ENOUGH LAND

How will solar development affect upstate New York agriculture?

"Buy land, they're not making it anymore."

— Mark Twain

30 October 2023

Kris Martin
Chautauqua County NY

ABOUT THIS DOCUMENT

Many upstate New York residents object to solar development on farmland, arguing that we should prioritize food production over energy generation. Others dismiss these concerns as unnecessary. This paper uses government and industry data—along with stated assumptions—to estimate how much agricultural land New York State's expected level of solar buildout will require. The assessment also places solar land use in the larger context of the state's farmland losses.

The chapters that follow address these overall questions:

- Why do we need to site solar facilities on farmland?
- How much solar capacity will the state need by 2050?
- How much farmland will this require?
- How much agricultural land do we have?
- What effects does solar buildout have on agriculture?

Appendices provide more information on related topics.

This document is neither a statistical analysis nor an academic work; it should not be used as a formal reference.

PREFACE

I built my first solar oven in the late 1970s. After several tries, I managed to bake a small but edible loaf of organic whole-wheat bread. Late at night, my friends and I argued the relative merits of active and passive solar. Active would never catch on—too expensive. Who would *buy* solar panels? We laughed.

Fast-forward to 2017, when I purchased a ground-mounted residential solar array: my own tiny effort to fight climate change. I carefully chose a site on my property where it wouldn't be readily visible to neighbors or passing drivers.

In 2018, I attended an open house for the first of two large solar projects near my home. Although the technology and concepts weren't new to me, the scale was. The project map showed row upon row of panels fully covering 800 acres of active farmland. Couldn't they see it was a safety hazard to put panels five feet from the road?

The map was bogus. The developer released the real one later, "after consulting with the community." Panels covered only 400 acres of the site, and reasonable setbacks were now included. The first map had been intended to panic us, the second to reassure us.

Finding that kind of manipulation unacceptable, I gravitated toward an "opposition" group and was promptly labeled a NIMBY.

NIMBY? I *put* solar in my back yard.

A few members of the group remembered a bitter struggle over siting a 1,000-MW natural gas plant down the road. We were promised jobs and training, minimal visibility, PILOT funds, lots of money for local businesses, and the warm feeling that we were helping the state reach its energy goals. Also, we didn't have a choice; the state approved the plant despite local objections. Things hadn't worked out quite as promised, and now gas was a bad thing. Some people weren't buying this a second time.

Then the larger, adjacent solar project was announced. People who had been complaining about fertilizer runoff one day were arguing the next that the project would use prime farmland. Really? Online resources showed little evidence of prime farmland on that site, and local records indicated that some of the topsoil had been stripped off and sold during the 1950s. For the most part, this was marginal land, a better choice for solar than the other site.

Maybe all farmland looks like prime farmland when agriculture is a charming, old-fashioned family pursuit: Pappa yoking up the oxen while Mamma, in her pretty gingham dress, scolds their red-cheeked children for chasing the hens.

In fact, most New York farms *are* operated by families, but the farms are bigger and more productive, and almost no one wears gingham.

I'm in no way an expert on agriculture or solar energy. I studied agriculture in high school for a couple of years, helped out on friends' farms, and read college agriculture texts in my spare time. Solar technology fascinates me: solar energy is magic. Solar window films and glass, solar fabrics, carports, aquavoltaics (floating panels on water bodies)…. I love this stuff but have never pursued it—or farming—as a career.

At a conference one day, a fellow informed me that solar buildout only required 1% of the state's farmland. If every farmer could use 1% of his or her land for solar, we could generate enough electricity to meet the state's needs.

I ran the numbers. New York State has 33,000 farms, each averaging about 200 acres. At two acres each, we'd end up with only a small fraction of the solar capacity New York requires. Not all farms are located near electric infrastructure, and not all farmers want solar on their land. The approach would be astronomically expensive and ultimately ineffective.

Maybe I could come up with more realistic estimates. Supporters of large-scale solar *and* those who opposed it needed some real numbers. I could produce them in a couple of weekends.

That was over three years ago.

Conflicts around solar have only intensified since then. The solar divide pits neighbor against neighbor, farmer against farmer. Many supporters of solar buildout will say I harbor too much sympathy for the people who fight projects. Quite a few of *those* people will find my words about the solar industry far too kind. These objections are part of a healthy and necessary exchange; this paper offers a starting point for discussion, not a conclusion.

In case you're wondering, I opposed the smaller solar facility and supported the larger one. The state approved both projects.

My questions are simple: how much solar energy do we need, and how much farmland will it require? What do these amounts mean for upstate agriculture? If you're curious, read on.

Kris Martin

Chautauqua County
October 2023

CONTENTS

PART ONE:

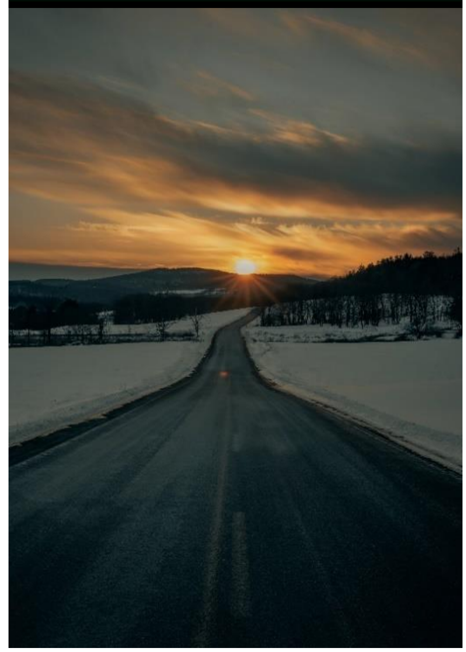
GATHERING ENERGY

THE SOLAR DIVIDE

This chapter introduces solar development on New York State farmland. It examines

- Conflicts associated with siting solar facilities on farmland
- Major types of photovoltaic (PV) solar
- Characteristics of land preferred for solar development
- Reasons for siting solar plants on farmland

> *"If you do not change direction, you may end up where you are headed."*
>
> — Lao Tzu



STATE OF CONFLICT

When solar projects are proposed on farmland, a divide forms in many communities. We hear concerns about food insecurity. Farmers who need to rent land from other agricultural operations are sometimes left with few options but to downsize. For some residents, the introduction of industrial elements into rural landscapes provokes strong responses that go far beyond aesthetic objections. Others feel we should prioritize solar development at all costs, and that solar buildout is actually a good way of preserving farmland.

