Renewable Target (SMART)	Program	Promotes installation of certain types of grid-connected solar photovoltaic (PV) arrays through incentives based on a fixed price per kWh of electricity generated. Promotes installation of grid connected solar projects with incentives for agrivoltaics. Specific kinds of dual-use systems can qualify for financial incentives under the SMART program; the land must be under continuous agricultural use for the 20-year program period. This program has been implemented and is ongoing.	Offers opportunity to gain lessons learned from implementation of a tariff-based approach to incentivize agrivoltaics projects.	Mass.gov. (n.d.). Solar Massachusetts Renewable Target (SMART) Program. https://www.mass.gov/info-details/solar-massachusetts-renewable-target-smart-program UMass Amherst. (2022a, February). Clean Energy Extension. Center for Agriculture, Food, and the Environment. https://ag.umass.edu/clean-energy/fact-sheets/dual-use-agriculture-solar-photovoltaics

Table 4 continued

Name/Location	Type of Approach	Description	Relevance to New York State	References
UMASS Clean Energy Extension	Research	Created a coordinated network of agrivoltaics stakeholders; awarded a three-year, $1.8 million award to study the effects of agrivoltaics on farms across the Commonwealth of Massachusetts.	Advances understanding of criteria necessary for viable, compatible dual use of agricultural land and solar installations over a range of agricultural production and conditions.	UMass Amherst. (2020, December 2). UMass Amherst Study Will Assess Impact of Dual-Use Solar Agriculture Installations in Massachusetts. https://www.umass.edu/news/article/umass-amherst-study-will-assess-impact photovoltaics
Massachusetts General Law c.61A: Assessment and Taxation of Agricultural and Horticultural Land	Legislation/Policy	Permits agricultural land to be used for agrivoltaics; amended in 2022 by enacting "An Act Driving Clean Energy and Offshore Wind," which allows solar energy facilities that qualify in accordance with a solar incentive program for agriculture to participate. Massachusetts policy does not require the same agriculture to exist post-solar and pre-solar.	Provides example for how New York State may consider adjusting its agricultural assessment law.	Commonwealth of Massachusetts. (2022, August). An Act Driving Clean Energy and Offshore Wind. Chapter 179: https://malegislature.gov/Laws/SessionLaws/Acts/2022/Chapter179
Innovative Solar Practices Integrated with Rural Economies and Ecosystems (InSPIRE) / University of Massachusetts – Amherst Grafton Solar Research Project	Pilot Program	A research site trial for DOE SETO; supporting peppers, kale, broccoli, beans and chard on Knowlton Farm. This program has been implemented and is ongoing.	The Grafton Solar pilot project is directly applicable to New York State, as the State explores opportunities for grazing cattle, as well as production of crops suited for growth and market in the State. New York ranked third for squash in the Northeastern States' Ranking in the Nation's Agriculture.	Hince. S. (2022, November 21). Farmland, Family, and the Future of Solar Energy. AgriSolar Clearinghouse. https://www.agrisolarclearinghouse.org/farmland-family-and-the-future-of-solar-energy/ Sullivan, M. (2022, September 21). Grafton Discusses Growing Crops under Solar Panels. Community Advocate. https://www.communityadvocate.com/2022/09/21/grafton-discusses-growing-crops-under-solar-panels/ AES. (n.d.). Grafton Solar. https://www.aes.com/grafton-solar

Table 4 continued

Name/Location	Type of Approach	Description	Relevance to New York State	References
New Jersey Dual-Use Solar Act/Dual-Use Pilot Program	Legislation/Policy and Program	Established the Dual-Use Energy Pilot Program for unpreserved farmland. Enables a limited number of farmers to have agrivoltaic systems on their property while the technology is being tested, observed, and refined. Eliminates restrictions for agricultural assessment that indicate acreage devoted to solar generation infrastructure cannot exceed 10 acres.	Results may inform considerations for how New York State may adjust its agricultural assessment law.	New Jersey Legislature. (2021, June 15). Retrieved from Senate Environment and Energy Committee Statement to Senate Committee Substitute for Senate, No. 3484. https://www.njleg.state.nj.us/bill-search/2020/S3484/bill-text?f=S3500&n=3484_S1
Rutgers Agrivoltaics Program	Program	Formed a committee to design, construct, and conduct research and outreach for agrivoltaics. This program has been implemented and is ongoing.	Intentions aligned with those of AGV SC and A-TWG. Resulting initiatives may be relevant to NYS agricultural context.	Rutgers. (n.d.). Rutgers Agrivoltaics Program. EcoComplex – Clean Energy Innovation Center: https://ecocomplex.rutgers.edu/agrivoltaics-research.html
Rutgers: Agrivoltaic Systems for Diversified Agriculture: A Project to Increase Technical Understanding of Agrivoltaics and Develop Novel Outreach Strategies for Farms Near Culturally Diverse Metropolitan Areas	Research	Will use funding to conduct trials at three solar array testbeds, where researchers are studying the growth of 11 different crops, grazing practices, and community perceptions of agrivoltaics.	Design configurations and crop selection support continued understanding of feasibility.	Department of Energy Solar Energy Technologies Office (SETO). (n.d.). Foundational Agrivoltaic Research for Megawatt Scale (FARMS) Funding Program. Retrieved from Solar Energy Technologies Office. https://www.energy.gov/eere/solar/foundational-agrivoltaic-research-megawatt-scale-farms-funding-program

Table 4 continued

Name/Location	Type of Approach	Description	Relevance to New York State	References
Vermont Agency of Agriculture, Food & Markets (VAAFM)	Program	Supports the viability and growth of agriculture in Vermont while protecting the working landscape, human health, animal health, plant health, consumers, and the environment. This program has been implemented and is ongoing.	Continued monitoring of the program may provide additional detail to support understanding of feasibility for agrivoltaics.	National Association of State Departments of Agriculture. (2022). Vermont Agency of Agriculture, Food & Markets. https://www.nasda.org/state-department/vermont-agency-of-agriculture-food-markets/
InSPIRE Vermont Saffron Site	Research	Study results showed that saffron can be grown successfully within solar fields and provide significant agricultural revenues.	Saffron cultivation has not yet begun in New York State at a commercial level. However, recent studies have proven that saffron could survive and produce an acceptable yield in the northeastern U.S. climate (Brown 2021). Currently saffron is sold in the U.S. for approximately $5,000/lb. (Agriculture, N.C. 2021).	AgriSolar Clearinghouse. (2022, January 27). Case Study: Saffron and Solar Farms. Retrieved from https://www.agrisolarclearinghouse.org/case-study-saffron-and-solar-farms/
Maple Ridge Meats	Research	Successfully grazed cows under solar panels by raising the height of solar arrays.	Demonstrates potential for agrivoltaics, including dairy farms and sheep grazing.	Opalka, B. (2019, February 5). Renewable energy growing among Vermont's animals and crops. https://energynews.us/2019/02/05/renewable-energy-growing-among-vermonts-animals-and-crops/
Maryland Community Solar Bill	Legislation	This bill establishes tax incentives for qualifying community solar projects to develop agrivoltaic programs where qualifying properties are exempt from county and municipal property taxes. Qualifying projects must provide at least 50% of the energy generated to low or moderate-income customers at a rate that is at least 20% lower than the base electricity rate.	Results may inform considerations for how New York State may adjust its agricultural assessment law.	Article II, Section 17I of the Maryland Constitution (Chapter 659)

Table 4 continued

Name/Location	Type of Approach	Description	Relevance to New York State	References
Federal				
DOE Solar Energy Technologies Office (SETO)	Research	Accelerates the advancement and deployment of solar technology in support of an equitable transition to a decarbonized economy; focuses both on research activities and commercialization activities.	New York State farmers or solar developers could apply for funding for pilot projects.	DOE. (2022b, January 10). Office of Energy Efficiency & Renewable Energy Solar Energy Technologies Office. USDA-DOE Agrivoltaics Workshop. https://www.agrisolarclearinghouse.org/wp-content/uploads/2022/01/2022_USDA-SETO_Agrivoltaics_Workshop_-_Compiled-r.pdf
InSPIRE Registered Agrivoltatics and Research Sites	Research	Seeks to improve the environmental compatibility and mutual benefits of solar development with agriculture and native landscapes InSPIRE explores solar and environmental synergies through four core research areas: • Co-locating solar projects on agricultural lands for mutual benefits. • Long-term ecosystem impact assessments. • Low-impact site preparation practices for ground-mounted solar projects. • Economic evaluation of solar and agricultural systems.	Offers ability to review ongoing research and pilots projects related to crops production, grazing, and ecosystem services across the United States. Continues to aggregate projects nationwide by voluntary submission.	InSPIRE (2020, August). Low-Impact Solar Development Strategies Guidebook. https://openei.org/wiki/InSPIRE/Guidebook

Table 4 continued

Name/Location	Type of Approach	Description	Relevance to New York State	References
DOE FARMS Research Sites	Research	Funding opportunities to reduce barriers to utility-and-community-scale solar energy deployment while maximizing benefits for farmers and local communities.	While none of the 2022 awardees are located in New York State, several projects are of interest to monitor for potential application to NYS, including Iowa State University's project that will model variations based on different design configurations; Ohio State University's project looking at animal health and productivity and integrate livestock and hay production trials; and the previously mentioned Rutgers University project.	Department of Energy-Solar Energy Technologies Office (DOE-SETO). (n.d.). Foundational Agrivoltaic Research for Megawatt Scale (FARMS) Funding Program. Retrieved from Solar Energy Technologies Office. https://www.energy.gov/eere/solar/foundational-agrivoltaic-research-megawatt-scale-farms-funding-program
USDA Climate Hubs	Program	Collaboration across USDA agencies designed to link USDA research and program agencies in delivery of information to agricultural professionals and producers. This program has been implemented and is ongoing.	The program should continue to be monitored to identify application to agrivoltaics.	US Department of Agriculture (USDA). (n.d.-a). What are the USDA Climate Hubs? https://www.climatehubs.usda.gov/about-us
Inflation Reduction Act (IRA)	Legislation/Policy	Will provide nearly $369 billion in investments towards clean energy and climate action.	IRA funding streams should continue to be monitored for potential application to agrivoltaics.	The White House. (2023, January). Building a Clean Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action. https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/

3.1 New York State Programs and Pilots

3.1.1 Empire State Development Pre-Seed and Seed Matching Fund Program

On January 5, 2023, Governor Hochul announced the launch of the $30 million Pre-Seed and Seed Matching Fund Program that will grant early-stage, start-up companies $50,000 to $250,000 in growth assistance, which they will match with funds from private sector co-investors, stating that: "The Pre-Seed and Seed Matching Fund Program will help these businesses gain their footing and create the jobs of the future while expanding access to funding in traditionally underserved communities." This program focuses on technology markets including agricultural tech and climate tech, among others (New York State 2023), which could include agrivoltaics.

3.1.2 Executive Law Section 94-c Co-Utilization Plans

For solar projects greater than 25 MWac, the 94-c Process has permitted 12 solar projects as of May 2023 (ORES n.d.-b). Of these, four have elected to include agricultural co-utilization plans within their permit applications. These projects include the Greens Corners Solar Facility, Morris Ridge Solar Project, Moraine Solar Project, and the Horseshoe Solar project, each of which is described briefly below. The identified tentative commercial operation dates for each of these projects is 2024, with the exception of the Moraine Solar Project which has a commercial operation date of 2025. Each of these permitted projects provides future opportunities to assess opportunities and constraints of integration of agrivoltaic activities into largescale projects. Other permitted projects have signaled intent to pursue co-utilization activities once each respective project is in operation. The 100-MWac Riverside Solar project being developed in Jefferson County, for example, indicates in its permit application that co-utilization activities will be pursued if determined feasible and that, if so, AES may prepare an Agricultural Co-Utilization Implementation Plan prior to commencement of affiliated activities. Similarly, the 90-MWac Homer Solar Energy Center being developed in Cortland County and the 119-MWac Tracy Solar Energy Center in being developed in Jefferson County indicate plans to discuss co-utilization opportunities with landowners based on site-specific needs.

The Greens Corners solar facility is a 120-MWac project being developed in the Towns of Hounsfield and Watertown in Jefferson County, NY. The fenced area is anticipated to enclose 1,070 acres. Developer Boralex indicates the majority of the site is currently agricultural land used for corn, soybeans, hay, and cattle, with additional corn, soybean, and hay operations in the surrounding area (Boralex n.d.). The Agricultural Multi-Use Plan describes integration of multiple agricultural activities which will be facilitated with support from a new Greens Corners Working Group anticipated to include representation by landowner, government, academic, and agricultural stakeholders. The project aims to co-locate farming activities that typically support dairy operations (such as alfalfa cultivation) and to conduct a Dairy and Solar Co-location Pilot featuring agricultural production of haylage in conjunction with manure injection (Boralex 2022). Injection allows for manure application to growing crops (grass, alfalfa, cover crops, etc.). The pilot seeks to prove that farmland that hosts solar can also be used to directly support a dairy operation. The project also includes a carbon sequestration pilot project and inclusion of commercial beekeeping. The Greens Corners Solar project is designed with two-in-portrait (2P) single-axis tracking solar panels (two PV modules installed in portrait along the racking support structure's torque tube), which would track the sun through the day on the north-south axis. The panels would be installed with an approximately 42-foot pitch that equates to an approximate minimum row spacing of 28 feet of open space between the rows when the panels are rotated zero degrees (i.e., table-top position or flat). The relationship of the solar panels to the perimeter fence was designed to accommodate approximately 35 feet of space between the ends of the rows and the fence line (LLC, G. C. 2022).

The Morris Ridge Solar Project is a 177-MWac project, under development in the town of Mount Morris in Livingston County, NY, anticipated to occupy approximately 1,060 acres. The project includes an Agricultural Integration Plan for managed sheep grazing and beekeeping (EDF Renewables 2020). To achieve this, the project plans to employ a rotational grazing system where sheep are moved as a group from one pastured area inside fenced arrays to the next. The project also plans to accommodate honeybees and honey production by incorporating pollinator-friendly vegetation and bee yards into the design. The bee yards will allow regional beekeepers a commercial scale space for honey production.

The Moraine Solar Project is a 94-MWac project under development in the Town of Burns in Allegany County, NY, anticipated to occupy approximately 594 acres (EDF Renewables 2022a). The project included in its permit application an Agricultural Co-Utilization Plan that describes how the project is being designed for compatibility with managed sheep grazing. The project plans to employ a rotational grazing system where sheep are moved as a group from one pastured area inside fenced arrays.

The Horseshoe Solar project is a 180-MWac project under development in the Town of Caledonia in Livingston County, and the Town of Rush in Monroe County, NY, anticipated to occupy approximately 1,300 acres. According to the Agricultural Integration Plan filed with its permit application, the project plans to implement a rotational grazing system where sheep are moved as a group from one pastured area inside fenced arrays.

Additional detail on the co-location of sheep grazing and agrivoltaics is provided in section 4.2.

3.1.3 New York Power Authority Sustainable Land Practices

In 2022, the New York Power Authority (NYPA) was awarded $102,000 by the American Public Power Association to Study Sustainable Land Practices Integrating Co-Located Agricultural Land and Solar Power Generation (American Public Power Association 2022). Funding through a Demonstration of Energy & Efficiency Developments grant will empower NYPA, in collaboration with the Electric Power Research Institute (EPRI), to encourage the establishment of best practices that will enable farmers, communities, solar developers, industry partners, equipment vendors, utilities, and other stakeholders to better understand the benefits of sustainable land-use practices and co-location of agriculture with solar generation. NYPA and EPRI released the report funded through this opportunity on February 16, 2023, which included a literature review, followed by stakeholder interviews and farmer surveys. The report also provides recommendations for additional research on agrivoltaics, including the need for additional comparative analysis of costs of conventional designs versus those that accommodate agrivoltaics, better understanding of community impact of agrivoltaics, methods for connecting solar developers to interested farmers, and how agrivoltaics may engage interest among new farmers (NYPA-EPRI 2023).

In May 2023, the New York State Build Public Renewables Act was passed, giving NYPA authority to own, operate, plan, construct, and finance renewable energy projects. Under this act, NYPA is to help lead the State's effort to decarbonize the grid and provide 70% of the State's renewable energy by 2030, be the provider of energy to all State-owned and municipal properties by 2035, and create a zero-emission statewide electrical system by 2040 (NYPA 2023a). Pursuant to the Act, NYPA will prioritize funding, siting, building, and owning renewable energy projects that actively benefit disadvantaged communities as defined by the climate justice working group, minimize harm to wildlife, ecosystems, public health and public safety, do not violate indigenous right or sovereignty and which are the most cost-effective to the State according to the best available cost modeling research.

3.1.4 New York State Agricultural Assessment

Under the New York Agricultural Districts Law (enacted in 1971), landowners with qualifying properties are allowed reduced property tax bills for land in agricultural production through "limiting the property tax assessment of such land to its prescribed agricultural assessment value" (New York State Department of Taxation and Finance 2021). Farmland that has received an agricultural assessment must remain in agricultural use for the next five years if located inside an Agricultural District or eight years if located outside of an Agricultural District. (NYSERDA 2023).

A conversion penalty will likely be imposed if farmland subject to such an assessment is converted to nonagricultural use within the five or eight years outlined above. Conversion penalties are equal to five times the taxes saved in the most recent year that the land received an agricultural assessment, plus interest. No conversion penalty is imposed if agricultural land is converted for oil, gas, or wind energy development that does not support agricultural production. However, because solar energy is not included in this exemption, a conversion penalty could apply if the electrical output of solar equipment substantially exceeds (e.g., is more than 110% of) a farm's anticipated electrical needs. Conversion payments generally become the landowner's responsibility at the time of conversion, although solar project developers will typically cover these costs as a part of their contract with the landowner (NYSERDA 2023). Since the agricultural assessment program was developed long before the novel agrivoltaic project types that are pursing the production of crops, livestock, or livestock products, according to AML 25-AA 301(2), some stakeholders have expressed uncertainty about how the local tax assessor may view such a project in light of an agricultural assessment application.[2] The A-TWG recommends that the State establish clear statewide tax guidance for agrivoltaics.

See sections 3.2.2 and 3.2.5 for information on how other states are altering their agricultural assessment processes to, in some circumstances, retain tax benefits for solar projects that integrate active agricultural activities.

3.1.5 NY Farm Viability Institute

The NY Farm Viability Institute (NYFVI) is a nonprofit grantmaking organization focused on improving the economic viability of New York State farmers through agricultural research and education projects. As of 2021, NYFVI had supported 302 projects across three grant programs: FVI, a farm viability program that awards approximately $1.5 million per year; a dairy program, which

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2 New York State Department of Taxation and Finance. Property tax forms – Agricultural assessment. https://www.tax.ny.gov/forms/orpts/agri_assessment.htm

provides support to individual farms; and a USDA specialty crop block grant, administered on behalf of NYSAGM. A new grant program was announced in 2023 geared toward assisting NYS food producers, processors, and other entities in bringing agricultural products to market (NYFVI 2021, NYFVI 2022, NYFVI 2023). Future grant projects may further research related to feasibility and reasonability of agrivoltaics projects in the State.

3.1.6 New York State Department of Agriculture and Markets Programs

NYSAGM is launching two new grant programs that may support farmers with exploring agrivoltaics, including a $1 million Beginning Farmers Grant Program and a $4 million Socially and Economically Disadvantaged Farmers Grant Program (NYSAGM 2023b).

In 2015, NYSAGM launched a Climate Resilient Farming Program focused on both mitigation of and adaptation to climate change. The program has awarded $12 million since it began (NYSAGM 2022). While awards to date have not included agrivoltaic elements, it is possible this program may be used to support initiatives related to agrivoltaics in the future (NYSAGM n.d.-b).

The New York State Soil Health Initiative, administered through NYSAGM, aims to facilitate farmer adoption of healthy soil practices through building on existing strengths and momentum of stakeholders. Its mission focuses on recruiting farmers to collaborate around monitoring and documenting soil health benefits, understanding economic benefits of soil health, creating outreach materials and supporting practitioner trainings, and developing a soil health “roadmap” for NYS (New York Soil Health n.d.). This program may support growth of knowledge for incorporating ecosystem services into agrivoltaics projects.

3.1.7 NYSERDA NY-Sun Program

NY-Sun is a NYSERDA solar program that provides the State with multiple resources that allow it to utilize solar energy for its homes, businesses, and communities while lowering energy costs. The New York State Public Service Commission Order expanding the NY-Sun Program notes, in reference to commenters recommending establishment of an incentive adder for agrivoltaics: “The Commission continues to support the establishment of an agricultural program to offer support and incentives to projects that are designed to maximize agricultural and environmental co-benefits. […] NYSERDA and Staff are directed to evaluate the potential for such an adder (whether on a stand-alone basis, or as an expansion of an existing adder focused on beneficial siting) and submit a proposal for Commission consideration if such an adder is deemed necessary and reasonable" (NYSDPS 2022, 49).

3.1.8 NYSERDA Environmental Research Program

In 2020, NYSERDA released Program Opportunity Notice (PON) 4270: Environmental ResearchPV Site Design, Info Gaps, & Mitigation Opportunities. This PON resulted in the Environmental Research Program competitively funding six research projects which are currently underway and producing data on crop and grazing potential, environmental and species use and mitigation opportunities, and optimal siting design considerations for large solar PV projects. The first project under PON 4270 considered here is a study of the agro-economic and environmental impacts of co-location of solar and agriculture. Under this project, the American Solar Grazing Association (ASGA) in collaboration with AgriSolar Consulting, would collect and analyze data on the agricultural, economic, and environmental impacts of co-locating agricultural enterprises such as commercial beekeeping and sheep grazing on PV sites. Data will be collected during the 2022 and 2023 grazing season, with reports and outreach anticipated in 2023 and 2024 (NYSERDA-ASGA n.d.).

Under this PON, the second project consists of a team at Cornell conducting microclimate monitoring research to determine land-use optimization of agrivoltaics for low-impact PV site designs. A key aspect of the work includes researchers engaging with the solar industry and NGOs to obtain site access to solar farms and develop collaborative partnerships. The lead researcher at Cornell leveraged this work with NYSERDA and was recently awarded a $1.5 million grant through the DOE Deploying Solar with Wildlife and Ecosystem Services Benefits program. The project will look at developing the first holistic framework to assess the costs and benefits of ecosystem services from solar facilities and influence how solar farms are designed, constructed, and operated to maximize benefits and minimize impacts to wildlife and ecosystems. The DOE grant will allow the team to continue the work funded by NYSERDA, which will provide a jumpstart to the project and bring real benefits to State solar farms, wildlife, and ecosystems.

The third project consists of research lead DNV GL assessing avian use of PV solar energy facilities through the specific lens of biodiversity, community composition, and conservation significance. The primary objective of the project is to better understand how PV systems can impact avian species behaviors and communities within or adjacent to a PV system. Additionally, this project will assess what landscape factors influence avian biodiversity at different spatial scales (NYSAGM 2022b).

The fourth project under this PON, led by Tetra Tech, Inc., will assess three concerns that often come up during the utility-scale siting process in New York State: the effects of utility-scale solar on groundwater hydrology and threatened and endangered wintering raptor and grassland bird species. Between November 2021 and March 2022, Tetra Tech conducted a wintering raptor survey at one of three sites where it is also performing grassland breeding bird surveys. Tetra Tech has also been conducting a groundwater hydrology study since April 2021, measuring groundwater levels, temperature, and pressure as well as air temperature and pressure measurements at another one of the three sites (NYSERDA 2022; NYSAGM 2022b).

3.1.9 NYSERDA Renewable Energy Standard Large-Scale Renewable (LSR) Tier 1 Program

The promotion of a vibrant agricultural economy is an important policy goal of New York State. NYSERDA recognizes the importance of collaboration between the agriculture and clean energy sectors as a critical part of the State's overall decarbonization strategy. As such, NYSERDA works in close coordination with NYSAGM and other stakeholders to responsibly support the development of renewable energy systems, such as wind and solar. Since the adoption of the Clean Energy Standard in 2016, the Tier 1 Program has implemented an increasing number of programmatic measures to incorporate the State's agricultural policies into its Renewable Energy Certificate (REC) procurement efforts (NYSERDA 2022d, 14). Two agrivoltaic related programmatic examples that have been incorporated into the Tier-1 Program's solicitations are the Smart Solar Siting Scorecard and the Agricultural Mitigation Payment Deferral Request process. Projects participating in Tier 1 solicitations that commit to co-utilization measures in their Smart Solar Siting Scorecard and Agricultural Mitigation Payment Deferral Request Form will be viewed favorably in evaluation.

Starting with the 2022 Tier 1 solicitation, NYSERDA began requiring proposers to submit a completed Scorecard. The Scorecard is designed to encourage the development of renewable energy projects that proactively commit to comprehensive community engagement and that minimize impacts on lands with high-quality soils, forests, and pertinent competing land uses. The Scorecard also encourages projects to include novel co-use, dual-use, and/or agrivoltaic initiatives in the development of renewable energy projects in addition to other siting considerations and site management practices.

Separately, during the proposal process in a Tier 1 solicitation, should the project's constructed facility area overlap with 30 acres or more of mineral soil groups 1 through 4, the project would be subject to an agricultural mitigation payment. In 2022, NYSERDA introduced the option for the solar project to request to defer and potentially offset the agricultural mitigation payment by submitting an agricultural co-utilization plan. The plan must be robust, include the production of agricultural crops, livestock, or livestock products, and be accepted by NYSERDA. For each dollar of gross expenditure made by the project for eligible co-agricultural expenses included within an agricultural co-utilization plan that has been accepted by NYSERDA, the agricultural mitigation payment may be reduced by $0.85 (85%) provided the project has adhered to NYSERDA's requirements and the terms of the accepted agricultural co-utilization plan (NYSERDA, n.d., 28).

3.2 Northeast States Programs and Pilots

3.2.1 Maine

To ensure responsible siting of solar energy on agricultural lands, the Governor's Energy Office and the Maine Department of Agriculture, Conservation and Forestry convened an Agricultural Solar Stakeholder Group to make policy recommendations to balance the need to protect Maine's current and future farmland against the need to develop sources of renewable solar energy. The Agricultural Solar Stakeholder group was recommended by Maine Won't Wait, Maine's four-year climate action plan from the Maine Climate Council (Maine Climate Council n.d.). Maine Won't Wait, released in December 2020, identifies data-driven strategies and recommendations to reduce Maine's GHG emissions, as required by law, to 45% below 1990 levels by 2030 and 80% by 2050. Strategy E from Maine Won't Wait is to "protect Maine's environment and working lands and waters." As part of this strategy, the plan calls for "develop[ing] policies by 2022 to ensure renewable energy project siting is streamlined and transparent while seeking to minimize impacts on natural and working lands and engaging key stakeholders" (Maine Climate Council 2020, p. 76). The final report of the Agricultural Solar Stakeholder Group was released on January 20, 2022 (State of Maine 2022). Based on its research and discussions, and additional public input, the Stakeholder Group advanced seven consensus recommendations to the Department of Agriculture, Conservation and Forestry and the Governor's Energy Office. The Stakeholder Group also developed relevant definitions and a matrix of siting considerations for practitioners (State of Maine 2021) (recommendations are numbered for reference only, not to indicate prioritization):

1. Creation of a centralized clearinghouse of information.
2. Dual-use pilot program.
3. Consideration of current use taxation.
4. Consideration of standards for dual-use and co-location in permit-by-rule review.
5. Development of hosting capacity maps.
6. Increased support for municipal planning capacity.
7. Consideration of program preference based on agricultural site characteristics.

Key resources emerging from these efforts included several documents aggregated by the Maine Farmland Trust (MFT) (MFT 2023), including *Balancing Solar Development and Farmland Protection: A Solar Siting Guide for Maine Towns* (MFT 2022). The guide supports municipalities by providing guidance on general agricultural solar siting guidelines, compiles relevant provisions from solar ordinances that have been adopted by towns in Maine and New England, and takes a deeper dive into different approaches that Maine communities are taking to support balanced solar siting at the local level. It is the result of insights and contributions from numerous municipal officials, farmers, partner organizations, and other stakeholders. Additionally, MFT developed an information sheet for farmers and farmland owners (MFT n.d.).

3.2.2 Massachusetts

In 2018, the Massachusetts Department of Energy Resources (MA DOER) established the Solar Massachusetts Renewable Target (SMART) program as a successor to the state's Solar Renewable Energy Credit (SREC II) program. The SMART program promotes installation of certain types of grid-connected solar PV arrays through incentives based on a fixed price per kilowatt-hour (kWh) of electricity generated. These incentives appear as a "tariff" payment provided to the solar array owner. The SMART program provides incentives for a variety of different types of solar installations that might be built on farms, including agricultural dual-use solar arrays designed to allow productive agricultural activities to continue under and between rows of solar panels; these systems are known as Agricultural Solar Tariff Generation Units in Massachusetts (Commonwealth of Massachusetts 2023).

A base compensation rate of \$0.14-\$0.26 per kWh of electricity produced, depending on the size of the system and the local electricity utility, is awarded to qualifying PV systems. Solar PV projects must submit a Statement of Qualification Application to MA DOER for consideration. Under Agricultural Solar Tariff Generation Units guidelines, the affiliated land must be under continuous agricultural production over the 20-year SMART program period; dual-use systems with the following design parameters will be reviewed in an expedited fashion:

- System capacity must be no more than 5 MWac and 7.5 MWdc.
- The lowest edge of the panel must be at least 10 feet above the ground at horizontal position for tracking systems, or at least 8 feet for a fixed tilt panel.
- During the growing season, the maximum sunlight reduction due to shading from the panels on any square foot of land under the dual-use system may be no more than 50% (UMass Amherst 2022a).

The SMART program has produced a variety of useful fact sheets for solar developers and farmers, including a guide to state-specific definitions and agrivoltaics systems requirements (UMass Amherst 2022a), a guide on farm operations considerations (UMass Amherst 2022b), and a guide on crop and livestock considerations (UMass Amherst 2022b). The SMART program has also produced a financial tool for comparing costs and benefits of a dual-use system with those of a conventional solar PV array (Hyperion Systems 2019). Funded by Innovative Solar Practices Integrated with Rural Economies and Ecosystems (InSPIRE), the SMART program developed an Excel-based model that provides a cost benefit summary that allows for a variety of generalizable inputs under two scenarios: farmer as the solar project landlord or farmer as the solar project owner (Microsoft Excel 2018).

Additionally, MA DOER has been collaborating with UMass Clean Energy Extension (UMass Amherst 2023), UMass Agricultural Extension, Massachusetts Department of Agricultural Resources, farming organizations and communities, solar developers, and the National Renewable Energy Laboratory (NREL) to create a coordinated network of agrivoltaics stakeholders. The DOE Solar Energy Technology Office recently selected UMass for a three-year, \$1.8 million award to study the effects of agrivoltaics on farms across the Commonwealth of Massachusetts (UMass Amherst 2020).

Massachusetts General Law c.61A: Assessment and Taxation of Agricultural and Horticultural Land, § 2A permits agricultural land to be used for agrivoltaics. In August 2022, this statute was amended by enacting “An Act Driving Clean Energy and Offshore Wind,” which allows solar energy facilities that qualify in accordance with a solar incentive program for agriculture to participate (Commonwealth of Massachusetts 2022). While this does not change the underlying agricultural eligibility requirements, the land must be eligible based on farming activity. If farming activity ceases, a rollback on taxes will be triggered and participants will face conversion penalties. This legislation also directs MA DOER to offer additional incentives for pollinator-friendly solar installations in the solar incentive program, as well as any successor solar incentive programs. Additionally, it establishes a commission to study the deployment of “dual-use sites” while minimizing ecosystem and agricultural impact.

A-TWG has recommended New York State establish clear statewide tax guidance for agrivoltaics; further exploration of Massachusetts’s Law and its preliminary outcomes may support this effort.

3.2.2.1 InSPIRE University of Massachusetts-Amherst Grafton Solar Research Project

The Grafton Solar project is acting as a research site for DOE Solar Energy Technologies Office (SETO) in Grafton, MA. UMass-Amherst is a research partner and is conducting research on a portion of the project’s acreage. The Grafton Solar project is supporting peppers, kale, broccoli, beans, and chard on Knowlton Farm, a family farm operating for over 150 years. The entire Grafton Solar site is a 2-MWac monocrystalline PV, fixed system community solar farm with a 1.4-MWac battery energy storage system, owned and operated by AES.

The solar modules are elevated to a height of 8 to 14 feet and feature large, inter-row spacing to allow cattle grazing and access for farm equipment (Figure 12 and Figure 13). The low edge of the panels are a minimum of 10 feet and 6 inches above ground level. The agricultural integration component of the project began in July 2022 with the planting of squash and introduction of beef cattle grazing. Figure 14 illustrates cows grazing directly underneath the array. The project will utilize rotational cattle grazing practices to improve plant, soil, and animal health (AES n.d.). The soil between the panels is prepared by the farmer prior to planting crops (New York Times 2023). Lettuce will be planted after the harvesting of squash. UMass Amherst and the American Farmland Trust are establishing site trials to assess crop productivity, soil health, and micro-climatic conditions (Hince 2022). The project has been positively received by municipal officials (Sullivan 2022). The project was fully operational and generating revenue within Massachusetts’s SMART program in late 2022, with full agriculture potential realized in 2025 (AES n.d.).

Figure 12. Farming Between the Solar Arrays at the Grafton Solar Project in Grafton, MA

Source: https://www.aes.com/grafton-solar

Figure 13. Farming Under the Solar Arrays at the Grafton Solar Pilot Project in Grafton, MA

Source: https://www.aes.com/grafton-solar

Figure 14. Cattle Graze the Grafton Solar Pilot Project in Grafton, MA

Source: https://www.aes.com/grafton-solar

3.2.3 New Jersey

In June 2021, the New Jersey Legislature passed the Dual-Use Solar Act, which establishes the Dual-Use Solar Energy Pilot Program for unpreserved farmland. On May 1, 2023, the New Jersey Board of Public Utilities (NJBPU) approved the agreement with Rutgers University for development and implementation of the Dual-Use Solar Energy Pilot Program (NJBPU 2023). The pilot enables a limited number of farmers to have agrivoltaic systems on their property while the technology is being tested, observed, and refined (NJBPU 2021). Under current law, to be eligible for farmland assessment, the amount of acreage devoted to the solar energy generation facilities, structures, and equipment may not exceed 10 acres and no more than 2 MWdc of PV power may be generated. The pilot program would eliminate these restrictions for a dual-use solar energy project on unpreserved farmland approved and constructed pursuant to the program and establish financial incentives for dual-use solar energy projects under this program. After the termination of the pilot program, NJBPU "would direct the BPU to adopt rules and regulations to establish a permanent dual-use solar energy program, which take into account the results of the pilot program and any research studies on the efficacy of dual-use solar energy projects in New Jersey" (New Jersey Legislature 2021).

Additionally, the Rutgers Agrivoltaics Program formed a committee to design, construct, and conduct research and outreach for agrivoltaics. This committee has a list of priorities for research projects and is identifying outside funding sources (e.g., DOE, USDA, private sector) (Rutgers n.d.). The Rutgers University New Jersey Agricultural Experiment Station is using $2 million allocated from the New Jersey State budget to examine if crops and cows can thrive under bifacial vertical and rotating solar panels (Morley 2022).