Faced with this bewildering range of possibilities, it's not surprising that people often focus on opinions rather than seeking out credible information.

SOLAR SOLUTIONS

What about other kinds of PV solar energy? Can't we use rooftops and capped landfills instead of farmland? Below are our present options for solar development and how they fit into the state's electric supply. Lost already? For an introduction to basic solar concepts, see Appendix A.

Two types of solar installations provide energy:

1. Distributed, which serves local distribution lines like those that run along your street or road
2. Grid-scale (sometimes called "grid-connected" or simply "large-scale"), which delivers much larger amounts of energy across the state via transmission lines

DISTRIBUTED SOLAR

Distributed solar is intended to serve a particular residence, business, or group of these that are billed at a discount for "subscribing" to a certain solar facility. Types of distributed solar include

- **"Rooftop" solar:** systems that are scaled for individual residences or commercial enterprises
- **"Landfill" or "brownfield" solar:** utility-scale solar plants built on capped landfills or other land that cannot be used readily for other purposes. A solar plant can be sited on land where hazardous waste is present, for example. The expense and complexity of installing solar in these

locations discourages many developers—even when incentives are available. Also, these tend to be smaller sites (under 200 acres), so they seldom produce very large amounts of energy.

- **Community solar:** These popular facilities are often around 5 MW in capacity and sited on 20-35 acres. In theory, these plants deliver energy through local distribution lines. Energy from these plants is sold through discounted "subscriptions." Note that residents may not be subscribing to a local project; the actual plant may be located in another part of the state.

GRID-SCALE SOLAR

To develop solar energy on the scale needed to meet New York's Climate Act goals, we need very large solar facilities. Grid-scale plants usually have a capacity of at least 20 MW and use hundreds or thousands of acres of land. Because farmland possesses the most desirable characteristics for constructing large solar installations, it is the easiest and cheapest place to site such facilities.

Energy from these plants is sold to utilities at wholesale prices and supplies the state's electric grid through transmission lines. You might recognize these lines by the tall structures supporting wires above fields and forests. The grid collects energy and supplies it across the state; in New York it is managed by the New York Independent System Operator (NYISO), which also handles the complex economics of New York's wholesale electricity market and is responsible for reliability planning.[1]

A community solar plant may supply varying amounts of local electricity during the day, but you probably want power at night, too. The grid supplies energy at times when local resources can't keep up with demand. At night, a power plant in the North Country might be keeping your lights on in the Finger Lakes. About 11,000 miles of transmission lines make sure everyone has power when they need it.

Residential service by no means makes up the majority of New York's electric use. Energy from the grid also serves municipalities, institutions, government facilities, schools, transportation systems, recreational venues, public properties, and so on.

The state does have about 7.5 million households[2] and over 523,000 businesses.[3] But we can see that one of the main reasons why "rooftop" and other small solar installations can't supply enough

---

[1] For a good overview of how all this fits together, see Union of Concerned Scientists website, "How the Electricity Grid Works," 17 February 2015, https://www.ucsusa.org/resources/how-electricity-grid-works, accessed 23 October 2023.

[2] United States Census Bureau, New York Quick Facts (2022), https://www.census.gov/quickfacts/fact/table/NY/PST045222, accessed 23 October 2023.

[3] New York State Department of Labor, "Industry Structure in New York State," 2016, revised 2021, https://dol.ny.gov/system/files/documents/2021/03/industry-structure-in-new-york-state.pdf.

electricity for the entire state is that the state simply needs so much more electricity than our homes and individual commercial businesses use. While a 9 kV residential (rooftop) array might cover the needs of one household during the day in sunny weather, it only produces the smallest fraction of what a grid-scale plant can. A 100-MW plant can provide electricity to thousands of households (though with the same weather and time constraints).

We need grid-scale power projects to supply energy for every type of customer at a reasonable cost. On a hot summer day in New York City, millions of people arrive home, turn on their air conditioners, and start preparing meals within a short timeframe. That's exactly the time of day when solar output is declining, so we need a lot of energy from other resources at these times.

It would be ideal if wind and battery storage could fill these requirements reliably, but right now we need gas, hydropower, and nuclear energy to provide electricity when solar and wind energy aren't available. Hydropower and nuclear energy are essentially emissions-free. But only gas—and possibly battery storage—can ramp up production fast enough to keep the electricity flowing steadily when the sun sets and demand spikes at the same time. Work is underway to see if battery storage can come online as rapidly as these gas plants, but of course the batteries must be fully charged whenever they're needed, which requires careful planning and scheduling.

Since grid-scale solar installations sell energy on the wholesale market, they must produce it as cheaply as possible; this means taking advantage of economies of scale. New York's best option for cheap solar energy is to build very large facilities as quickly as possible.

New York has chosen to expand solar energy development as swiftly as can be managed, but we may be missing opportunities available to states with slower timelines. For example, other states may benefit from advances in integrating agricultural and solar land uses, while our own buildout will probably be too rapid to incorporate agricultural co-location on a large scale.

Clear-cutting forests for solar development

In the past, clear-cutting forests for solar projects was widely accepted. Many members of the public have questioned whether clear-cutting is a net-zero carbon process and is ultimately sustainable. The solar industry responds that the clean energy produced by panels quickly offsets any release of carbon that results from clearing forests.

If solar facilities are indeed superior to forests as low-carbon form of land cover, clear-cutting is a positive, "green" siting solution. But forests serve other functions in the environment (and in the carbon cycle), and the practice is growing more controversial.