3.2.3.1 Rutgers Highlight

Rutgers University features the Rutgers Agrivoltaics Program which is leading research on agrivoltaics in the state. The Rutgers New Jersey Agricultural Experiment Station received $2 million in the 2022 State Budget for building research and demonstration agrivoltaic systems on its research farms. Rutgers' agrivoltaics committee has identified the following potential research projects that it will pursue as funding becomes available:

- Impact on yield and quality of vegetables, nursery crops, sod, cranberries, blueberries, and grapes.
- Impact on pastures and animals (sheep, cows, horses) grazing underneath solar panels.
- Opportunities for Controlled Environment Agriculture (greenhouses and high tunnels), including the use of supplemental lighting powered by PV.
- GHG-based-life cycle assessment for conventional field production versus crops grown under agrivoltaic systems, including the impact on water consumption and renewable energy generation.
- Optimal design of agrivoltaic systems for NJ farms (pole placement and height, panel type and efficiency, panel tilt angle, tracking systems, etc.).
- Economic opportunities and challenges for agrivoltaics in NJ (Rutgers n.d.).

Rutgers was recently awarded $1.6 million under the DOE Foundational Agrivoltaic Research for Megawatt Scale (FARMS) program for a project in Piscataway, NJ, entitled Agrivoltaic Systems for Diversified Agriculture: A Project to Increase Technical Understanding of Agrivoltaics and Develop Novel Outreach Strategies for Farms Near Culturally Diverse Metropolitan Areas. Rutgers will use the funding to conduct trials at three solar array testbeds, where researchers are studying the growth of 11 different crops, grazing practices, and community perceptions of agrivoltaics. In addition, Rutgers will be partnering with American Farmland Trust to develop and deliver a training and technical assistance program for farmers, agricultural landowners, and aspiring agrivoltaics specialists.

Details on specific proposed installations and crop selection are forthcoming. Rutgers committee members indicated in December 2022 that there will be a crop rotation strategy that employs a cereal rye cover crop. A presentation entitled "Rutgers Agrivoltaics Program Update and Lessons Learned" outlines the details of the three solar array testbeds in the pilot program (Specca 2023).

- **Animal Farm (Cook Campus, New Brunswick, NJ):** Vertical bifacial, bottom of the panels 5 feet above the ground, row spacing = 20 or 40 feet, 170 kilowatts direct current (kWDC).
- **Snyder Farm (Pittstown, NJ):** Single-axis trackers, pivot point at 8 feet above the ground, maximum pivot angle: +/- 60 degrees from horizontal, bifacial panels, portrait orientation (single high panel mounting), row spacing = 32 feet, 82 kWDC.
- **RAREC (Bridgeton, NJ):** Single axis trackers, pivot point at 8 feet above the ground, maximum pivot angle: +/- 60 degrees from horizontal, bifacial panels, portrait orientation (single and double high panel mounting), row spacing = 34 feet, Ideal Case: 249 kWAC, Worst Case: 50 kWAC (pending local utility approval).

Under the DOE FARMS award, Rutgers will be growing high-value crops such as soybeans, hay, and corn under a single axis tracker. Details on this effort will emerge as the project progresses. The agrivoltaics field trials and test arrays will be an outdoor classroom for the farmer training and technical assistance program that will be developed in partnership with the American Farmland Trust. Details on this effort will emerge as the project progresses.

3.2.4 Vermont

The Vermont Agency of Agriculture, Food & Markets (VAAFM) supports the viability and growth of agriculture in Vermont while protecting the working landscape, human health, animal health, plant health, consumers, and the environment (National Association of State Departments of Agriculture 2022). VAAFM supports co-utilization of solar sites with agriculture, as generating electricity on farms can reduce expenses for farmers and create a diversified and consistent revenue stream. In addition to their role in helping farmers with new enterprises, the agency is responsible for reviewing potential energy projects for overall impacts to farmland, and how best to construct a facility so that the land can ultimately be returned to productive agriculture following decommissioning (Opalka 2019).

3.2.4.1 InSPIRE Vermont Saffron Site

In 2015 the North American Center for Saffron Research and Development began conducting a multi-year study of saffron crops grown under and adjacent to ground-mounted solar arrays (AgriSolar Clearinghouse 2022a). The study includes two years of field data from the 2019 and 2020 growing seasons at the Peak Electric solar field in Burlington, Vermont.

In 2019, the saffron yield was low, as expected for newly planted saffron corms, with a higher yield in the raised bed plots. In 2020 the plots produced higher-than-average yields, with some plots producing yields three times higher than average. Highest yields occurred in the lots located in the aisle and around the perimeter of the solar panels, with yields of 17 pounds of saffron/acre, which would be equal to $192,775/acre at an average price of $25/gram. The plots directly under the solar panels did not show this increase in production. These plots showed a 30% decrease in yield, indicating that the area under the panels is not an ideal micro-climate for saffron production; however, the study results showed that saffron can be grown successfully within solar fields and provide significant agricultural revenues. Saffron is a perennial crop and yields usually increase annually for at least 3 years. Therefore, greater revenues from saffron solar fields are anticipated in future years (AgriSolar Clearinghouse 2022a).

3.2.4.2 Maple Ridge Meats

Maple Ridge Meats, a 650-acre cattle farm located in Benson, Vermont, has successfully grazed cows under solar panels by raising the height of solar arrays. Constructed in 2016 on a 4.5-acre area, the solar arrays are mounted so that their lowest edge is 8 feet above the ground (Kryzanowski n.d.). This minimizes the footprint of solar arrays by using land for grazing while providing cattle with shelter. However, it required extra engineering and cost as racking was installed to deeper depths and panels needed to be raised to allow cattle to pass underneath. “Support poles must be dug deeper, up to 10 feet into the ground, and panels must be raised an extra 3 feet or more to provide clearance for the animals. Arrays, angled at 30 degrees, are at least 6 feet above ground, instead of 3 feet, and exposure to stronger winds at the higher top ends requires additional support braces” (Opalka 2019). This is an alternative in areas where sheep flocks may be limited or cattle grazing already occurs.

3.2.5 Maryland

In June 2022, the Maryland legislature passed a community solar bill, enacted under Article II, Section 17(c), of the Maryland Constitution (Chapter 659). This bill establishes tax incentives for qualifying community solar projects to develop agrivoltaic programs where qualifying properties are exempt from county and municipal property taxes. Qualifying projects must provide at least 50% of the energy generated to low- or moderate-income customers at a rate that is at least 20% lower than the base electricity rate.

3.3 United States Federal Programs and Pilots

Federal programs to support agrivoltaics include the DOE SETO, the USDA Climate Hubs, and the recently adopted Inflation Reduction Act. In January 2022, USDA and DOE hosted an interagency workshop on agrivoltaics to more clearly define the federal government's agrivoltaics research and commercialization roles (DOE 2022b). Workshop slides outline the respective roles as follows:

DOE SETO aims to accelerate the advancement and deployment of solar technology in support of an equitable transition to a decarbonized economy. Agrivoltaic Research activities focus on Fostering agrivoltaics community; Analysis, economics, and social science; and research related to Ag-energy science and field work. SETO's Commercialization activities focus on manufacturing and competitiveness and include work related to innovative solar PV design, such as racking and mounting strategies, as well as solar-powered aeration for aquaculture.

USDA focuses on administering the regional Climate Hubs; promoting rural development via loans and loan guarantees for rural cooperative generation, transmission, and distribution; administering the Natural Resources Conservation Service (NRCS), which can address on-farm energy production in the context of conservation planning; and overseeing development of the new USDA Climate Smart Agriculture Partnership, which will focus on the production of climate-smart commodities.

Each of these programs is described further in sections 3.3.6 and 3.3.7, respectively.

3.3.1 United States Department of Energy Agrivoltaics Programs and Pilots

Three significant DOE programs include InSPIRE, FARMS, and Community-Centered Solar Development.

3.3.1.1 2022 InSPIRE Registered Agrivoltaics and Research Sites Overview

DOE's InSPIRE seeks to improve the environmental compatibility and mutual benefits of solar development with agriculture and native landscapes. InSPIRE evaluates opportunities for cost reductions and assesses the environmental compatibility of solar energy technologies through low-environmental impact designs and approaches (InSPIRE 2020). InSPIRE explores solar and environmental synergies through four core research areas:

- Co-locating solar projects on agricultural lands for mutual benefits.
- Long-term ecosystem impact assessments.
- Low-impact site preparation practices for ground-mounted solar projects.
- Economic evaluation of solar and agricultural systems.

InSPIRE combines innovative field-based research with analytical studies to provide foundational data to landowners, agricultural entities, the solar industry, and State decision-makers. The InSPIRE team utilizes peer-reviewed methods across all research field plots to ensure comparability. Specifically, the InSPIRE team analyzes the ecological and economic implications of:

- Native vegetation growth underneath and around ground-mounted solar installations.
- Agricultural crop performance under innovative solar configurations.
- Impacts of low-impact solar development approaches on soil quality, carbon storage, stormwater management, microclimate conditions, and solar efficiencies.
- Benefits of pollinator-friendly solar on beneficial insects and local agricultural yields.

InSPIRE has produced useful resources such as the Low-Impact Solar Development Strategies Guidebook (InSPIRE 2020) to provide insights and best practices associated with low-impact solar development. The guidebook is intended to assist solar developers, State agencies, and other interested parties in siting, designing, installing, and operating low-impact solar development projects. InSPIRE also produced a *Farmer's Guide to Going Solar* (DOE n.d.-a).

As of December 2022, the DOE InSPIRE census, which is based upon voluntary submission of data, registered 304 agrivoltaics installations across the United States producing a total of 1,920 MWac across 10,851 acres of land (NREL 2022). These sites support one or a combination of ecosystem services (e.g., pollinator or native vegetation support), sheep grazing, or crop production. The majority of the registered sites are located in Minnesota (144), Illinois (38), Wisconsin (35), and New York State (15). Seventeen sites are noted as InSPIRE research sites, none of which are in the State. There are 15 sites listed in NYS ranging in size from 4.5 to 30 acres. All sites incorporate grazing; several indicate habitat and ecosystem service components, as well. The vast majority of all listed sites support ecosystem services, followed by grazing. The majority of the registered crop production sites were pilot-scale experiments that used fewer than 1 acre of production for solar sites sized between 0.01 and 0.04 MWac (OpenEI InSPIRE 2023).

3.3.1.2 2022 DOE FARMS Research Sites Overview

To reduce barriers to utility- and community-scale solar energy deployment while maximizing benefits for farmers and local communities, DOE SETO announced an $8 million funding opportunity on May 5, 2022; six selected agrivoltaics projects were announced on December 8, 2022 (DOE n.d.-b). The FARMS funding opportunity has three areas of interest:

- Integrated agriculture-energy impact studies that investigate how agrivoltaic designs impact both agriculture production and energy production.
- Research related to socioeconomics, studying how agrivoltaics can fit into existing agricultural communities and economies or enable new ones.
- Resources for replicable and scalable agrivoltaics that lower the barrier of entry to agrivoltaics, making it easier for interested agricultural producers and solar developers to benefit from the opportunities that agrivoltaics provides (DOE 2022c).

The selected projects include demonstration projects for crop production, sheep grazing, and ecosystem services as well as desktop research, and industry surveys. Each project has specific deliverables that will provide decision support tools, training programs, case studies, or guides to support the development and operation of production-scale projects. Iowa State University's project, which studies horticulture and beekeeping at solar sites, will result in an agrivoltaics training program for farmers. Ohio State University will focus on grazing and forage (hay) production trials. Three of the selected projects have an equity component focused on engaging minorities, indigenous populations, rural community members, or other marginalized groups. Rutgers University's pilot project, through close collaboration with NJBPU and the New Jersey Department of Agriculture, will test agrivoltaic opportunities on three facilities. Development of these facilities is ongoing.

3.3.1.3 Community-Centered Solar Development

To better understand and enact more community solar development amidst the growth of LSS in the United States, the DOE SETO is supporting the Lawrence Berkley National Laboratory with its Community-Centered Solar Development project (Lawrence Berkley National Laboratory 2023). The main research questions of the project are as follows:

- What are the key positive and negative drivers leading to support and opposition to LSS projects?
- How generalizable are these findings across a national sample of LSS neighbors?
- How has historical LSS development impacted local tax revenue, employment and/or income as well as previous land uses, and how can those findings inform understanding of likely future impacts?

- To what extent do LSS projects exacerbate or mitigate inequities within hosting communities and, if the former, how might they be mitigated going forward?
- What strategies can communities employ to align LSS development with local land-use plans and community needs and values?
- How can community members take a larger role in local LSS development?

There are six tasks at the center of this project:

- Task 1: Case Study Analysis. Analyze six existing solar projects (brownfield, agrivoltaics, and greenfield, including those in underserved communities) using interviews to uncover the key factors that led to project success or threatened failure.
- Task 2: National Large-Scale Solar (LSS) Neighbor Survey. Conduct a national random survey of at least 1,000 LSS project neighbors, oversampling among site types, to reexamine case-study findings at a broader empirical scale enabling national generalization.
- Task 3: Tax, Income, and Employment Impacts. Conduct one nation-wide analysis of LSS impacts on local tax, local individual- and firm-level income or employment, characterize a baseline average economic impact, and conduct a deep topical dive to allow greater applicability at a more local level.
- Task 4: LSS Mapping & Categorization. A geographic categorization will be completed of all existing U.S. LSS sites, as well as analyses of land-use and capacity trends to better understand future LSS development potential.
- Task 5: Community-Based Solutions and Visioning. Engage in planning with six potential LSS host communities to utilize information from the previous tasks to develop community-centered and audience-specific plans for prospective LSS developments. Produce a guidebook and check list for a broader audience.
- Task 6: Outreach and Dissemination. Establish a technical advisory committee, arrange internships with students from Task 5 communities, and conduct extensive outreach and dissemination on all project deliverables (Lawrence Berkley National Laboratory 2023).

3.3.2 USDA Climate Hubs

USDA Climate Hubs are a collaboration across USDA agencies designed to link USDA research and program agencies in delivery of information to agricultural professionals and producers. The Climate Hub mission is to “develop and deliver science-based, region-specific information and technologies, with USDA agencies and partners, to agricultural and natural resource managers that enable climate-informed decision-making, and to provide access to assistance to implement those decisions” (USDA n.d.-a).

The USDA’s Northeastern Climate Hub website includes the site “Agrivoltaics: Coming Soon to a Farm Near You” (USDA n.d.-b) suggesting that USDA may have interest in using the Climate Hub framework to explore agrivoltaics feasibility and benefit. The site provides a link to a separate USDA pilot program—the Rural Energy Pilot Program—for funds related to renewable energy development, suggesting that funding in this program may be utilized to support agrivoltaics activities. In January 2022, USDA announced that $10 million will be available under the Rural Energy Pilot Program $10 million to help rural communities reduce energy costs. The application closed July 18, 2022 (USDA n.d.-c). Awardees have yet to be announced.

3.3.3 Inflation Reduction Act

The Inflation Reduction Act (IRA) was signed into law on August 16, 2022, and will provide nearly $369 billion in investments towards clean energy and climate action. The IRA provided $19 billion to the USDA to support farmers and ranchers in adopting and expanding climate-smart activities and systems (The White House 2023).

The IRA Guidebook outlines 12 programs that support climate-smart sustainable agriculture and rural economic development that have received funding amounts ranging from $10 million to $8 billion (The White House 2023). Topics address the following:

- Addressing natural resources concerns and the protection and conservation of natural areas.
- Improvement of soil carbon and sequestering carbon dioxide.
- Compensation of agricultural and forest producers who adopt conservation practices.
- Relief for distressed farm loan borrowers affected by COVID-19.
- Protection and restoration on wetlands for landowners, land trusts, and other entities, such as wetlands on working farms and ranches.
- Education and provision of tools for our nation's farmers, ranches, and forestland owners.
- Reduction of GHG emissions.
- Assistance for distressed borrowers of direct or guaranteed loans administered by USDA's Farm Service Agency.
- Outreach, mediation, and training efforts on issues concerning food, agriculture, agricultural credit, agricultural development, rural development, or nutrition to underserved farmers, ranchers, or forest landowners.
- Increasing underserved producers land, capital, and market access.
- Addressing racial equity issues within the USDA and all USDA programs.
- Cultivation of diverse institutions as food and agriculture professionals.
- Assistance and support for underserved farmer, ranchers, and foresters.

Several topics could be relevant to support advancement of agrivoltaics, underscoring the need to monitor USDA programming emerging from the IRA.

4 Focus Areas: Dairy Farming, Sheep Grazing, and Specialty Crops

This report aims to provide greater depth of information on opportunities and constraints for agrivoltaics in a New York State-specific context. Three types of agriculture of particular interest for assessing the applicability, feasibility, and reasonability for co-location with solar development in the State are dairy farming, sheep grazing, and specialty crops. Dairy farming warrants special attention given its outsized importance in the agricultural landscape and economy. The sheep industry is explored further given its demonstrated success regionally and need to understand considerations for scale. Additionally, specialty crops warrant further attention given sector size in the State and potential for overhead panels to provide protections against severe weather.

4.1 Dairy Focus Area

The following sections provide an overview of New York State's dairy industry and its supporting infrastructure and includes information on research and pilots considering how agrivoltaics might be applied to this industry. Table 5 presents an overview of farms, production diversity, and the market value of different agricultural products in the State. As indicated in the table, dairy and milk production is overwhelmingly the highest grossing product with nearly $3 billion in sales in 2017 (NYSAGM 2022).

Table 5. New York State's Diverse Agriculture, 2017

Source: 2022 New York State Food Supply Resiliency Report–NYSAGM.