SEEING SITES

Where are the easiest places to site large-scale solar? We've seen why grid-scale projects are needed to meet Climate Act goals. Logistically, what are the best places to site these facilities?

Ideal land for solar consists of large and/or adjacent parcels of flat, cleared land located near electric and transportation infrastructure. Often this describes farmland. Farmland comes in several categories: cropland, pastureland, woodland, and so on. Cropland is typically the farmland most useful for producing food, as opposed to pasture or other categories. It is usually clear, sunny, and located close to transmission and transportation infrastructure. The state has about 4.3 million acres of it, and this land is in high demand for a variety of uses, including commercial and low-density residential development.[4] Because New York cropland is considerably less expensive than that of other Northeastern states, it offers excellent value for solar development. For more on this, see *For sale or rent: cheap .* About half of cropland is prime farmland, which has the state's most versatile and capable soils.

While New York State offers a few incentives for avoiding productive farmland, to date most large-scale development has taken place on cropland. Some developers clear-cut forests as an alternative to building on farmland, but this is often a controversial and environmentally problematic approach. Clear-cutting destroys habitat and can require more erosion control measures, for instance.

Steep or rocky terrain, land located far from transmission or distribution infrastructure, and shaded or awkwardly oriented parcels are much less useful for solar development, as are wetlands.

THE 1% SOLUTION

"Solar development requires only 1% of New York's total area." —*Commonly stated estimate*

When they think of solar buildout, some upstate residents imagine panels covering large swathes of formerly agricultural or wooded landscapes. They're only too happy to hear that all those panels won't require much space after all. If they only require 1% of the state's land, people will barely notice them, right? Perhaps the question they should be asking is: "*Which* 1% of the state's area?"

THE OTHER 99%

Let's assume that the total of 1% is correct. While that sounds insignificant, remember that solar facilities are not sited in random locations. New York has a *total area* of 34,917,452 acres.[5] Of this area, 4,758,471 acres consist of water,[6] leaving a *land area* of 30,158,981 acres that comprises several major categories with varying suitability for solar development.

Additionally, certain areas may not be conducive to large-scale solar development, including transportation infrastructure (e.g., roads, railroads, and many airports) and areas of consistent land fragmentation here most parcels are under 20 acres[7]

Category	Acres	Percent of land area
Total area	34,917,452	-
Water	4,758,471	14%
Forest	18,600,000	62%
Agricultural	6,866,171	23%
Urban extent	2,350,227	8%
Terrain or land cover not suited to solar buildout	11,149,440	36%
Protected areas	5,000,000+	20%

Table 1: NYS land categories and acreage

[4] American Farmland Trust (AFT), "Agricultural Land Conversion Highlight Summary New York," 2020, https://storage.googleapis.com/csp-fut.appspot.com/reports/spatial/New_York_spatial.pdf.

[5] US Census Bureau, TIGERweb geographical data, https://tigerweb.geo.census.gov/tigerweb/, accessed 23 October 2023.

[6] US Census Bureau, TIGERweb geographical data, accessed 23 October 2023.

[7] A search on New York State land/farmland parcels (non-residential properties) of 20 acres or fewer for sale produced 7,157 properties, while land/farmland over 20 acres totaled 1,903 properties. Realtor.com website, https://www.realtor.com/realestateandhomes-search/New-York/type-land,farms-ranches/lot-sqft-871200, accessed 23 October 2023.

This suggests that at least 50% of the state's land isn't very useful for solar development. Our major options for large-scale solar development are forests and agricultural land, which make up about 85% of our total land. Keep in mind that there is some overlap between categories; some protected areas may be forested, for example. If we do avoid farmland and forests—along with other land categories where solar would be unsuitable—we're left with surprisingly little land. Given the complications associated with clear-cutting, that leaves agricultural land as the best option for siting solar facilities. In the future, an estimated 84% of large-scale development will take place on agricultural land.[8] While this option isn't popular with many state residents, it appears to be the only realistic option for the extensive level of solar buildout required by the New York State Climate Act.

The authors of one article on public support for projects observed low levels of support for solar installations on farmland in active production. Forested sites were equally unpopular. Respondents rated solar installations both on farmland and forests a dismal 1.8 out 5, where 5 indicates strong support.[9]

While forests and farmland may be the general public's least popular choices for building solar facilities, these are will be the preferred sites for future grid-scale solar plants.

[8] Venktesh V. Katkar, Jeffrey A. Sward, Alex Worsley, K. Max Zhang: "Strategic land use analysis for solar energy development in New York State," Renewable Energy, Volume 173, 2021, p. 873, ISSN 0960-1481, https://www.sciencedirect.com/science/article/abs/pii/S0960148121004900?via%3Dihub.

[9] Nilson Roberta S., Stedman, Richard C., "Are big and small solar separate things? The importance of scale in public support for solar energy development in upstate New York," Energy Research & Social Science, Volume 86, 2022, 102449, https://www.sciencedirect.com/science/article/pii/S2214629621005363).

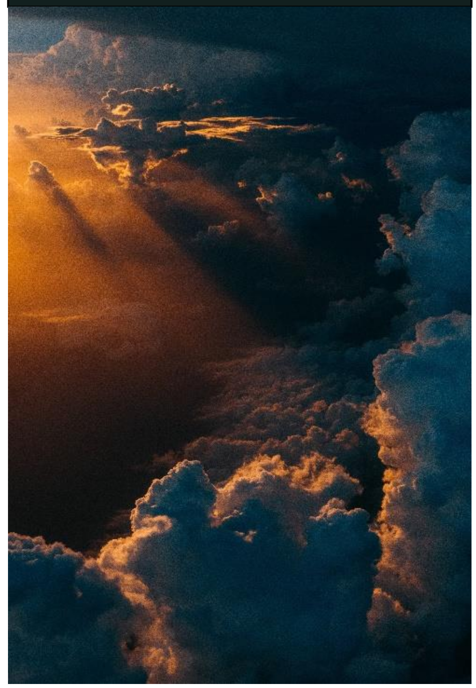
GROWING ENERGY

This chapter considers how much solar energy will be needed by 2040 and 2050. It discusses

- Capacity estimates: sources and amounts
- Selected estimates of the capacity of future buildout for 2040 and 2050
- How much solar capacity is planned for the near future
- How much solar has been installed to date, and how much we might need beyond the estimates here

The price of light is less than the cost of darkness.