Farm Type	Number of Farms	Land in Farms (Acres)	Market Value of Products Sold ($) and Government Paystubs
Dairy and milk production	3,799	2,170,136	$2,984,884,000
Hay and all other crop farming	9,636	1,801,627	$335,834,000
Oilseeds and grain farming	2,058	1,080,237	$417,658,000
Beef cattle ranching or farming	4,603	658,369	$179,755,000
All other animal production including aquaculture, equine, and apiculture	4,864	288,414	$77,144,000
Vegetable and melon farming	1,978	284,824	$376,233,000
Fruit and tree nut farming	2,247	250,197	$402,170,000

Table 5 continued

Farm Type	Number of Farms	Land in Farms (Acres)	Market Value of Products Sold ($) and Government Paystubs
Greenhouse, nursery, and floriculture	1,990	157,087	$384,222,000
Sheep and goat farming	1,201	64,692	$14,944,000
Cattle feedlots	165	46,156	$34,348,000
Poultry and egg production	517	41,998	$199,705,000
Hog and pig farms	380	22,434	$21,421,000
Total New York State	33,438	6,866,171	$5,428,317,000

4.1.1 Industry Perspective

Dairy farming is New York State's largest agricultural sector. As reported in section 2, the State ranks fourth in the country for milk production, and dairy from cows was the number one agricultural product sold, comprising $2.5 billion in sales and representing 47% of all agricultural product sales in the State (USDA-NASS 2017a). Collectively, along with California, Wisconsin, Idaho, and Texas, the State produces more than 50% of the country's annual milk supply (USDA-ERS 2022c), and New York State's nearly 3,600 dairy farms produce over 15 billion pounds of milk annually (NYSAGM 2020).

Dairy farms constitute both pasture based and concentrated animal feeding operations (CAFOs). The majority of the State's roughly 500 CAFOs are dairy farms with 300 or more cows. NYSDEC defines CAFOS as "an animal feeding operation (farm) that meets certain animal size thresholds and that also confines those animals for 45 days or more in any 12-month period in an area that does not produce vegetation" (NYSDEC n.d.). The predominant New York State dairy farming model consists of confined climate-controlled housing of dairy cattle coupled with extensive forage production of corn for silage and grain, soybeans for protein, and alfalfa/grass hay. Animal manure is agronomically applied to the soil as crop nutrients. Christopher Laughton, Director of Knowledge Exchange at Farm Credit East notes that dairy grazing is a minority of dairy operations. Most dairy farms grow silage corn in their fields and feed it to cows that remain in a barn, which contributes to the need for farm acreage to accommodate growth of forage crops. Forages such as hay and corn are grown on State dairy farms for dairy cow rations. There are higher costs associated with milk from grazed cows, but farmers potentially receive a grass-fed revenue premium from milk buyers (Darby et. al. 2022). New York State is also home to the greatest number of organic dairy farms in the country (509 farms) and ranked third nationally for quantity produced from organic farms (USDA-NASS 2021).

Table 6 and Figure 15 show the New York State 2017 Census of Agriculture and REDC acreages for feed and forage typically associated with the dairy farming, respectively; however, this is not exclusive to the dairy farming.

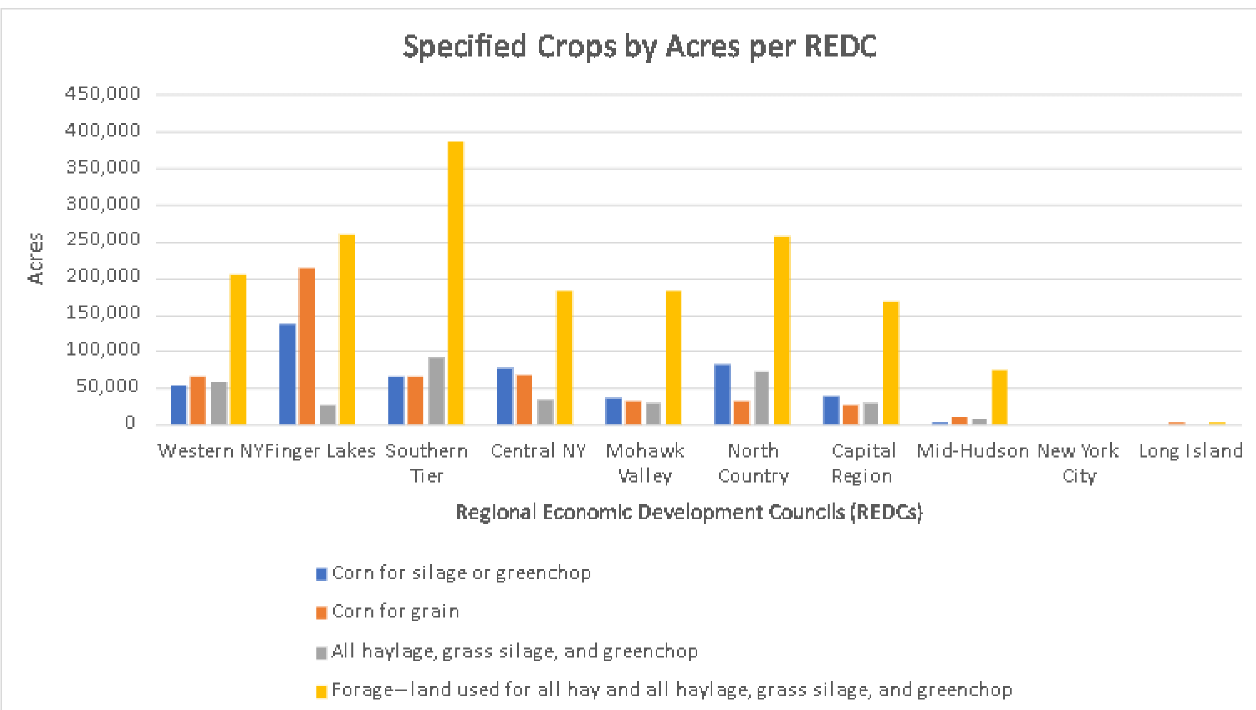
Table 6. Specified Crops for Feed and Forage Associated with the Dairy Industry by Acres Harvested

Source: 2017 Census of Agriculture – State Data, USDA, National Agricultural Statistics Service.

Crop	Farms	Acres	Quantity
Corn for silage or greenchop	3,800	515,400	8,983,500 (tons)
Corn for grain	3,700	524,500	84,124,900 (bushels)
All haylage, grass silage, and greenchop	6,400	793,700	4,946,900 (tons, green)
Forage – land used for all hay and all haylage, grass silage, and greenchop	17,900	1,811,600	4,654,900 (tons, dry equivalent)
Totals*	31,800	3,645,200	

Figure 15. Specified Crops for Feed and Forage Associated with the Dairy Industry by Acres per REDC

Source: USDA-NASS, 2017 Census of Agriculture Volume 1, Chapter 1: State Level Data, Table 76. Summary by Tenure of Farm Operation.



Figures 16 and 17 illustrate the total number of cattle and calves (beef cattle, dairy cattle, calves, heifers that had not calved, steers, and bulls) and total number of farms (farms that produce any of the following crops: corn for silage or greenchop; corn for grain; all haylage, grass silage, and greenchop; and forage— land used for all hay and all haylage, grass silage, and greenchop) in each REDC as provided by the USDA-NASS 2017 Census of Agriculture. The Southern Tier region has the greatest number of farms with 6,121 farms, and the Finger Lakes region has the greatest number of cattle and calves,totaling 372,395.

Figure 16. Total Number of Cattle and Calves per REDC

Total cattle and calves include beef cattle, dairy cattle, calves, heifers that had not calved, steers, and bulls.

Source: USDA-NASS, 2017 Census of Agriculture Volume 1, Chapter 1: State Level Data, Table 76. Summary by Tenure of Farm Operation.

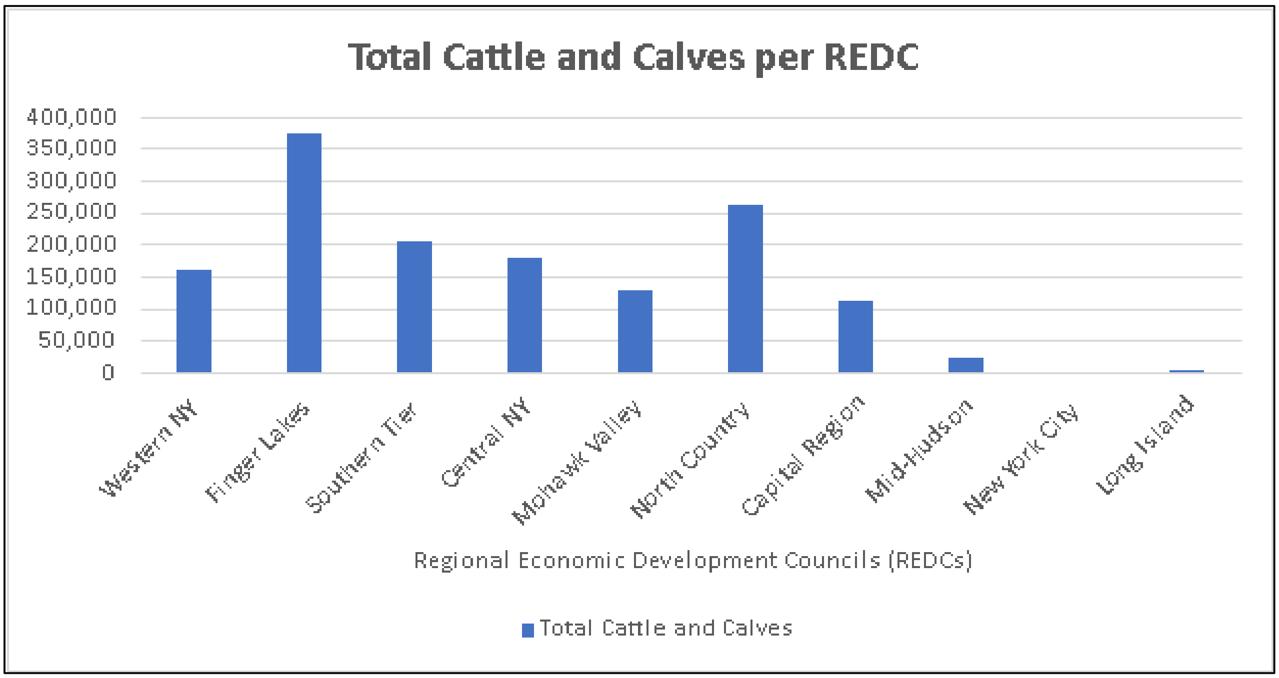
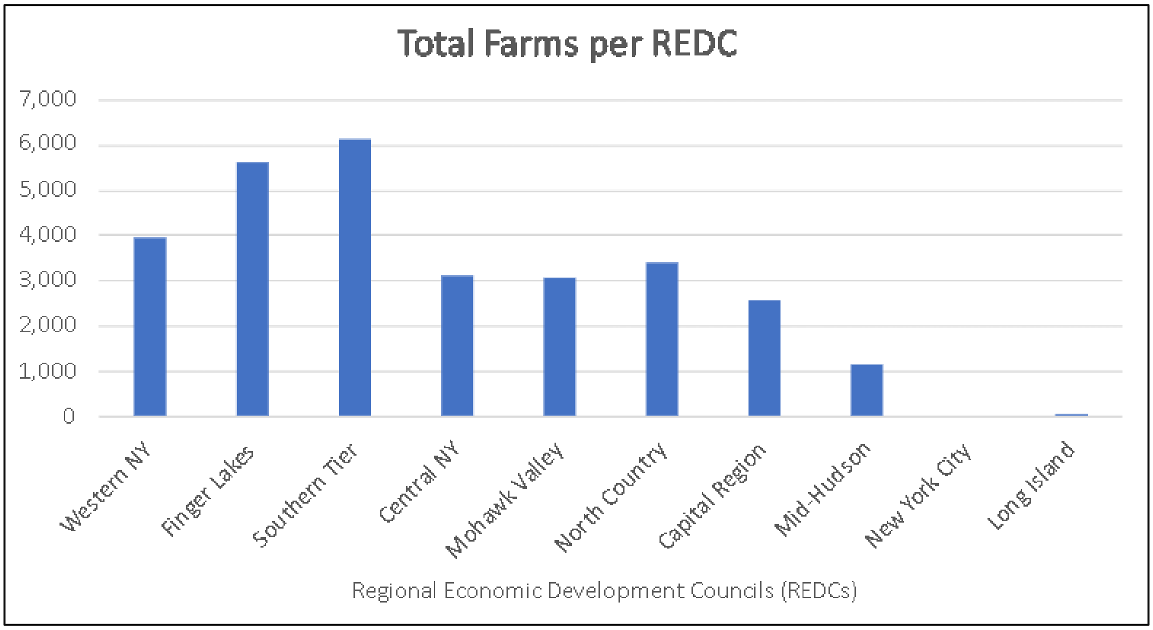


Figure 17. Total Number of Farms per REDC

Total farms indicate the total number of farms that produce any of the following crops: corn for silage or greenchop; corn for grain; all haylage, grass silage, and greenchop; and forage—land used for all hay and all haylage, grass silage, and greenchop.

Source: USDA-NASS, 2017 Census of Agriculture Volume 1, Chapter 1: State Level Data, Table 76. Summary by Tenure of Farm Operation.



In 2020 there were 3,658 dairy farmers (in steady decline from a high of 5,370 in 2010), with an average gross income of $763,000. The number of dairy cows remained the same as 2018 and 2019 at approximately 625,000 cows. Demand and production per cow increased by 1.6% from 2019 and total milk produced increased 1.4% (NYSAGM 2020).

Primary production costs include feed, labor, and fuel expenses. “Although milk prices increased in 2021, particularly later in the year, expenses increased as well, leaving farms forced to implement various strategies to control costs and gain efficiencies in order to remain profitable” (Farm Credit East 2022, 19).

High-quality pasture is an important, economically viable substitute feed source as pasture is the least costly feed source available (Penn State Extension 2016). A study conducted by the Penn State Extension revealed that cow grazing resulted in about $100 to $200 advantage in profit per cow compared to confined feeding systems. “Savings in feed costs likely account for at least half of the decrease in total costs and improved farm profitability with grazing systems. In New York State, pasture-based dairy farms returned $71 more yearly net farm income (NFI) per cow for a six-year period” (Horner and Milhollin 2020).

In 2016 USDA's ERS and NASS surveyed organic and conventional silage-fed dairy farms as part of the 2016 Agricultural Resource Management Survey. The survey found that organic dairy production costs are substantially higher than those for conventional dairy. However, organic operations received significantly higher prices for their milk. Organic gross returns per hundredweight of milk produced were about twice the gross returns by comparably sized conventional operations. With higher costs, but much higher gross returns, small organic dairy farms realized higher net returns than small conventional farms (MacDonald 2020).

In the February 2022 publication "Smart Solar Siting on Farmland: Achieving Climate Goals While Strengthening the Future for Farming in New York," American Farmland Trust authors note that dairy farmers have faced economic struggles as input costs rise and exceed price received for milk. Additional challenges arise from availability and price of rental farmland, which can diminish profit margins. Authors also noted that based on a survey of nearly 750 farmers, land trusts, and government officials, dairy farmers were contacted more frequently by solar developers about hosting arrays as compared to other farmers (Levy, Ruiz-Ramon, and Winter 2022).

4.1.2 Dairy and Agrivoltaics

As indicated in section 3.3, DOE SETO provided funding through the FARMS program for six selected agrivoltaics projects in December 2022. One of the grant awardees was Ohio State University with a $1.6 million award and a $550k cost share. This project aims to focus on animal health and productivity under solar sites to inform vegetation management in Ohio and other states where grazing and hay production are important to rural economies (DOE-SETO n.d.). "This project will conduct livestock and hay production trials using precision agriculture technologies on an operating 180-megawatt solar site without modifications to the site design. The researchers will plant forage crops, like hay, and monitor animal behavior and forage production at the facility, quantifying yield, nutrient levels, impacts on solar operations, and impacts on soil health" (DOE-SETO n.d.).

The Ohio State University Extension has a Farm Energy Fact Sheet Series that provides information on a wide array of agriculture and natural resources related topics. One fact sheet titled "Forage as Vegetative Cover for Utility-Scale Solar in Ohio" provides recommendations for forage establishment and maintenance and explores considerations for seed mixes based on nutrient value to livestock. This fact sheet recommends cool-season pasture mix for year-long coverage, which can be used as abundant ground cover, livestock forage, and can provide pollinator benefits (Ohio State University 2021). Cool-season pasture mixes offer a mix of legume and grass varieties. Kentucky bluegrass, tall fescue, meadow fescue, orchardgrass, perennial ryegrass, and meadow fescue typically perform well in Ohio and can mature to around 3 feet in height. Successful cool-season legumes include alfalfa, birdsfoot trefoil, and many species of clovers. According to the fact sheet, seed variety and regular scheduled mowing throughout the growing season is imperative to maintain a grass height of 18 to 24 inches. Additionally, pasture mixes require two to four harvests per year to maintain grass height below PV panels, while also maintaining nutritional value forage for livestock consumption (Ohio State University 2021).

In 2019, one study conducted at the University of Minnesota West Central Research and Outreach Center examined the effects of shading from PV panels on grazing cattle. No difference in fly prevalence, milk production, fat and protein production, and drinking bouts were observed between the treatment and control cattle. There was an observed difference in body temperatures, with lower body temperatures observed in shade cows between milking times than no-shade cows, leading the study authors to conclude that incorporation of agrivoltaics into dairy pasture could reduce the intensity of heat stress events in dairy cows (Sharpe et al. 2020). It will be important to understand the potential impacts of climate change on dairy cows and the dairy industry to better contextualize the implications of this research.

Another study was conducted at the University of Minnesota West Central Research and Outreach Center in 2022, which examined the growth of 14 different forage and grain crops. These crops were grown at three different solar sites and a full-sun control site in the context of feeding them to a dairy herd (University of Minnesota 2022). This study addressed the growing benefit of agrivoltaics as a solution to decreased land availability and the expansion of solar in rural areas while offsetting feed expenses. The three solar sites included a tilted 30-kW ground mount solar array, a flat top 50-kW ground mount solar array, and a tilted 240-kW ground mount solar array. All three solar sites were erected 8-10 feet above the ground to provide shading for the dairy cows as a method of heat abatement. Image 4 shows the 30-kW solar photovoltaic ground-mounted system for solar shading at the University of Minnesota West Central Research and Outreach Center in Morris, Minnesota.

Figure 18. Cattle Graze the University of Minnesota West Central Research and Outreach Center Solar Project in Morris, MN

Source: https://doi.org/10.3168/jds.2020-18821 https://wcroc.cfans.umn.edu/

The 240-kW site was discontinued due to a lack of moisture and plant growth. The results indicated that sorghum-sudan grass, grass alfalfa mix, grass red clover mix, and grass white clover mix accumulated significant biomass in the partial-shade 30-kW solar site, and corn and soybeans had the greatest biomass in the mostly shaded 50-kW solar site (University of Minnesota 2022). While the yields were less than the full-sun control site, these results depict the co-location crop growth and solar farms as a viable option. Due to outside controls impacting the study (deer consuming a portion of the crops and abnormally arid summer conditions), more studies are necessary to draw conclusive results. However, results indicate that implementing agrivoltaics could provide flexible economic opportunities to farmers in the form of energy savings and reduced feed expenses for grazing dairy herds (University of Minnesota 2022).

In 2020, at the EDF Renewables Lab Les Renardières, EDF Renewables and the French National Institute for Agricultural, Food, and Environmental Research tested a 115-kilowatt peak (kWp) demonstration project where raised panels were installed on a 1,700 square meter (18,298.7 square feet) field of alfalfa 5 meters (16.4 feet) above the ground to provide access for agricultural machinery (EDF Renewables 2022b). The demonstration project overlapped with a particularly hot and dry summer, and initial results showed that the crop under the panels yielded a harvest 12 times higher than the neighboring control field, indicating that the shading from the panels may have protected the alfalfa crop. Alfalfa is a forage crop for dairy cows. Results suggest it would be beneficial for New York State to better understand implications for climate change on forage crops associated with the dairy industry to better contextualize the implications of this research.

4.2 Sheep Grazing

The following sections provide an overview of the sheep grazing industry as a whole and within New York State and considers supporting infrastructure and market conditions. It also considers the current state of agrivoltaics related to sheep grazing and provides context for understanding opportunities and constraints for scaling.

It is important to recognize the potential exponential increase in solar grazing if it becomes a predominant agrivoltaic activity in the State. Cornell University researchers estimate that three sheep per acre is a general benchmark to use for a stocking rate in a managed grazing program on New York State solar sites. Ground mounted solar installations typically occupy 4 to 8 acres per MWac; assuming a conservative average of 7.5 acres per MWac (NYSDPS 2020), a 1,500-MWac estimated pipeline would be built on roughly 11,250 acres and could engage up to 33,750 mature sheep if these acres were to be fully grazed. This projected number of needed animals to fully graze New York solar sites would represent an increase of more than 33% of the current sheep flock (USDA-NASS 2023).

Beyond the utility-scale solar pipeline, NY-Sun Program has a stated goal of 10,000 MWdc of installed distributed generation (DG) solar capacity by 2030 and is on track to meet the prior goal of 6,000 MWdc of DG solar by 2025 (NYSERDA 2021). This goal of a total of 10,000 MWdc of DG solar could roughly double the acreage of potential grazing represented by the estimated utility-scale pipeline with a conservative assumption that majority of the Upstate Commercial/Industrial capacity is deployed on farmland and would be suitable for grazing.

New York State has hosted grazing on solar sites since at least 2016. Early adopters include Cornell University, which pushed for co-located grazing at DG sites installed at Cornell properties around the Finger Lakes Region. Currently, grazing on solar sites in the State is largely limited to DG projects, as the State's first upstate utility-scale solar sites are only recently entering commercial operation. There are no firm numbers on total acres grazed, but it is estimated to be over 2,000 acres in 2023. ASGA estimates that in 2022 sheep were grazing on between 20,000 and 25,000 solar acres nationally—approximately 5% of completed U.S. solar projects (ASGA 2022).

4.2.1 Industry Perspective

4.2.1.1 The U.S. Sheep Industry

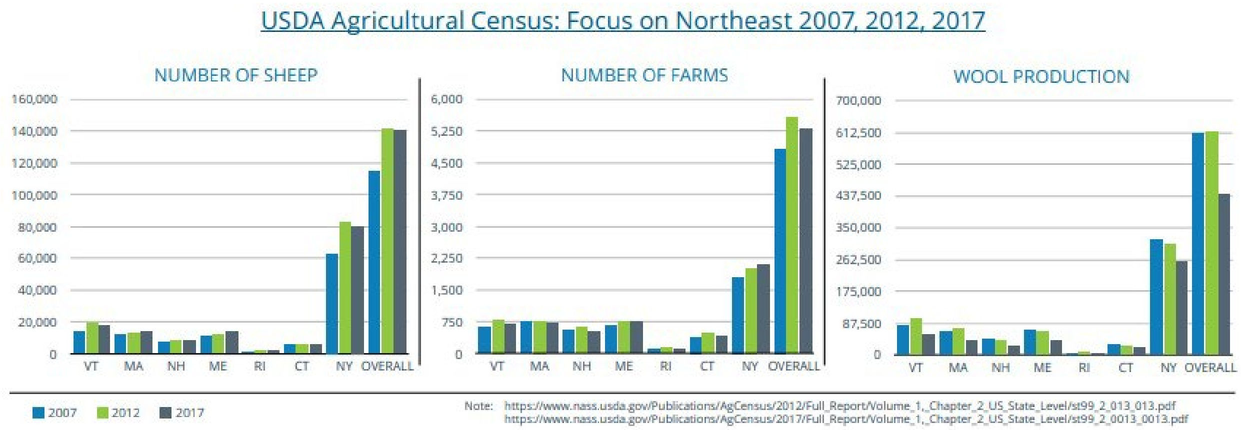
U.S. sheep and lamb inventories are tracked by the USDA NASS on an annual basis and by using the National Census of Agriculture, conducted every five years. In 2019, there were over 101,000 sheep farms and ranches (USDA-NASS 2017a), and, as of January 31, 2023, there were 5.02 million head of sheep (all types) in the country (USDA-NRCS 2023). The leading sheep and lamb producing states by volume of animals are in the Western U.S. where most of the bigger range-sheep operations are located. Some of these ranches may raise as many as 10,000 head of sheep, but most larger operations manage between 2,000-5,000 breeding ewes. Seasonally, during lambing, sheep numbers may increase by more than 100% with high numbers of multiple lamb births. Access to pastures for grazing is a key constraint to livestock operations, and it is noteworthy that some western producers may use multi-year leases of state and federal lands as an important seasonal grazing strategy. The largest ranches are generally focused on lamb production and treat wool as a byproduct.

4.2.1.2 Sheep in New York State and New England

The eastern part of the country comprises small to moderate sized, pasture-based farms predominately grazing on private land. Eastern farm flocks typically average less than 100 animals. A 2010 industry survey indicated that 64% of the industry was managing flocks of 1–100 head of sheep (Trinidad 2010). While top sheep producing states like California and Texas host between 550,000–675,000 sheep and lambs, New York State counts under 80,000 animals. Yet this is significant production nationally (19th overall), and substantial in the Northeast when compared with the other New England States of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont that together count less than 55,000 animals (USDA-NASS 2023). Figure 19 illustrates that the State is the sheep industry leader in the Northeast. It is also a leader in organic sheep production with a peak inventory of 2,350 certified organic sheep and lambs totaling $388,594 in sale value in 2021 (USDA 2022a).

Figure 19. Northeast Sheep Industry

Source: USDA-NASS 2023



4.2.1.3 Current Production and Demand

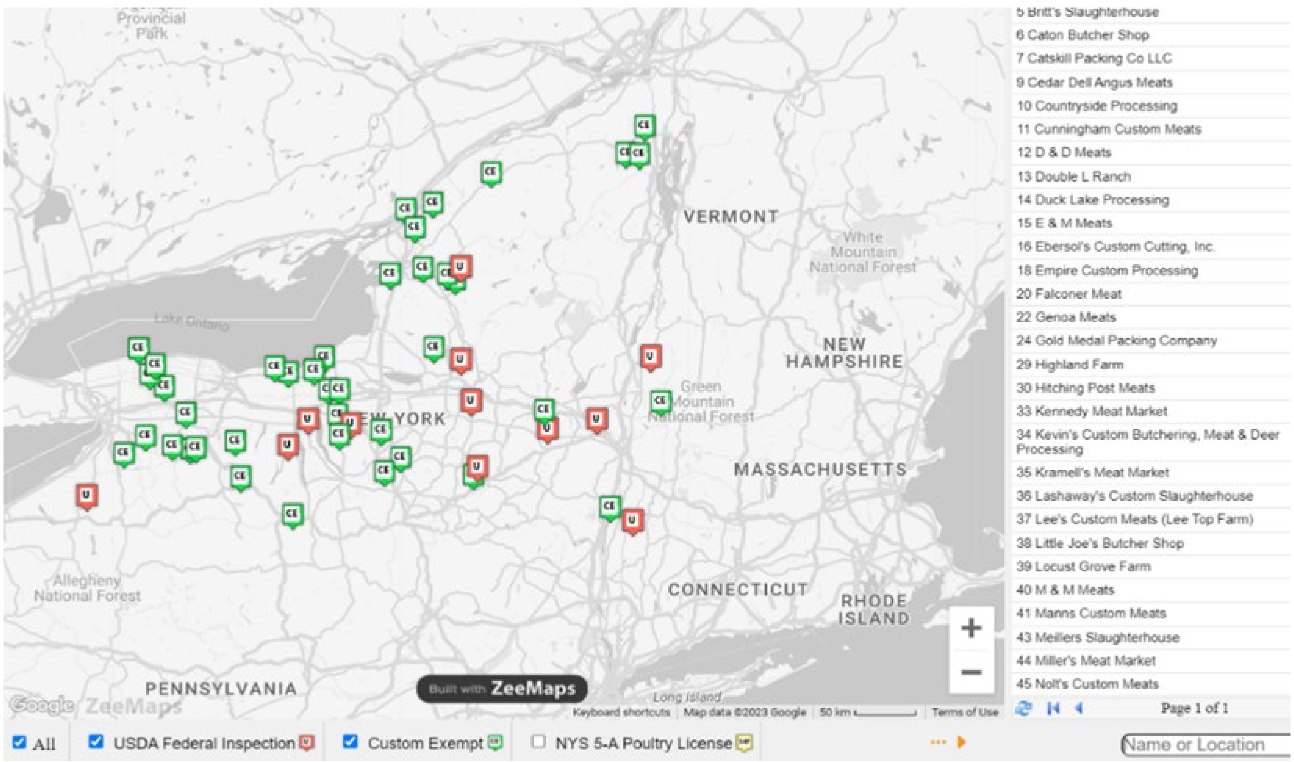
The New York State National Census of Agriculture counted 2,017 sheep farms in 2012 and 2,113 farms (all sheep) in 2017. On these operations, 86,298 sheep and lambs were counted in 2012 but that number fell to 80,195 in 2017. Anecdotally, sheep numbers in the State have since rebounded and now number around 90,000. The upcoming 2022 census will help to clarify the status of sheep production in the State.

The U.S. sheep, lamb, and wool industry had a total economic impact of close to $6.0 billion in 2017 (Shiflett 2017). The same year, New York State sheep and lamb sales were valued at $12,194,000 (USDA-NASS 2017a). These values are tracked through sales of animals brought to the market at one of the 20 different livestock auction houses in 18 different State counties. By comparison, Massachusetts and Pennsylvania host two livestock auctions each, while New Jersey and Connecticut each have just one auction house. These nearby auction locations are important; for instance, the New Holland, Pennsylvania Livestock Auction Stable is known to be the highest volume sale in the East. It is common for livestock buyers to purchase animals at smaller, regional auctions to be transported to the larger sale in Pennsylvania for better auction pricing. Some western producers regularly ship market lambs east to New Holland for a better potential return.

New York State-based animal processing infrastructure capable of harvesting sheep and lamb includes 11 USDA federal inspected slaughterhouses (of 62 USDA inspected across New England), as well as 20 more facilities that offer custom-exempt processing across the State (Figure 20). Around half of these custom facilities also offer mobile, on-farm harvest, and Kosher and Halal specific procedures (Cornell Cooperative Extension 2022). Nearby, New Jersey also has 15 livestock processors, the majority of which offer Halal services. The presence of these processors and custom services indicates steady multicultural demand for regionally produced livestock.

Figure 20. Livestock Processors in New York State

Source: www.ccelivestock.com/livestock-processors-in-ny-state

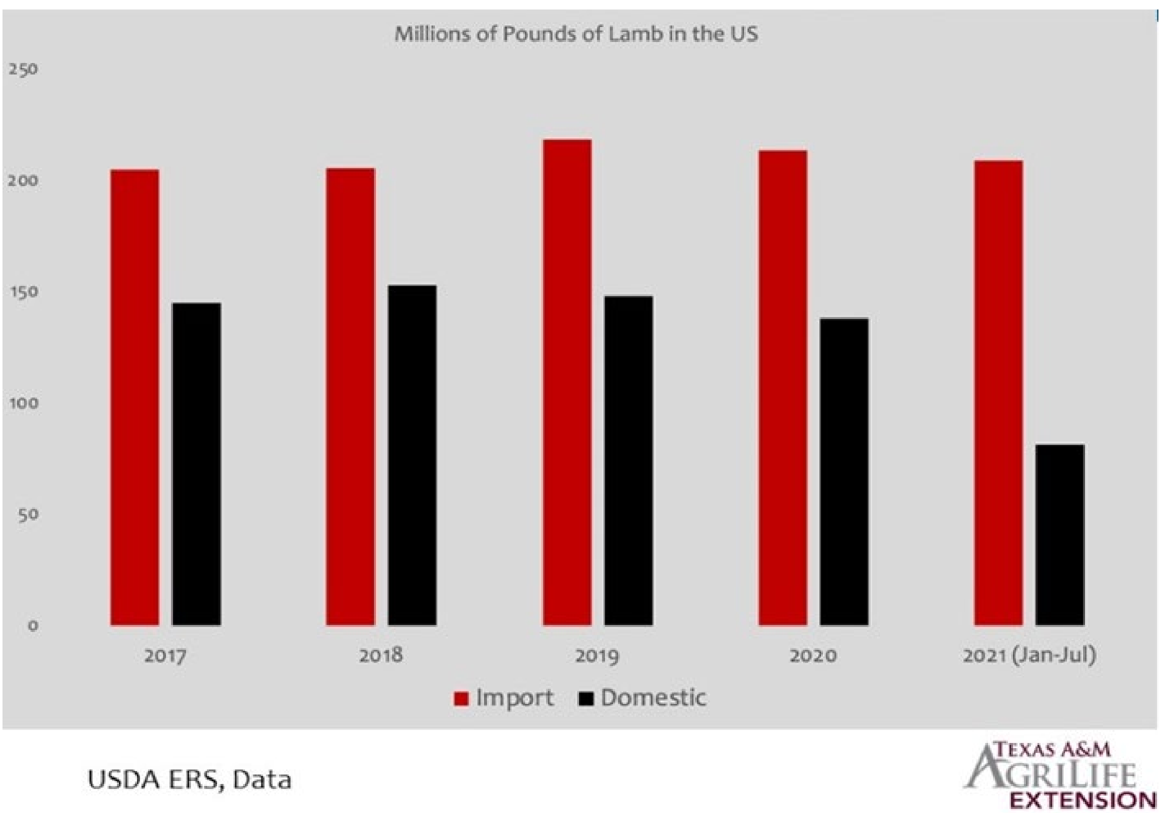


4.2.1.4 Opportunities and Constraints

While the robust network of regional, custom-exempt animal processors is an asset to nearby communities, the animals harvested at these facilities are not for resale and do not enter the market. What is needed is improved access to large volume, USDA-inspected facilities with the scale of labor, services, and storage capacity to meet the needs of more sheep farmers' broader market demand. According to a 2020 Tufts University research study, the average number of livestock producers that use a given processing facility is 170, and there are insufficient facilities available to serve local producers. This causes a bottleneck in delivering locally raised food to the community. Additionally, labor and cost efficiencies make harvest of beef and hogs more lucrative than lamb for existing processors. Tufts' research identified that most processors would prefer to limit the lambs they harvest due to inconsistent, seasonal delivery of animals, the intricacies of butchering small lambs, and the lower return on revenue (Peters 2020). These factors make it more difficult for sheep producers to schedule their animals with processors for custom harvesting or USDA-inspected services.

Simultaneously, to meet the needs of a "grossly under supplied demand" for domestic lamb and mutton, the United States imports over 300 million pounds of meat annually from New Zealand and Australia (approximately 350 million pounds in 2022) (USDA-AMS 2023) (Figure 21). Sheep producers in Australia and New Zealand generate a consistent supply of processed, boxed lamb for export, and their production costs are thought to be 30–50% cheaper than those of U.S. lamb producers (Anderson 2023).

Figure 21. Imported and Domestic Production of Lamb (Millions of Pounds)



Using estimates for a lamb with a dressed carcass weight of 50 pounds (48% of live animal) and saleable meat yield (retail consumer cuts) of 87% (Jacob and Calnan 2018), the 300 million pounds of meat annually imported into the United States represents over 6 million animals—more than the current population of sheep in the United States (USDA-NASS 2023). This volume of lamb imports is daunting, and it presents an opportunity for U.S. sheep producers with the right processing infrastructure to fulfill domestic lamb demand with fresh, regionally produced animals raised in conjunction with renewable energy production versus a frozen product shipped to the United States from across the globe.