— Arthur Nielsen



In 2019, The Climate Leadership and Community Protection Act (CLCPA or Climate Act) was signed into law.[10] It requires that the state's electricity supply be emissions-free by 2040. By 2050, greenhouse emissions must decrease to pre-2000 levels.[11] The Climate Act specifies the development of 6,000 MWdc[12] of distributed solar capacity by 2025—in other words large increases in residential, commercial, and especially community solar installations. This target was later expanded to 10,000 MWdc by 2030.[13]

We are already shuttering fossil fuel and nuclear plants, and their capacity must be replaced with clean alternatives, not more fossil fuel projects. For instance, when the Indian Point nuclear plant was closed, its emissions-free generation was replaced by energy from new gas plants—not renewable energy resources, as some assume.[14]

REQUIRED CAPACITY

Solar, wind, hydropower, nuclear, and strategic fossil-fuel plants will be our main energy sources in the near future. We need to balance these energy resources to minimize fossil fuel use while still providing reliable service.

---

[10] New York State Senate Bill S6599, signed by the governor on 18 July 2019, https://www.nysenate.gov/legislation/bills/2019/s6599.

[11] NYSERDA press release, "New York State Climate Action Council Finalizes Scoping Plan to Advance Nation-leading Climate Law," 19 December 2022, https://www.nyserda.ny.gov/About/Newsroom/2022-Announcements/2022-12-19-NYS-Climate-Action-Council-Finalizes-Scoping-Plan-to-Advance-Nation-Leading-Climate-Law.

[12] When panels generate electricity, it is DC (direct current, like the electricity from a battery). A solar array might generate 1 MW of DC electricity, so the capacity would be 1 MWdc. Electricity for the grid must be AC (alternating current, like your household appliances). Capacities in this paper are MWac unless designated otherwise. Unfortunately, it isn't always clear whether an amount if AC or DC. DC capacities are higher than AC; a 10 MWdc array might be equivalent to 8 MWac. For more information, see Appendix A: Solar basics.

[13] New York State Office of the Governor Pressroom, "Governor Hochul Announces Approval of New Framework to Achieve At Least 10 GW Distributed Solar," 14 April 2022, accessed 19 May 2023, https://www.governor.ny.gov/news/governor-hochul-announces-approval-new-framework-achieve-least-ten-gigawatts-distributed-solar.

[14] US Energy Administration (EIA), Today in Energy, "New York's Indian Point nuclear power plant closes after 59 years of operation," April 30, 2021, https://www.eia.gov/todayinenergy/detail.php?id=47776.

State and private groups have modeled different renewable resource mixes and scenarios to determine how much solar capacity is required to meet future goals. The source documents in the table below provide a range of estimates. The scenarios selected for this comparison closely match the Climate Act's ambitious goals, including the electrification of sectors such as transportation and buildings. Each estimate reflects certain concerns of its authors. For instance, studies prepared for the New York State Climate Action Council (CAC) *Scoping Plan* consider socioeconomic factors as well as reliability, while NYISO estimates tend to look more at grid resilience.

Source	Document	2040 Solar capacity (MW)	2050 Solar capacity (MW)
Analysis Group	*Climate Change Impact and Resilience Study – Phase II (for the NYISO) — CLCPA scenario*	50,000	–
The Brattle Group	*New York's Evolution to a Zero Emission Power System (for NYISO Stakeholders) – existing technologies scenario*	61,000	–
The Brattle Group	*New York's Evolution to a Zero Emission Power System (for NYISO Stakeholders) —high-electrification scenario*	38,000	–
NY Climate Action Council (CAC)	*Scoping Plan (statewide)*	43,000	65,000

Table 2: Solar capacity required by 2040 and 2050 – sources and estimates

For 2040 estimates, this paper uses information from Analysis Group's *Climate Change Impact and Resilience Study – Phase II.* In their 2020 study for the NYISO, Analysis Group concludes that to reach Climate Act goals, we will need 50,140 MW of total solar capacity (distributed and grid-scale) by 2040.[15] This study focuses on reliability during the transition away from fossil fuels in the context of a changing climate, using plausible scenarios such as winter storms and wind lulls. This report was among the first to detail the pressing need for (still-unidentified) energy resources to balance the intermittency of wind and solar. The commonly used lithium-ion battery technology cannot provide the long-duration storage required during extended periods (several days, or even weeks) when solar and wind don't produce enough energy.

Not surprisingly, credible estimates for 2050 are difficult to find, leaving us with the CAC's estimate from *Scoping Plan* technical appendices.

Figure 1: 2040 Zero-emissions fuel mix (simplified) shows a set of zero-emissions generating resources modeled to meet Analysis Group's scenario that best matches Climate Act requirements. "DE resource" (also "DEFR") refers to *dispatchable emissions-free energy resources.* A dispatchable" resource

[15] Analysis Group, "Climate Change Impact and Resilience Study — Phase II," September 2020, https://www.nyiso.com/documents/20142/15125528/02%20Climate%20Change%20Impact%20and%20Resilience%20Study%20Phase%202.pdf/89647ae3-6005-70f5-03c0-d4ed33623ce4 (Cumulative total of grid-connected and distributed solar).

can respond immediately when demand spikes. For obvious reasons, intermittent energy resources such as solar and wind cannot fill this role.

Like the NYISO, the New York State Reliability Council (NYSRC) estimates notes that DEFRs are vital to the grid's reliability, especially given intermittency issues; offshore wind lulls of up to 86 hours are not uncommon.