An open question to be answered by the U.S. sheep grazing industry is: if fenced, protected solar pastures and management service fees paid to graziers may help to drive down costs of U.S. lamb production and improve its competitiveness, both in terms of price and environmental impact, with imported product.

In December 2022, the American Lamb Board was awarded close to $5 million from the USDA Partnerships for Climate Smart Commodities to measure and report carbon sequestration, soil health, and ecosystem services provided by sheep grazing on demonstration sites, including solar, throughout the United States and market the resulting climate-smart lamb products (USDA 2022b). Currently, none of these demonstration sites are located in New York State. The American Lamb Board project—Measuring the Climate Benefits and Emissions of Prescribed Grazing and Promoting the Consumption of Climate-Smart Lamb—is located in California, Texas, North Carolina, and Montana. ASGA is a key collaborator in further development of a national network of solar grazing trainings and certification to support industry best practices and hopefully improve market access (AgriSolar Clearinghouse 2023b). The growth of dual-use sheep and solar energy production at New York State renewable energy facilities presents an opportunity for State agencies to work together and support an expansion of needed regional food processing infrastructure—the technical skills and capacity—to facilitate increased production of affordable, homegrown sheep and lamb raised on NYS-based solar projects.

4.2.1.5 Markets for New York State and New England Sheep Wool

The United States was once among the top wool producing countries in the world. It now imports nearly as much wool as it exports. China, Australia, and New Zealand are the top global producers growing fine (Merino type), "combing wool" intended for suiting and apparel production. This quality of wool maintains a place among commercial textile fibers. Overall, wool's market share, and that of most other farmed fibers (cotton, silk, flax, and animal) has been steadily losing ground to man-made and synthetic fibers since 2008. According to the International Wool Textile Organization 2019 World Fiber Production and Consumption report, man-made fiber blends, recycled fibers, and synthetics account for more than 73% of global production. Wool's share was just 1.1% at that time (International Wool Textile Organization 15th edition).

In 2022, American wool production was 22.2 million raw pounds equaling 11.54 million pounds of clean wool (Savage 2023). This wool is consumed by:

- The U.S. Department of Defense, which purchases 15–20% of annual production for uniforms and bedding (ASI, Samuelson, pers. comm. 2021).
- The U.S. domestic wool industry.
- Wool exports to the countries possessing manufacturing resources (the U.S. once owned).
- Placement into storage since, depending on the quality, it may have little market value.

In New York State, the sheep-wool harvest was just over 250,000 pounds according to the 2017 agricultural census. This was produced by 801 State sheep-wool farms, mostly with small flocks of less than 100 head. In 2019, this wool was valued at ~$0.45/pound (Hohman and Havas 2020). At such low value, wool is clearly not the primary income source for producers, but it may add to the overall viability of the farm enterprise if it can be shorn and processed affordably and marketed and sold competitively with other U.S. regional and specialty wool products. It is possible that solar grazing fees could help to subsidize an expansion of regional wool production.

New York State has a thriving fiber community and hosts important early-stage processing resources that are vital to textile production in the Northeast. Commercial scale washing of wool (scouring) is a primary bottleneck for the U.S. domestic textile supply chain. Battenkill Fibers in Greenwich, NY, and the Hudson Valley Textile Project, which is developing an expanded scouring facility in Mechanicville, NY, are bright spots for the industry. USDA is spurring economic development by directing an award of $30 million to a cohort of five national organizations, including the New York Textile Lab, to support the expansion of climate-smart wool and cotton production on 135 farms and ranches spread across 2.1 million acres (NCAT n.d.).

Globally there is sustained demand for wool as a luxury fiber and increasingly when it is blended with man-made and synthetic fibers to make green fashion products. Demand for so called “eco-fibers” was valued at $40 billion in 2019, and that demand is projected to grow to over $58 billion by the year 2025 (Kelly, O’Connor, and Ostrander 2020). Wool products grown and processed in NYS solar and textile facilities are hardly represented in the marketplace, but with supports they could emerge in the future as an added outcome of regional dual-use sheep and solar production from the State’s evolving agrivoltaic food, fiber, and energy landscape.

USDA is investing $3.1 billion in 141 selected projects under Partnerships for Climate-Smart Communities. A project entitled Climate Beneficial Fiber: Building New, Accessible, and Equitable Market Opportunities for Climate Smart Cotton and Wool is partnered with the New York Textile Lab and seeks to expand the existing Climate Beneficial Fiber program into several states including New York State. Another project, NYS Connects: Climate-Smart Farms and Forests, “will build on existing strong partnerships in the conservation and agricultural communities to expand climate-smart markets” (USDA 2023). NYSDEC is the project’s lead partner.

In 2022 New York Governor Kathy Hochul signed the New York textile act, which aims to accelerate growth of fiber growing, processing, and textile manufacturing in the State. This legislation supports the State’s textile manufacturing industry through economic development and training programs and creates a Natural Fiber Textile Workgroup, chaired by the NYSAGM Commissioner focused on growing market opportunities (NYS Senate 2023–2024).

4.2.2 Sheep Grazing and Agrivoltaics

4.2.2.1 Case Studies

DG Solar Currently Grazed

An example of a “typical” NY DG solar array using contracted grazing for its vegetation management is the Nexamp Newfield Solar project in Newfield, NY (Figure 22). This project was commissioned in 2019 and hired a contract grazier for full-vegetation management of its facility since the initial year of operations. Although the project is sited on what was largely previous hayfields, the site is poorly drained and had not had active agriculture for several years before construction. The 40-acre project site is stocked with approximately 150 sheep for the grazing season. The animals are rotationally grazed, using portable, electric net type fencing for interior paddock delineation. Water is delivered to sheep in the site on a weekly basis throughout the season.

Although this site was not designed with animal grazing in mind, this has not been a barrier to success on a site of this size. The perimeter fence is secure, with chain link installed to grade. The site seeding competes with the vegetation that was already established on site, and while there is a stubborn Goldenrod population, it is managed with annual mechanical mowing. To manage for more productive forage over time, Nexamp has invested in additional seeding of a species blend that is compatible to grazing that was frost seeded into the soil by the contracted farmer.

Figure 22. Sheep Graze the Nexamp Solar Project in Newfield, NY

Source: Agrivoltaic Solutions

Planned Utility-Scale Project

The Morris Ridge Solar Energy Center is a 177-MWac project in the Town of Mount Morris, NY, developed by EDF Renewables and anticipated for commercial operation in 2024. This project was planned with sheep grazing in mind starting very early in the design and development process. EDF Renewables dedicated project development time to work through details of site design to accommodate sheep as well as extensive outreach to potential farm partners for contracting grazing services at the site. EDF Renewables also facilitated an in-depth study on the potential impact of the agrivoltaic activities on the local economy, titled: The Morris Ridge Solar Project: Agricultural Integration Plan: Managed Sheep Grazing and Beekeeping (Agrivoltaic Solutions, LLC. 2020).

A significant amount of planning must go into the solar site design phase for inclusion of sheep in a project of this scale. Considerations around animal movements, water sourcing and delivery, location of access gates, and additional fencing for paddock divisions must be made long before construction begins. The site has the potential to utilize over 2,800 sheep in a grazing program of full-vegetation management, which requires a more comprehensive effort and level of investment in the site design to host the animals. A particularly important piece in the planning process was the creation of a Prescribed Grazing Plan, which provides guidance for the animal stocking rate and rotation schedule for moving grazers through each section of the site to achieve the targeted vegetation compliance. The grazing plan is conceived to meet standards outlined in the USDA NRCS Code 528 Conservation Practice Standard—Targeted Grazing (USDA-NRCS 2017). The stocking rate is determined on a project section basis using NRCS soil survey data to estimate Animal Unit Months, a measure of available forage yield.

EDF Renewables plans to work with a local farm partner to perform the on-site grazing.

Ongoing Research

Numerous research and pilot efforts are underway to advance knowledge and best practice development for integration of sheep grazing at solar sites. The following represent a few relevant to New York State.

Under Partnerships for Climate-Smart Commodities, USDA has tentatively selected an American Lamb Board project entitled, Measuring the Climate Benefits and Emissions of Prescribing Sheep Grazing and Promoting the Consumption of Climate-Smart Lambs. This project plans to measure and report carbon sequestration, soil health, and other GHG benefits, as well as other associated ecosystem services provided by prescribed sheep grazing. Four different pilot demonstration sites will be utilized, including potentially one in New York State (USDA 2023).

In 2021, USDA funded a project out of Cornell University entitled, A New Dawn for Shepherds: Grazing Sheep Under Utility-Scale Solar Arrays. The project will focus on New York State, Pennsylvania, and New England with the goal of increasing cooperation among producers and industry organizations as it relates to farmers grazing sheep under solar arrays (USDA 2021).

4.2.2.2 Normal Operations

The contracting process for solar grazing is similar to that for conventional vegetation management. Bids are solicited for specific solar sites, and generally priced by the acre on a per service or per season basis. Grazing bids are generally on a per season basis as the grazing process happens over a longer period than a mowing service. Contracts will specify maximum vegetation heights, and provide parameters around trimming of equipment pads, maintenance of exterior vegetation around the site perimeter, access roads, etc.

Preparation for the grazing season will include site visits to examine perimeter fencing and identify areas where additional fence patching may be needed, such as low spots and culverts that could offer entry to predators. In circumstances where water is to be transported to the site, water delivery tanks and troughs will be set up prior to sheep delivery. In most cases, the grazing contractor will be responsible for installing low-exclusion fencing around the site equipment pads to keep them clear of sheep and reduce manure and loose wool around the electrical equipment. Temporary fencing and energizers will be installed prior to sheep delivery to commence the grazing rotation.

In the Northeast, sheep are generally deployed to solar sites in late April and May. Often, the initial weeks of grazing will begin with a lower stocking rate, which increases in animal numbers to match accelerating forage growth through June. As the weather begins to become drier in July and August, and forage growth slows, the stocking rate is reduced to account for the lower forage yield. Most sites have completed grazing activities by September/October, and the sheep are removed.

Rotational and prescribed grazing is the accepted practice for pasturing and targeted grazing of a solar array. Rotational grazing is important in several aspects of site management: more concentration of the grazing activity leads to less selective consumption of plant species, which results in a cleaner, mowed result with less variation in the residual plant material. Furthermore, manure deposition is more even and distributed, and plant regrowth is more vigorous with less root damage. Additionally, rotational grazing has special importance to sheep health and well-being. Sheep are particularly susceptible to Barber Pole Worm, *Haemonchus contortus,* which is transmitted via feces in grazed pastures. To break the worm life cycle, pastures need a rest period of at least 28–35 days, and ideally more than 42 days. The intentional design of the rest period in a managed grazing system is highly important to maintaining high levels of animal health and productivity.

The alternate scenario to a sheep flock spending the season rotating around a single site, is a system in which a grazing contractor has a number of solar sites in a geographic area and moves the sheep between the sites. This scenario would still be considered rotational grazing; however, each site would function as an individual paddock in the system.

From time to time throughout the season, mowing and trimming will often be used in several ways. Additional alley mowing can be employed as a control to help smooth out the forage growth curve early in the season and reduce the need for drastic increases and subsequent decreases in sheep numbers. Mowing is also useful for remedial work or piecemeal management of specific species that are less palatable to sheep and that may remain after grazing, such as thistles. An example of this is at the Arnprior Solar site near Ottawa, Ontario, where the solar grazier bales vegetation on site and brings it to the home farm for winter feed (Oehm 2021).

4.2.2.3 Site Considerations and Best Practices

There is currently no single cohesive set of standards or best practices developed specifically for animal grazing in solar facilities. ASGA is working to develop regional solar grazing training programs in partnership with the American Lamb Board (American Lamb Resource Center 2023). There have been independent initiatives in some states to develop frameworks around solar grazing best practices, such as the Maine Solar Farm Grazing Best Management Practices developed by the Maine Department of Agriculture Conservation and Forestry (2021). Others such as New York State look at fitting grazing programs into the framework of Targeted Grazing (ASI 2006), such as the NRCS Prescribed Grazing 528 Conservation Practice Standard (USDA-NRCS 2017).

Because rotational and targeted grazing are well established and recognized forms of land management, there are a wide range of frameworks for guiding best practices that can fit particular goals and different regional conditions.

A consideration that requires greater attention is how best and to what degree local farmers and landowners can be engaged in the practice. Figure 11 shows that, as of 2017, sheep and goat farming accounted for just 64,692 acres, which was 1% of total land in farms. As such, it is likely that many agricultural areas where solar may be located will not intersect with existing sheep grazing practices. Additionally, working within a fenced solar facility may require insurance that is unfamiliar to existing farmers and landowners. Education and training may be needed to support farmers in engaging with solar grazing activities. ASGA and American Lamb Board are currently working to develop a network of vetted, approved, and uniform state-based, solar grazing training and education. Visit ASGA on their website at www.solargrazing.org for a solar grazing contract.

4.2.2.4 Site Design for Managed Grazing

Managed sheep grazing has become the predominant form of co-location at ground mount solar arrays for several reasons. One of these is that integrating sheep grazing on a solar array is very cost-effective. Due to the size and behavior of sheep, there are minimal requirements for modification of standard site layouts. Unlike cattle, sheep do not require special raised or reinforced racking.

Sheep grazing stands apart from other forms of co-location in how it fits into normal site operations. The sheep fulfill a functional role on the site that aligns the interests of the participating farmer and the site operations team.

There are still many design considerations that must be considered when integrating livestock into a solar array. This is especially true with larger sites that will host flocks numbering in the thousands. The main areas of focus when designing a solar project for sheep grazing include:

- Perimeter fencing.
- General wire control, and height of CAB system and other raised cabling.
- Animal flow throughout the site and additional perimeter gateways.
- Water sourcing and delivery.
- Sheep exclusion areas, i.e., equipment pads, some combiner boxes.
- Interior paddock fencing.
- Seed mixes, and pre- and post-construction seeding protocols.

Additionally, the Prescribed Grazing Plan will involve thinking strategically about rotation design and sheep flow on a site with more than one fenced area. There are practical limits to how large a flock should be deployed in a single area, and it often makes sense to graze a large site with two or more separate flocks of sheep in sections with proximity to minimize trucking and longer flock moves.

4.3 Specialty Crops Focus Area

The following section provides an overview of New York State's specialty crops and supporting infrastructure and includes information on research and pilots considering how agrivoltaics might be applied to this industry. The USDA defines specialty crops as "fruits and vegetables, tree nuts, dried fruits and horticulture, and nursery crops, including floriculture" (USDA n.d.-d).

4.3.1 Industry Perspective

According to the 2017 Census of Agriculture State Profile, New York State fruits, tree nuts, and berries yielded $398 million in sales, which makes up approximately 18.9% of total crop sales in the State (USDA-NASS 2017c). The State ranks seventh in the country that produce fruits, tree nuts, and berries (USDA-NASS 2017c). Table 7 provides farms and related production diversity of fruits, tree nuts, and berries in 2017. As referenced in Figure 10 in section 2, the Finger Lakes region is the predominant market for fruits, tree nuts, and berry sales, with over $180 million in sales in 2017. Apples and grapes are the key specialty crops in terms of number of farms and land acreage in farms (USDA-NASS 2017c). Berries, including blueberries, blackberries, raspberries, and strawberries, are also significant specialty crops in New York State (USDA-NASS 2017c). In December 2021, NYSAGM announced that more than $1.2 million will be given to seven advanced research, education, and marketing projects to help specialty crop farms across the State grow and remain competitive, illustrating the importance of specialty crops to its economy (NYSAGM 2021).

Table 7. New York State's Fruit and Tree Nut and Berries Farming Production 2017

Source: New York State 2017 Census of Agriculture

Crop Type	Number of Farms	Land in Farms (Acres)
Apples	1,421	50,450
Grapes	1,175	33,142
Blueberries, all	837	1,828
Raspberries, all	606	589
Strawberries	568	1,229
Pears	440	891
Peaches	431	1,391
Blackberries and dewberries (including marionberries)	301	225
Cherries, sweet	290	676
Plums and prunes	254	407
Cherries, tart	196	1,927
Currants (black or red)	121	112
Elderberries	109	27
Apricots	92	143
Hazelnuts	74	60
Other berries	61	28
Chestnuts	59	145
Nectarines	53	103
Other nuts	50	201
Walnuts, English	39	50
Aronia berries	33	(D)
Persimmons	19	4
Pecans, all	17	64
Figs	9	2
Boysenberries	7	1
Kiwifruit	7	(D)
Cranberries	6	(D)
Plumcots, pluots, and other plum-apricot hybrids	4	2
Pomegranates	3	(D)
Lemons	3	(Z)
Loganberries	2	(D)
Dates	1	(D)
Almonds	-	-

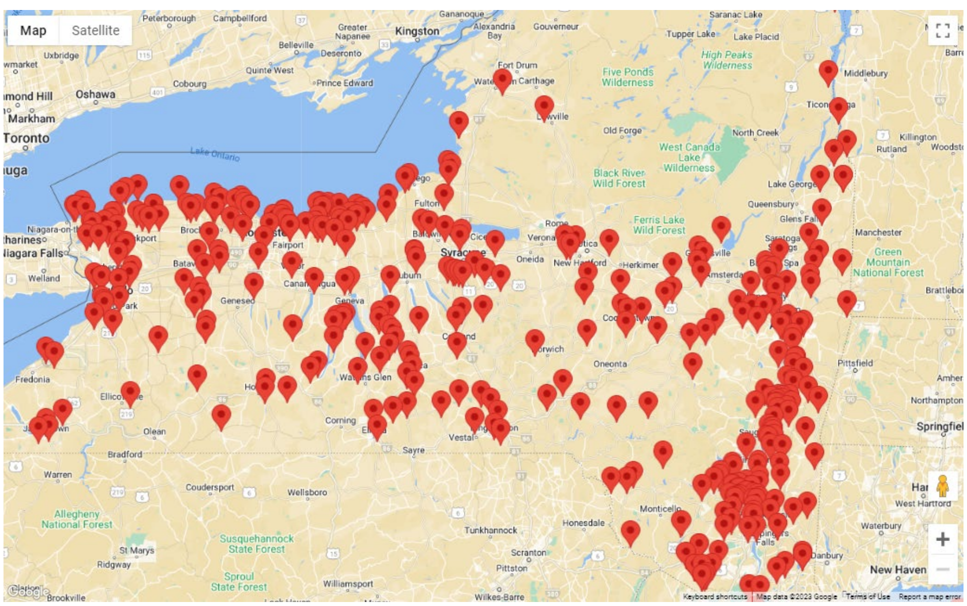
Note: - = represents zero; (D) = withheld to avoid disclosing data for individual farms; Z = less than half of the unit shown.