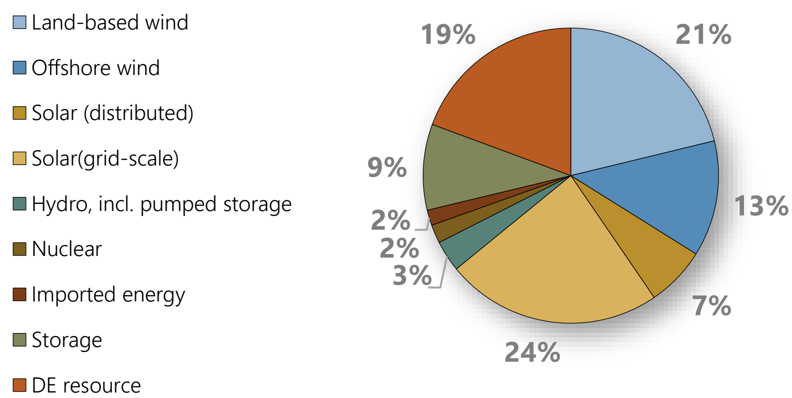


Figure 1: 2040 Zero-emissions fuel mix (simplified)

The NYSRC agrees that many of the attributes provided by traditional resources including 24/7 operating capability, ramping response, aggressive start times, and reliable operation are important attributes that DFERs need to provide with the penetration of new clean intermittent resources to the New York electric grid..... In the interim until DFERs are properly defined and commercialized, decisions regarding retirement of existing resources must be carefully technically analyzed to ensure system reliability and public safety is maintained throughout New York State. This becomes even more important as many renewable energy projects are delayed in realizing commercial operation and electrification efforts in other sectors (buildings and transportation) will further increase electric load demand..... In the interim until DFERs are properly defined and commercialized, decisions regarding retirement of existing resources must be carefully technically analyzed to ensure system reliability and public safety is maintained throughout New York State. This becomes even more important as many renewable energy projects are delayed in realizing commercial operation and electrification efforts in other sectors (buildings and transportation) will further increase electric load demand. [16]

Resource	MW
Land-based wind	35,200
Offshore wind	21,063
Solar (distributed)	10,878
Solar(grid-scale)	39,262
Hydro, incl. pumped storage	5,656
Nuclear	3,364
Imported energy	2,810
Storage	15,600
DE resource	32,137

Table 3: 2040 simplified fuel mix amounts

Gas plants address most of our needs for dispatchable resources, and it is possible that energy storage may perform this function in the future. Such resources backstop intermittent generation and provide energy during periods—days, or even weeks—when solar and wind aren't producing enough energy to meet grid demands.

At present, we don't have scalable, dispatchable, economical emissions-free resources ready to deploy. The NYISO further explains:

[16] NYSRC, "NYSRC Comments in PSC Large Scale Renewable Proceeding," 16 August 2023, https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={C074FE89-0000-C810-B8D5-8BFF31D43F91}.

By 2040, all existing fossil generators are assumed to be retired to achieve the CLCPA target for a zero-emission grid and are replaced by… DEFRs. These resources… will meet the flexibility and emissions-free energy needs of the future system but are not yet mature technologies that are commercially available (some examples include hydrogen, renewable natural gas, and small modular nuclear reactors)…. As more wind, solar, and storage plants are added to the grid, dispatchable emission-free resources must be added to the system (or fossil generation retained) to meet the minimum statewide and locational resource requirements for serving system demand when intermittent generation is unavailable.[17]

Figure 48: Summer Generation by Resource Type – CCP2-CLCPA

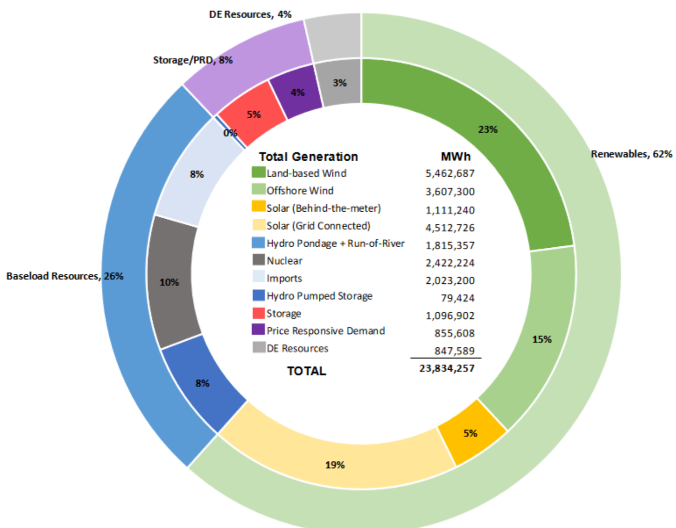


Figure 3: Analysis Group/NYISO -Summer generation by resource type (graphic from [Climate Change Impact and Resilience Study – Phase II: An Assessment of Climate Change Impacts on Power System Reliability in New York State)](https://)

Figure 46: Winter Generation by Resource Type – CCP2-CLCPA

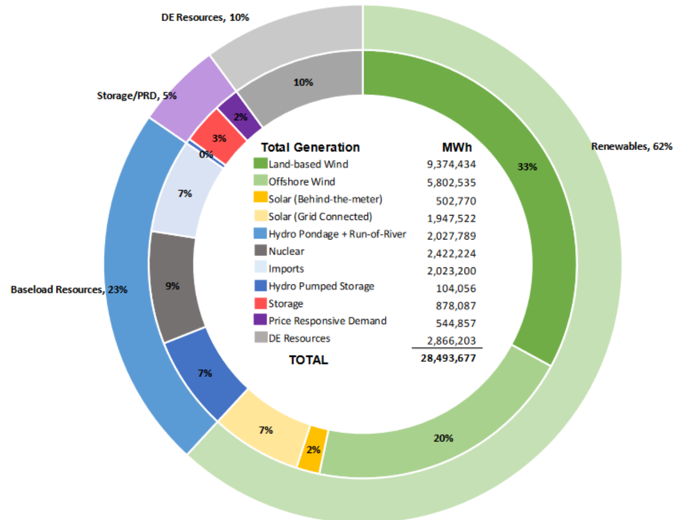


Figure 2: Analysis Group/NYISO - Winter generation by resource type (graphic from Climate Change Impact and Resilience Study – Phase II: An Assessment of Climate Change Impacts on Power System Reliability in New York State)

Thus, when considering the timeframe of renewable energy resource buildout, it's clear that the identification and deployment of DEFRs play a vital part.

To put solar energy's contribution to the state's electric supply in perspective, let's look at what actual generation can be expected.

In winter, the solar resources in yellow, previously identified by capacity, are expected to produce 9% of the state's actual energy.

As might be expected, summer generation is significantly higher, at 24%.

[17] NYISO, "2021-2040 System & Resource Outlook (The Outlook)," 22 September 2022, https://www.nyiso.com/documents/20142/33384099/2021-2040-Outlook-Report.pdf.

Planned capacity

Before a grid-scale energy project connects to the state's grid, the developer submits an interconnection request to the NYISO, which maintains a queue showing developer and project names, capacity, county, and so on.[18]

Capacity in the pipeline

As of 30 September 2023, the queue included a total of 200 planned grid-scale solar projects, with a cumulative capacity of over 20,000 MW and an average facility capacity of 100 MW.[19] These projects are undergoing state and utility approval processes. Projects are added and withdrawn frequently, so the contents should be assessed accordingly.

Every estimate included in *Table 2: Solar capacity required by 2040 and 2050 – sources and estimates* calls for an average increase in solar buildout of at least 2,000 MW every year during the next 17 years. Not only will we need to transition to emissions-free energy sources; electricity use is expected to double by 2050 as we "electrify everything" to reduce emissions.[20]

Built capacity

How much solar capacity do we have now? As of February 2023, 154 MW of grid-scale solar capacity and 3,541 MW of distributed solar were operating in the state, for a total capacity of 3,635 MW.[21] Several grid-scale plants are under construction and expected to be online by the end of 2023. Community solar plants and other forms of distributed generation have grown quickly in New York State.

Right now, very few grid-scale plants are online. Much more is included in the pipeline of resources that will begin generating over the years ahead. Over the next decade, grid-scale solar generation is expected to surpass community solar.

Note that all the previous capacity estimates entail upgrading the state's aging and insufficient transmission infrastructure to some degree.

Full capacity and future demand

How much overall utility-scale solar capacity could New York State install? A research study analyzed land cover and other characteristics of locations in the state. They determined what would work well for solar development and concluded that solar buildout must include agricultural land

---

[18] Several projects that are planned to produce energy for New York State would be constructed in Pennsylvania, and New York developers also produce electricity for utilities in other states. This document assumes New York's solar generation for other states' markets is equivalent to generation in other states for New York's wholesale electricity market, and that some arrangement has been reached as to which state claims the zero-emissions status for this capacity.

[19] NYISO website, Planning/Interconnection process, "NYISO Interconnection Queue," accessed 16 October 2023, https://www.nyiso.com/planning. These numbers include both solar and solar+storage projects and include projects in Pennsylvania for New York State markets. New York State also produces energy for other states' markets; it is assumed for the purposes of this paper that these imports and exports are even.

[20] NY CAC: "Scoping Plan - New York's Climate Leadership & Community Protection Act," December 2022, https://climate.ny.gov/resources/scoping-plan/, see Tech Supplement Annex 2. Key Drivers Outputs [XLSX].

[21] NYISO, "2023 Gold Book," April 2023, https://www.nyiso.com/documents/20142/2226333/2023-Gold-Book-Public.pdf/c079fc6b-514f-b28d-60e2-256546600214..

if we're going to meet Climate Act goals. If we use all the non-agricultural land available, the total needed exceeds our plans for 2040 buildout:

> According to National Renewable Energy Laboratory (NREL), the technically feasible buildout would total 984,000 MW, while more detailed research estimates that developers could build as much as 140,000 MW of solar capacity on land the solar industry would consider suitable… with 22,500 MW on non-agricultural land.[22]

If the cost of solar energy is as low as the industry states, solar may take a more prominent role in the transition to a zero-emissions grid than other energy sources. We should keep this in mind when looking at increasing demand that is likely to emerge in the future.

For instance, data mining could account for as much as 7% of all carbon emissions in New York State by the end of the decade.[23]

By necessity, previous capacity estimates assume that energy use will increase predictably as electrification takes place. Decarbonizing the transportation sector, for example, requires extensive electrification. In general, though, these estimates don't fully account for new sources of demand from data mining, cannabis growing, or extensive "green hydrogen" production.[24] And even without these changes, electric use has tended to increase over time.

---

[22] Venktesh et al.

[23] Meher Bhatia, "'It Cannot Get Any Worse': Cornell Professors Decry Energy Costs of NY Bitcoin Mining," 7 December 2021, https://cornellsun.com/2021/12/07/it-cannot-get-any-worse-cornell-professors-decry-energy-costs-of-ny-bitcoin-mining/.

[24] Green hydrogen uses renewable energy to produce hydrogen, which could help replace fossil fuels as a cleaner alternative. Presently, it is an expensive option that shows promise but requires developing a distribution network and/or adapting existing equipment. Costs will probably decrease over time. As with any new energy technology, we must still learn how to produce, distribute, and use it most effectively.

PART TWO:

CONTESTED LANDSCAPES

SOLAR LANDSCAPES

"I think this land may be profitable to those that will adventure it."