4.3.1.1 Apples

In 2017, there were 1,421 apple-producing farms across 50,450 acres in New York State (USDA-NASS 2017c)—ranking second in the top apple production in the U.S., preceded by Washington and followed by Michigan (AgMRC 2021). Apples are grown across six major State production districts (New York Apple Association 2023). In 2021, apple utilization totaled 1.33 billion pounds valued at $345 million (USDA-NASS 2022d). Research out of Cornell University suggests that the already sizeable impact of apples on the State's economy may be 21% greater than what is currently reported when the impact of local and regional food systems is more accurately taken into account (Schmit et. al. 2019). Schmit et. al. (2019) compared the default fruit farming production function in IMPLAN and the apple farming production function they constructed to reach this conclusion. Figure 23 illustrates the number of apple producers and is sourced from the New York Apple Association, which provides information about the apple industry in the State. Location types depicted include pick-your-own sites, apple cider locations, farm growers, and green markets, among others.

Figure 23. Apple Producers in New York State

Source: https://www.applesfromny.com/find-apples/



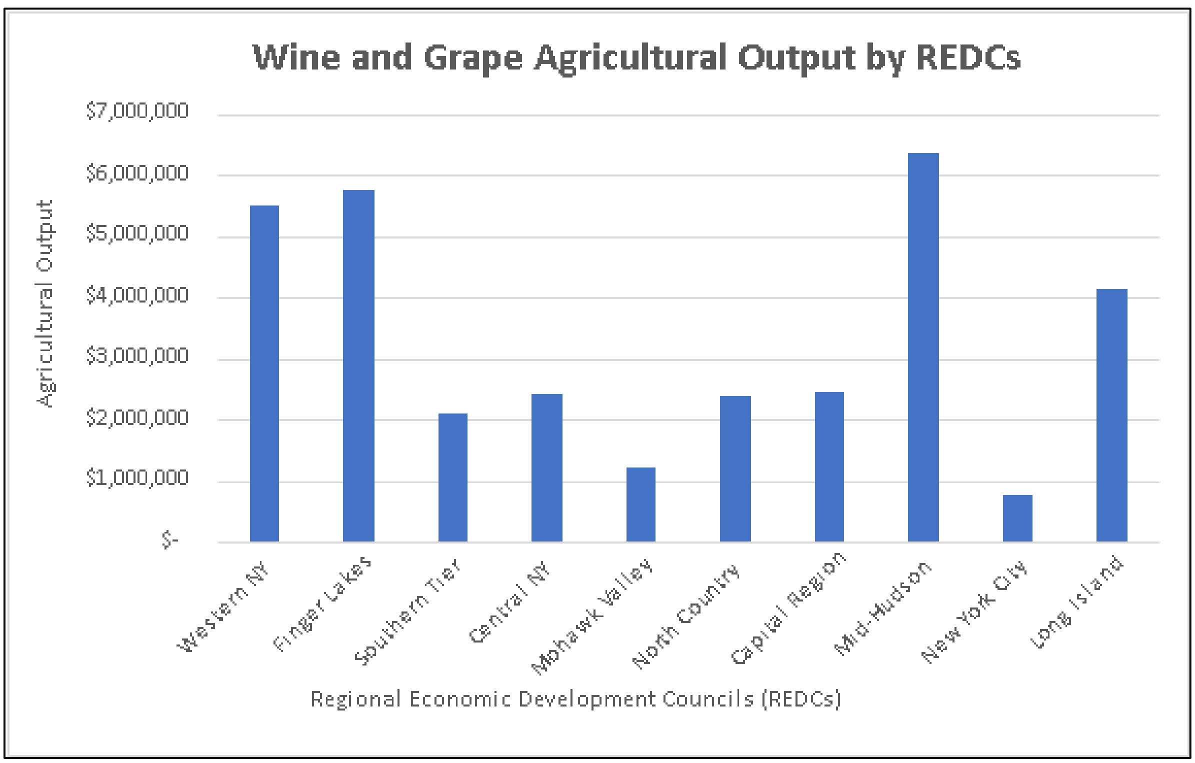
4.3.1.2 Grapes

There were 1,175 grape producing farms across 33,142 acres in New York State in 2017 (USDA-NASS 2017c), and the State ranks sixth in the country for grape-production, preceded by Missouri and followed by North Carolina (AgMRC 2023). In 2017, vineyards contributed to 2,248 jobs (direct impact, supplier impact, and inducted impact) resulting in $53,035,800 in wages and $118,879,400 in output (JDA 2019). In aggregate, the wine and grape industry directly generates $6.65 billion of economic activity (JDA 2019). There are four major grape growing regions: Lake Erie Region, Long Island, Finger Lakes, and Hudson River Region (Cornell CALS, n.d.).

Figure 24 illustrates the 2019 agricultural output of wine and grapes per REDC in New York State. Agricultural output measures the value of all sales of agricultural products and the goods and services they produce. As indicated in the figure, the Mid-Hudson region had the greatest agricultural output with nearly $6.5 million in sales, followed by the Finger Lakes, Western New York, and Long Island regions.

Figure 24. Wine and Grape Agricultural Output by REDCs, 2019

Source: https://newyorkwines.org/industry/statistics/



4.3.1.3 Berries

Despite the relatively short growing season, in 2016 and 2017 berries accounted for $6.5 million in sales, with $6 million from strawberries, $300,000 from blueberries, and $120,000 from raspberries and blackberries (Fruit Growers News 2018).

As Table 7 shows, berries, including blueberries, raspberries, strawberries, blackberries, cranberries, boysenberries, aronia berries, and other berries, account for approximately 33% of the specialty crop farms and approximately 4% of land in acres on specialty crop farms in New York State.

4.3.1.4 Peaches

There were 431 peach producing farms across 1391 acres in 2017 (USDA-NASS 2017c). Nearly a quarter of NYS peach production in occurs in the eastern part of the State (Cornell Cooperative Extension n.d., c).

4.3.1.5 Pears

There were 440 pear producing farms across 891 acres in 2017 (USDA-NASS 2017c). The majority of pear production is also concentrated in eastern New York State (Cornell Cooperative Extension n.d., b).

4.3.2 Specialty Crops and Agrivoltaics

Research and pilot programs related to co-locating specialty crops and solar arrays throughout the United States and globally can meet a multitude of challenges related to climate change. Experts refer to this kind of co-location as dynamic agrivoltaics, which “aims to improve the agricultural production by modifying the climate above plants, then producing clean, renewable, low-cost energy” (Sun’Agri n.d., b). Orchard/horticulture farming type crops such as apples, pears, berries, and grapes are generally row-based and already require some protection against extreme weather conditions, opening potential for co-location with solar arrays (DOE 2022d).

According to NREL’s “The 5 Cs of Agrivoltaic Success Factors in the United States: Lessons From the InSPIRE Research Study,” higher-value horticultural and specialty crops are more commonly found in elevated agrivoltaics systems (Macknick et. al. 2022). In general, the partial shade created by solar installations raises crop cultivation considerations, including amount of sunlight, changes in the microclimate, and soil moisture (InSPIRE n.d.).

Furthermore, in 2022 researchers from the Agricultural and Food Policy Research Group, University of Hohenheim in Stuttgart, Germany, published their results of a meta-regression by a mixed effects model, to estimate the susceptibility of different crop types to shading based on literature data. The results suggest grain legumes and maize are most susceptible to reduction in solar radiation, with a large decline in yield starting at 1% reduction in solar radiation. However, berries, fruits, and fruity vegetables may show initial benefits up to 40% shade (Laub et al. 2022). Further research on shading and crop yield would support efforts to optimize agrivoltaic design for specialty crops.

4.3.2.1 Apples

In 2021, the Fraunhofer Institute for Solar Energy Systems ISE in Germany alongside other research partners established an agrivoltaics system for research in Gelsdorf, Rhineland-Palatinate. The project will run for five years and will use eight apple varieties to explore a range of research questions (DOE 2022d). The project will investigate apple production under four different crop protection systems: foil roofing (blocks rain), hail protection nets (does not block rain), APV with permanent, light-permeable PV modules (blocks rain), and tracking PV modules (blocks rain if necessary) (DOE 2022d; Fraunhofer ISE 2021). The project hopes to demonstrate both the economic benefits for farmers in addition to potential for climate change adaptation and crop protection (Fraunhofer ISE 2021). For its agrivoltaics projects in Germany with a 20-year team, the Fraunhofer ISE estimated the levelized cost of electricity to range between €0.07 and €0.12 per kWh, averaging €0.093 per kWh (Bellini 2021).

A study conducted in 2019 over an apple orchard in Mallemort, France, examined the effect of shading below solar panels on apple production (Juillion et. al. 2019). Researchers found that having solar panels over their apple trees resulted in a 30% reduction of water needed without any impact on fruit growth (size) (Juillion et. al. 2019). The study area covered 730 square meters and the PV modules rotated following a “Solar Tracking” approach (Juillion et. al. 2019).

There is an agrivoltaic project co-sponsored by Cornell College of Agriculture and Life Sciences, Sun’Agri, and New York State Solar Farm focused on apples currently under development in Hudson Valley, NY. The project plans to replicate technology successfully utilized by Sun’Agri in France in Upstate New York. The project will be approximately 250 kWDC and will be placed on a single access tilt that sits at a height of 5 meters, which will enable normal farm operations underneath the array (Schwartz and Buono, n.d.).

4.3.2.2 Grapes

In California, Sunzaun Somerset Vineyard began experimenting with panels between its rows of grapevines in 2022. The vineyard has a vertical solar system with 43 bifacial modules with a total power of 23 kW (AgriSolar Clearinghouse 2023a). The vertical design is adaptable for changes in panel size and allows for energy production on both sides of the array (Kennedy 2023). Although it is too early to determine the full benefits of this type of agrivoltaitc system, it exemplifies opportunities for innovation with specialty crops such as grapes (AgriSolar Clearinghouse 2023a).

Agrivoltaics developer Sun'Agri has two research sites in France that investigate the impact of shading from dynamic agrivoltaics systems on grape vines (Sun'Agri n.d., c). In Piolenc, Sun'Agri installed a 280 panel, 84-kW viticulture agrivoltaics system (Rollet 2020). This system is 4.2 meters tall with 2.25 meter between the rows (Sun'Agri n.d., a). A spokesperson from Sun'Agri explained that "out of 1,000 m² of vines planted with [the] black grenache [red wine grape], 600 m² were covered by our dynamic agrivoltaic system" (Rollet 2020). The company used an algorithm driven by artificial intelligence to "determine the ideal tilt of the panels according to the sunshine and water requirements of viticulture, growth model of the crop, soil quality and weather conditions." The PV structure sheltered the vines during heatwaves, decreased water demand by 12-34% and improved the aromatic profile of the grapes (Rollet 2020). Overall, this study suggests that the benefits of dynamic agrivoltaics include reduced heat stress, heatwave protection, improved yields, temperature management and reduced water use (Sun'Agri n.d, b).

In LaGaillarde, France Sun'Agri has a 230 panel array over Syrah grapes (Sun'Agri n.d,c). In Rians, France, solar developer Ombrea and the Canal de Provence Company partnered to experiment with co-locating solar arrays and grape vineyards. They found a 51% reduction in scorching hours for vines under the arrays, a 66% reduction in temperature in periods with too much sunlight, and systematically lower soil temperature under controlled shading (SolarPower Europe 2023).

4.3.2.3 Blueberries

Through funding from BlueWave Solar and the Northeast Sustainable Agricultural Research and Education program, the UMaine Cooperative Extension researched the economic and agronomic feasibility of dual-use solar on commercial wild blueberry land in Rockport, Maine from August 2020 to August 2022 (UMaine Cooperative Extension n.d.). The study was conducted on the 12 acres of a 40-acre plot that were south facing (NYPA 2023b). The study sought to "identify whether use of distinct construction and solar installation methods can minimize the impact of construction on existing wild blueberry fields" and to understand the impact of shade provided by solar arrays on wild blueberry production (Calderwood et. al. 2022). The researchers preliminarily determined that "under-panel soil moisture levels were 35–54% greater than those in the external control," which suggests that soil moisture retention increases under solar panels (Calderwood et. al. 2022). The Northeast Sustainable Agricultural Research and Education (SARE) program offers grants and education to farmers, educators, service providers, researchers, and others to address key issues affecting the sustainability of agriculture throughout the Northeast (Northeast SARE n.d.).

Since New York State blueberries vary from the wild variety utilized in the study, additional research on the varieties would be beneficial. Although high-bush blueberries are grown throughout the majority of the State, crosses between Maine's low-bush berries and northern high-bush blueberries—which tend to be hardier in the winter—can be found in northern New York State and the Adirondacks (Cornell Cooperative Extension n.d., a).

4.3.2.4 Raspberries

In the Netherlands, BayWa r.e. and Dutch farmer Piet Albers have been experimenting with agrivoltaics and raspberry cultivation since 2019, with the agrivoltaics installation now covering 3.3 hectares (Lichner 2021). Lichner (2021) reported that in the BayWa r.e. pilot installation, the sloping of the module roofs allows for warm air to escape making it five degrees lower under than modules than under conventional plastic sheeting (Lichner 2021). Project manager at BayWa r.e. Stephan Schindele noted "less temperature variation under the [agricultural photovoltaics (agri-PV)] encourages plant growth because less energy has to be put into temperature management" while "at the same time, better airflow reduces fungal pressure, which decreases the need for fungicides" (Lichner 2021). SolarPower Europe defines agri-PV as "the smart combination of agricultural infrastructure with a photovoltaic installation" (SolarPower Europe n.d.).

As a result of this pilot, BayWa r.e. designed a semi-transparent solar module that allows for the right amount of sunlight to pass though while not impacting solar panel performance (BayWa r.e. n.d.).

According to a case study posted to the AgriSolar Clearinghouse, Jack's Solar Garden in Boulder, Colorado is the largest commercial agrivoltaics research site in the United States with a 1.2-MWac, single-axis tracking solar system. NREL, Colorado State University, and the University of Arizona all conduct research on a variety of potential agrivoltaic applications at Jack's Solar Garden. Raspberries are among the crops grown, though results of this research are yet to be published (AgriSolar Clearinghouse 2022b).

4.3.2.5 Strawberries

A farm in Eyrargues, Bouches Du Rhone, France, co-located a solar array and strawberries (SolarPower Europe 2023). They found that the shading from the greenhouses with the arrays on top reduced water requirements by 20 to 30%. An Enel Green Power Agri-PV project in Greece found a 18% increase in yield of strawberries grown in the corridors between modules (SolarPower Europe 2023).

4.3.2.6 Peaches

In France c, Sun'Agri is developing a pilot project that involves the cultivation of peaches, apricots and cherries. The demonstration project aims to find solutions to protect crops from climate hazards recently experienced in the Rhône Valley—such as high temperatures and droughts, spring frosts, and hailstorms. The initial project—related to apricots, cherries, and nectarines—will have 1.9 MWdc capacity and be situated on 2.6 hectares (6.4 acres) and will have anti-hail nets that deploy automatically during a hailstorm event. A separate experimental array will be built on a half-acre site where Kinolea peaches will be cultivated (Deboutte 2022a).

4.3.2.7 Pears

In Bierbeek, Flanders, a Belgium-based energy research team led by KU Leuven developed an agrivoltaics pilot project focused on pears with the goal of protecting against hail damage (Bellini 2020). They placed the solar modules at a height of 4.6 meters and used transparent back sheets and conventional, equally spaced 156-by-156-millimeter silicon cells (Bellini 2020). The results of the study have yet to be published.

4.3.2.8 Hops

In Hallertau, Germany a $1.64 million project commissioned by Agri Energie is combining solar arrays and hops (Enkhardt 2023). The area of the facility is 1.3 hectares and will produce enough energy for nearly 200 households (Enkhardt 2023). The use of steel masts will protect hops from sunlight and hail, reduce evaporation, and support the plants (Enkhardt 2023).

In Luçon, France Q Energy France is piloting a project combining solar arrays and hops on 1 hectare of land (Deboutte 2022b). The Chamber of Agriculture of the Pays de la Loire region will validate the results of the pilot (Deboutte 2022b).

5 Design Considerations Affecting Agrivoltaics

Key design factors for any ground-mounted solar energy facility include solar cell type, racking design, height of panels, and spacing between panels. These factors affect the power density and energy yields that must be considered to better understand compatibility with agrivoltaics. Similarly, the placement, orientation, and spacing of solar panels can directly impact crop growth and yield. Each design choice comes with cost considerations for solar developers that include upfront capital expenditure and long-term operation and maintenance costs. Additionally, design choice can impact crop selection and productivity, resulting in potential cost implications for farmers.