— Henry Hudson

In addition to the farm acreage we're already losing, solar development adds to the overall pressure on farmland. How much land will full solar buildout by 2040 and 2050 require? This chapter

- Reviews capacity estimates
- Discusses different estimates of land requirements for solar development
- Identifies additional farmland consumption that may take place beyond a plant's footprint, with several examples

Of this total solar capacity, we can assume community solar will comprise at least 10,000 MWdc, per the 2030 state requirement. Together with other forms of distributed solar, the total should reach at *least* the amount estimated by Analysis Group. Community solar has expanded very quickly upstate, thanks in part to generous state incentives. If those incentives remain in place, there is no reason to think community solar development won't continue to expand.

The upper limit imposed by the state on distributed solar development is 10 MW per plant. Many developers site two or more plants to provide this capacity. In many cases, two 5-MW plants are sited together, but larger configurations are possible, as in the case of Norbut Solar's Chaumont NY facility, which includes five arrays and totals about 25 MW on 236 acres.[25]

CAPACITY REQUIREMENTS

As we discussed in the last chapter, meeting Climate Act goals means installing 50,000 MW of solar energy by 2040 and 65,000 by 2050. How much land will that require?

LAND REQUIREMENTS

To determine how many acres are needed to meet Climate Act goals, we must determine how many acres one megawatt of solar capacity requires. Determining the acreage turns out to be complex. It depends, for instance, on the solar plant's latitude, technology used, terrain, row spacing, and type of surrounding land. Residential locations may require more screening, for example. Very large plants may require additional land for mitigating wetlands and sensitive habitat for threatened and endangered species. Community solar plants often require fewer acres per MW than grid-scale ones, perhaps in part due to the kinds of sites they occupy, less frequent need for mitigation, and less extensive screening requirements.

[25] Norbut Solar Farms website, https://norbutsolarfarms.com/all-projects/projects/516-chaumont/, accessed 29 July 2023. The combined capacity is listed as 35 MWdc, which is probably roughly equivalent to 25 MWac. The grid-scale Branscomb Solar has a capacity of 20 MW (27 MWdc).

Among a variety of popular sources, the range of possible acreage values runs from 4 acres per MW to 10 acres:

- American Farmland Trust[26] 7.5
- Great Plains Institute (GPI)[27] 10
- NYS Department of Public Service (NYS DPS)[28] 7.5
- NYSERDA[29] 4-8
- Solar Energy Industries Association (SEIA)[30] 5-10
- SolarLandLease.com[31] 4-7
- US Bureau of Land Management (BLM)[32] 8.5
- Wood Mackenzie (GreenTech Media)[33] 6-8

A recent study suggests markedly reduced estimates but is not specific to upstate New York.[34] In the future, acreage per MW may be increasingly important for developers as land prices inevitably rise:

The cost of most components of a utility-scale PV plant (e.g., modules, inverters, and tracking systems) will tend to decline with greater deployment due to technology- or manufacturing-related learning. In contrast, the cost of the land on which to build the plant is more likely to *increase* with greater deployment.[35]

As we noted previously, right now, land costs present less of an issue in upstate New York than in many locations in the eastern United States.

ADDITIONAL ACREAGE REQUIREMENTS

The higher figures listed by some sources include more of the related land outside the fenceline that is used for the plant, especially surrounding areas that may potentially become unavailable to farmers or other landowners. Examples of areas outside the fenceline:

- Setbacks
- Shading buffers
- Access roads outside the fenceline

---

[26] American Farmland Trust, Webinar: "Smart Solar Siting on Farmland in New York," February 2022, https://www.youtube.com/watch?v=JPdsAtztnRM, accessed 11 August 2023

[27] Wyatt, Jessi and Kristian, Maggie, "The true land footprint of solar energy," The Great Plains Institute, 14 September 2021, https://betterenergy.org/blog/the-true-land-footprint-of-solar-energy/.

[28] NYS DPS: White Paper on Clean Energy Standard Procurements, Appendix A. Case no. 15-E-0302, item no. 686, 18 June 2020.

[29] NYSERDA website, NY-Sun 2023 Solar installations on agricultural land, accessed 24 October 2023

[30] SEIA website, Land Use & Solar Development, https://www.seia.org/initiatives/land-use-solar-development, accessed 25 October 25, 2023.

[31] SolarLandLease.com website, "How much land does a solar farm need," https://www.solarlandlease.com/how-much-land-does-a-solar-farm-need, accessed 22 October 2023.

[32] US BLM website: "Solar energy," https://www.blm.gov/programs/energy-and-minerals/renewable-energy/solar-energy, accessed 24 October 2023.

[33] GreenTech Meda: "How to Make Money From Land as a Solar Developer," 5 August 2013, https://www.greentechmedia.com/articles/read/how-to-make-money-from-your-land-as-a-solar-developer.

[34] M. Bolinger and G. Bolinger, "Land Requirements for Utility-Scale PV: An Empirical Update on Power and Energy Density," IEEE Journal of Photovoltaics, vol. 12, March 2022, https://emp.lbl.gov/publications/land-requirements-utility-scale-pv.

[35] Bolinger and Bolinger, "Land Requirements."

.

- Berms and screening areas
- Construction laydown and parking areas outside the fenceline
- Habitat, cultural resource, and wetlands mitigation acreage
- Overhead and buried wires
- Conservation areas that preclude other land uses

In recent years, project documents have begun to state specifically that the land requirements include both elements inside *and* outside the fenceline. While this trend is encouraging, it doesn't account for agricultural land loss that may occur near the plant footprint.

Following are examples of how additional land outside the fenceline may be lost on agricultural sites. These examples show general problems on a range of project scales:

1. Larger grid-scale project with irregular array shapes
2. Small array impeding access to previously farmed areas
3. Larger grid-scale project impeding access to parts of fields
4. Summary of land use changes on a grid-scale project
5. Fragmentation of land and impeded access to areas on a large grid-scale project

Example 1: Section of grid-scale array showing generally fragmented and irregular character of arrays

Figure 4: Example 1 - Irregularly shaped arrays

Because few New York residents have seen large solar plants, many assume they are roughly rectangular, with cohesive, regularly shaped footprints. They might be surprised by the amount of sprawl associated with siting large plants and with the irregular shapes of arrays.