The following provides a limited review of design considerations for agrivoltaics occurring within a solar array (i.e., directly underneath PV modules and/or in the rows between PV modules). Additional opportunities for agricultural co-utilization within the greater footprint of a solar facility site (e.g., in the buffer area between the outer edge of PV modules and the security fence or as vegetative screening outside the security fence) are not specifically evaluated below.

5.1 Typical Solar Array Design Considerations

The majority of solar modules in use today have crystalline silicon cells, which provide high efficiency, low cost, and an expected lifetime of 25 years or more (Office of Energy Efficiency and Renewable Energy n.d.).

The types of PV modules commonly installed in ground-mounted PV systems are monofacial and bifacial (NYPA-EPRI 2023):

- **Monofacial:** modules that collect light from the front side, typically have a transparent front and opaque back.
- **Bifacial:** modules that collect light from both sides of the module, able to collect light coming from the sun and reflecting off the ground.

Because the bifacial PV energy gain relies on reflected light, the more the ground can reflect, the more power the panels can produce, which could be affected by type of ground cover or vegetation underneath the panels.

Common types of ground-mounted racking systems, as would be used in an agrivoltaic setting, are fixed-tilt or tracking options (NYPA-EPRI 2023):

- **Fixed-tilt:** a racking structure that has as static PV module azimuth, typically south facing in the northern hemisphere
- **Tracker systems:** follow the sunlight from east to west, capturing more sunlight through the course of the day, but may require more spacing between rows to avoid shading. Tracker systems can be single axis, which rotates on either a north/south or east/west axis, or dual axis, which rotates on both the north/south and east/west axis (Reasoner and Ghosh 2022).

The modules (or panels) are arranged in “portrait” or “landscape” and may include one or more modules stacked in this orientation. These options also affect inter-row spacing and potential compatibility with agrivoltaics. In the United States, utility-scale solar typically involves ground-mounted modules with a minimum module height of 20 inches from the ground. In the northeast, the minimum module height is often closer to 36 inches from the ground to account for buildup of snow in the winter. Both fixed tilt and tracker racking systems can be elevated to allow a broader range of agriculture operations within the solar arrays (NYPA-EPRI 2023). In addition, tracker systems can be designed to limit or maximize the tilt angle of the module and create additional room underneath panels for agricultural operations.

The ground coverage ratio (GCR) reflects the layout of the PV modules and is defined as the ratio of the module surface area to the area of ground that the array occupies. A GCR of 0.5 means that, when the modules are horizontal (or level), half of the surface below the array is covered by the modules. A GCR of 1 indicates that there is no space between the rows of PV modules. This parameter is important because shading can occur between neighboring rows of modules in arrays of this type.

Several racking manufacturers have also developed tracking systems that can be programed to either track or not track the movement of the sun to optimize the amount of light reaching crops cultivated underneath modules. At least one company has a phone application where the user can set the desired parameters for module tracking (Alonso Group 2021).

Further research in photovoltaic technology is ongoing, and new technological advances will continue to inform the design of solar sites and agrivoltaic accommodation. For instance, the development of other semiconductor materials is well under way to make other, more efficient and versatile solar cells commercially viable (Office of Energy Efficiency and Renewable Energy n.d.). Researchers are also investigating the use of artificial intelligence (AI) to optimize solar tracking for more efficient energy production (Vodapally and Ali 2023); the same technology can support optimization for crop yield.

For example, SolarEdge and SolarGik designed an AI-powered solar tracking system with agrivoltaics in mind that can automatically adjust solar panel angles according to agricultural seasonal patterns, weather, and sunlight (Deboutte 2023).

5.2 Cost Considerations in Agrivoltaic Settings

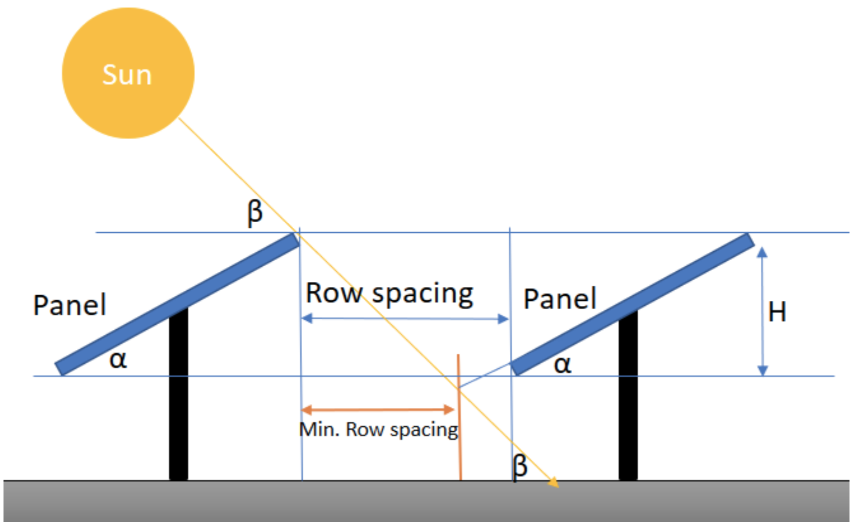
For elevated PV module setups in agrivoltaics, row spacing is generally increased to allow sufficient sunlight through for agriculture under the modules, which in turn increases the acreage required for energy production (Clean Energy Council 2021). Additionally, raising the height of arrays to allow for agricultural machinery or taller agricultural products (e.g., trees, corn, cattle) underneath the arrays requires a higher capital expenditure for materials and installation (McCall et al. 2023).

Tracking module systems are more costly than fixed-tilt racking. Dual-axis systems are effective at maximizing energy generated; however, this style of racking is also more expensive to install and operate than single-axis systems (Reasoner and Ghosh 2022). Vertically oriented bifacial arrays are also a more costly capital expense than fixed-tilt, monofacial modules but have the advantage of requiring less land, result in less interference with agricultural activities, and are easier to keep clean (Abidin et al. 2021).

5.3 Applying Solar Design Criteria to Support Agrivoltaics

The effects of certain design criteria that may allow for novel agricultural uses within a solar project can be understood through comparing the power density and energy yields of select types of solar racking configurations. “Power density” refers to the number of watts generated per unit area and “energy yield” refers to the amount of energy kilowatt hours generated from solar modules, taking into consideration external factors like reflection, heat, dirt, and shade compared to the total potential energy. Figure 25 illustrates the features and arrangement of components used in modeling power density and energy yield.

Figure 25. Key Design Parameters Relevant to Calculating Power Density and Energy Yield Changes for Agrivoltaics



Assuming a 5-acre buildable area rectangle based on a single-axis tracker configuration with one module in portrait and typical design specifications allows for creation of layouts and alternatives that simulate energy yield estimates for each racking design configuration. The analysis considered combinations of several racking design types (single-axis tracker, fixed-tilt, and vertical designs) with a limited but select variations of row spacing and module orientations. As Table 8 shows, variations in module orientation, inter-row spacing, and other parameters affect yield as measured in power output and shading, among other factors relative to the first racking design configuration (Scenario 1), single-axis tracker with one module in portrait.

The single-axis tracker with 1 module in portrait versus 2 modules in portrait resulted in an equivalent power density and energy yield with same ground coverage ratio despite row spacing of 11 feet and 23 feet respectively. Also notable, increasing a single-axis, tracker range of motion from 60 to 70 degrees resulted in a slight increase of 0.3 acres of additional land per MWdc between the modules when the tracker is at maximum tilt angle.

With modules in a vertical position, the effects on yield with increasing row space were also different depending on the orientation of the modules to south or west azimuth. Preliminarily bifacial gain in a vertical design is extraordinary in a west/east azimuth orientation compared to a southern orientation and as row spacing increases, a west oriented module results in a higher yield than the true south orientation.

Table 8. Comparison of the Power Density and Energy Yields for Variations in Solar Racking Design Configurations and Row Spacing

Scenarios	1	2	3a	3b	4a	4b	4c	5a	5b	5c
Metrics	**Design Configuration Description**									
	1P (60°)	20° Fixed Tilt	2P (70°)	2P with crop shade	Vertical Scenario A	Vertical Scenario B	Vertical Scenario C	Vertical Scenario A	Vertical Scenario B	Vertical Scenario C
MWdc	1.7	2.2	1.7	1.7	2.6	1.3	0.9	2.7	1.3	0.9
MWac modeled in Energy Estimate^	1.3	1.7	1.3	1.3	2.0	1.0	0.7	2.0	1.0	0.7
Module Orientation/Azimuth	South	South	South	South	South	South	South	West	West	West
Pitch	18'	27'	37'	37'	12'	23'	35'	12'	23'	35'
Inter-Row Spacing	11'	13'	23'	23'	11'	23'	35'	11'	23'	35'
Ground Coverage Ratio (GCR)	40%	52%	40%	40%	6%	3%	2%	6%	3%	2%
Total # of Acres	5	5	5	5	5	5	5	5	5	5
Acre/MWdc	3	2	3	3	2	4	6	2	4	5.6
Year 0 MWh Estimate	2,602	3,002	2,587	2,418	2,268	1,393	1,007	2,205	1,410	1,036
MWh/Acre	511	590	508	475	446	274	198	433	277	204
Specific Energy Yield (kWh/kWp dc)	1,565	1,354	1,556	1,454	861	1,058	1,118	831	1,063	1,150
Specific Yield Change from Scenario 1	n/a	-13%	-1%	-7%	-45%	-32%	-29%	-47%	-32%	-27%
Global Irradiance on Rear Side, %	9%	8%	6%	6%	25%	28%	29%	98%	92%	90%
Shadings: Electrical Loss, %	0%	0%	0%	-4%	-4%	0%	0%	-3%	-1%	-1%

^All scenarios were grid limited in the energy yield simulations to have an inverter loading ratio of 1.3

1p (60°) = 1 module in portrait on a single axis tracking system with a range of motion of 60° +/-

2P (70°) = 2 modules in portrait on a single axis tracking system with a range of motion of 70° +/-

Vertical = 2 modules in landscape on a fixed tilt racking system in a vertical (90°) orientation

6 Key Findings and Recommendations for Continued Research and Engagement

This report summarizes the A-TWG's AGV SC initial series of meetings, limited literature review and related investigations to advance an understanding of New York State's agricultural landscape and review the current status of agrivoltaic programs and pilots from a perspective of relevance to the State in order to identify ongoing efforts that should be monitored, identify knowledge gaps, and ultimately support A-TWG's ability to provide guidance on best practices and potential policy support mechanisms for those practices deemed most pertinent to the State. The guiding framework considers applicability, feasibility, and reasonability for each aspect of the research performed. Section 2 lays the foundation for applicability, recognizing that meaningful application of agrivoltaics must consider New York State's specific agricultural economy. Section 3 provides review of current pilots and programs to identify agrivoltaic pilots and programs in New York State, the Northeast, and incentivized through federal programs that support growth of knowledge in agrivoltaics. Recognizing the importance of dairy farming to the State and existing proven applications of solar sheep grazing, as well as emerging practices related to specialty crops, section 4 advances an understanding of the applicability and feasibility of the pursuit of agrivoltaics in these three contexts. Section 5 initiates the review of feasibility of agrivoltaics from a solar design perspective.

Each section of this limited literature review underlines the need for ongoing investigation of opportunities and constraints to agrivoltaic solutions in the State, which will need to be addressed to move toward an understanding of reasonability. This reasonability must consider not only what is feasible to employ as well as relevant to the agricultural economy, but also what will ultimately be economical and desirable to farmers and solar developers to employ. This component will be critical to understanding what, if any, incentive structures and/or programs should be pursued to accelerate viable agrivoltaic solutions in the State. Additionally, potential future advancement of support and acceleration mechanisms will need to develop criteria for determining how success is defined within an agrivoltaic operation that considers agricultural yield, soil and ecological health, solar performance, long-term viability, levelized cost of electricity, and ratepayer impact, among other factors.

New York State's diverse and dynamic agricultural sector is a significant contributor to the State's economy on multiple levels. The variation among and between counties with respect to farmland, crops, and livestock indicates a similar diverse opportunity for types of agrivoltaic projects that may warrant further consideration. To support further development of solar while promoting land-use efficiencies, supplementing agricultural revenue streams, and minimizing land-use competition, the following recommendations should be considered:

- Improving understanding of crops currently imported, if they can be grown within the State and with agrivoltaics, and what opportunities may exist to strengthen the foodshed.
- Providing greater understanding of regional context of opportunities across the State, including consideration for beneficiaries, agricultural sector impact, and land-use change in proximity to transmission infrastructure.
- Providing competitively sourced funding of agrivoltaics demonstration projects coupled with applied research with a preference for solutions that offer the most relevancy and scalability to the State's agricultural economy.
- Developing and/or prioritizing incentives and programs for agrivoltaics associated with the most valuable crops, livestock, and/or livestock products.
- Improving understanding of how solar development will impact land use in the context of NYS's Climate Act goals.
- Identifying and/or developing opportunities to better connect farmers and developers interested in pursuing agrivoltaics with one another.
- Continuing research beyond what is currently considered in the scope of this report. For example, vegetable farming is important for food resilience within the State and could be explored further. Additionally, this report does not explore opportunities for enhancing or supporting ecosystem services associated with clean energy generation and agrivoltaics, such as opportunities to improve soil quality.

In considering the dairy industry's percentage of the State's agricultural market share and supported agriculture land-use, it will be important to develop and continue to monitor dairy farming relevant agrivoltaic pilots in New York State and regionally. Additional research is needed to understand economic implications of solar design and operational practices that accommodates sizable graziers, as well as related to long-term dairy forage crops, including corn, soybean, and alfalfa production, and needed rotations for maintaining and/or supporting retainment of nutritional values. Additionally, advancing research on climate change impacts to the dairy industry will provide greater context for understanding the benefit of using solar panels as a shading feature for grazing cattle and forage crops.

Sheep grazing has had demonstrated success in New York State. However, education, training, and legal support may be necessary to support local farmers and landowners with participating in and benefitting from solar grazing programs. Because sheep grazing requires relatively minimal change to common solar design configurations, stakeholders would benefit from development and dissemination of grazing-ready site design standards. These could be integrated early on in project design allowing for consideration of sheep grazing throughout the lifespan of a project. From a market perspective, greater attention is needed to understand potential growth of the lamb and sheep products market, implications for expansion of enabling support infrastructure, and considerations for what the State's role may be in expanding the market. Additionally, the State may consider the potential for avoided greenhouse gas emissions from local sourcing of lamb and sheep products rather than import from locations like New Zealand and Australia.

Preliminary research is underway assessing agrivoltaics as a mechanism, particularly the dynamic functionality of an overhead louvered agrivoltaics design, to support resilience for specialty crops against impacts of severe weather and climate change. Additionally, research from the Agricultural and Food Policy Research Group in Germany suggests that berries, fruits, and fruity vegetables may show meaningful benefit from shade. This points toward opportunity to further research specialty crops in the New York State context to better understand shade implications on growth and potential affiliated agrivoltaic design optimization strategies, as well as continued research on the feasibility for agrivoltaic application to address severe weather and climate impacts in this region. Cost considerations will need to be studied to determine overall value of the application.

The growing examples of legislation, programs, pilot, and full-scale projects in the State, regionally, nationally, and globally demonstrate multiple approaches to addressing barriers to agrivoltaics and reducing uncertainties related to project risks and liability. To further the understanding of the applicability of these approaches, New York State could:

- Closely evaluate projects with the most relevance to the State's objectives and continue to monitor existing and emerging State and federal programs that New York State may leverage to identify best practices.
- Consider modifications to the NYSERDA Model Solar Energy Local Law rule to promote agrivoltaics and revise language that could be considered a barrier.
- Initiate engagement with NYSAGM to determine potential for certification programming related to agrivoltaic agricultural products.
- Work with NYSAGM to integrate language considering agrivoltaics into the Farmland Protection Planning Grants Program and affiliated programs.
- Establish clear statewide tax guidance for agrivoltaics.

Finally, the effects of changing certain design criteria of the solar array's racking system to increase the inter-row spacing available for agricultural uses within a solar project demonstrated multiple scenarios with little change to power density or energy yields. These encouraging results for a preliminary look at compatibility of solar and agriculture prompt consideration of further evaluation, including:

- New or additional design configuration variations.
- Comparing changes in capital cost, operating cost, and levelized cost of electricity.
- A deeper dive into compatibility with commonly used farm equipment needed to grow certain crops to better understand the associated minimum requirements for inter-row spacing and turning radius; in turn, evaluate the estimated PV energy yields for such design configurations, particularly in terms of MWh per acre of land.

Additionally, design opportunities for solar and agricultural integration should further explore opportunities both within and outside the project fenceline, including more focused attention toward site buffer zones and opportunities to alter visual buffering vegetation strategies, and—considering the lifespan of a project and continued demand for solar development—exploration of the potential impacts of emerging technologies (e.g., AI and robotics) on agricultural feasibility within site design.

Future research and review should prioritize improved understanding of the economics behind implementation of agrivoltaics, both at the project level and in consideration of broader land-use change considerations as the State and private entities utilize greater acreage to onboard solar energy to meet State and private climate goals. Research should also consider land-use efficiency. Monitoring existing relevant efforts and addressing research gaps will enable informed review of potential policy considerations for incentivizing uptake of agrivoltaics projects. Additionally, to reach an understanding of reasonability for projects that support the economic case for both farmers and solar developers to invest in agrivoltaics, it will be important to gain a better understanding of farm economics as a whole, and how multiple policy levers may be utilized to support not just agrivoltaics uptake, but agricultural viability as a whole. To support and prepare for future planning, each of the above should consider integration of climate scenario analyses to better understand implications to New York State's agricultural makeup and economy under multiple scenarios and multiple time horizons.

Together with additional State efforts to understand land-use implications of LSS development, future work will continue to seek to inform potential future actions to investigate the opportunities and constraints associated with agrivoltaic uptake that consider agricultural landscape and provide education on best practices for implementation of agrivoltaics projects in New York State.

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