In the case of projects over 20 MW, developers often secure land from several landowners on parcels that aren't necessarily adjacent. This example[36] shows the complex shapes that may occur when developers try to maximize acreage on a primarily agricultural site. Arrays are shown in the dark sections. Not all the land outside the fenceline is in production, but the 220-acre footprint takes roughly 300 acres of farmland out of production. This consumption does not include land used for mitigation and conservation. Most of the site comprises prime farmland.

Sometimes narrow or awkwardly shaped areas adjacent to a plant can no longer be used efficiently because they are too small or otherwise difficult to reach with farm equipment. In most cases, such land is eventually removed from production. In an Article 10 proceeding brief, an AGM expert explains why production may cease in some areas outside the footprint of grid-scale plants:

[36] Examples shown here are from publicly available sources in the Department of Public Service document database. Because they may not represent finalized plans, projects are not identified specifically.

> The primary agricultural impact associated with the construction of a commercial solar energy generation facility is the permanent conversion of farmland to a non-agricultural use…. Additionally, impacts to current viable agricultural lands remaining outside of the security fencing also have the high likelihood to become abandoned and/or orphaned…. The scenarios cited above create narrow strips of land that, although will be available to agricultural producers (at the landowner's discretion), will be unattractive for most farm operators, as they are inefficient to harvest crops due to the limitations of acreage and maneuverability for normal agricultural equipment, leading to fallow conditions and eventual abandonment, and ultimately loss of available farmland.[37]

EXAMPLE 2: SMALLER ARRAY LIMITING ACCESS TO OTHER FARM FIELDS

The site plan in ***Error! Reference source not found.*** shows a very simple example of how additional loss of land may occur. At 6 acres per MW, this 5-MW array has a direct area (footprint) of 30 acres within the fenceline. Vertical lines denote rows of panels; the fenceline follows the shape of the array. Access roads and screening are located outside the fenceline.

Figure 5: Example 2 - 5-MW array impeding access to farmland previously in production

The area originally comprised a section of one farm field, and wetlands have been cultivated in areas of the field. Note the array's slightly irregular shape.

The highlighted section shows areas that may be problematic for future use. Dotted areas show delineated wetlands. Most of this acreage has been kept in production for years. The darkened area along the right edge marks woodlands. Given the shape of the direct area, portions of the surrounding land may be difficult for the farm operator to use in the future. An access road bisects the field.

While typically the project would be described as sited on 30 acres, specific areas surrounding the array may become difficult to use:

- Wetlands between the array and wooded areas along the east edge of the field
- Possible berms and screening borders
- Irregular array outlines located on wetlands that may already be difficult to access
- Sections of the field broken up by project access roads
- Land that can no longer be used for crops because of altered drainage patterns

Clearly more than 30 acres would be taken out of production in this case. The actual amount would depend on factors such as soil characteristics, wetland details, and farm machinery currently in use.

---

[37] NYS Dept. of Agriculture and Markets, "Initial brief of the New York State Dept. of Agriculture and Markets," DMM case no. 17-F-0617, August 2020, https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={F65F2F1E-CD24-4C60-B9E2-9C757FE50797}.

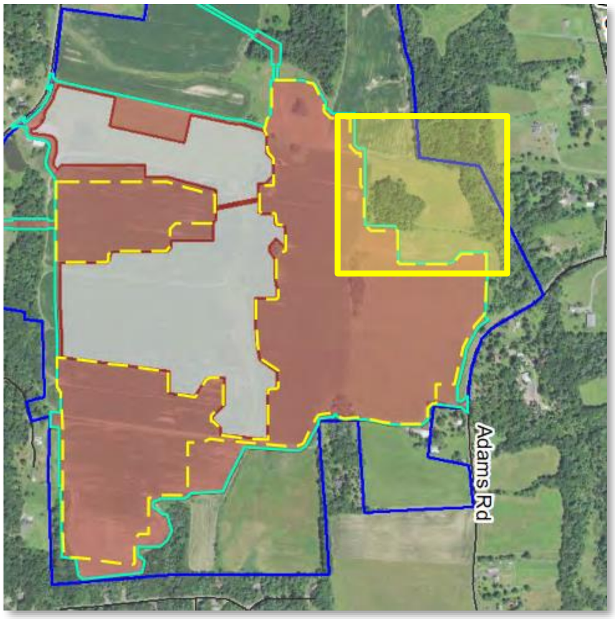


Figure 6: Example 3 - Section of grid-scale project on farmland

EXAMPLE 3: SECTION OF A GRID-SCALE ARRAY IMPEDING ACCESS TO FARMLAND

This satellite image of an array site shows how a small area near the array can be isolated by the layout of a solar project and probably abandoned. In this example, red overlays inside the yellow dashed fenceline represent solar coverage and areas of disturbance that will occur during plant operation. Blue lines show the edges of the facility area, which is owned by one farmer.

The red-shaded array segments on the right will occupy central portions of a field in active production. The yellow rectangle above the fenceline highlights a roughly 8-acre section of the field that will be isolated by part of the array extending across the field. The array location eliminates previous access to that area, which consists of wetlands that are presently being cultivated. Other areas around the array may likewise be affected.

While this section might still be reached from another access point, the area is small enough that it is likely this part of the field will be allowed to revert to its natural wetlands state. Drainage and vegetation will change over the next 30+ years, and it is questionable whether the area can be returned to agricultural use after several decades. Because the area lies outside the fenceline, it is not included in the project acreage. If it is taken out of production, however, it adds to the overall loss of farmland on the site.

EXAMPLE 4: MULTIPLE LAND-USE ISSUES ON A GRID-SCALE SOLAR PROJECT SITE

In looking at land use on a larger scale, this example focuses on how more extensive agricultural land loss may occur both inside and outside the project fenceline. This site has a facility area of 830 acres, owned by one family. The family owns additional acreage offsite for a total of 1,200 acres.

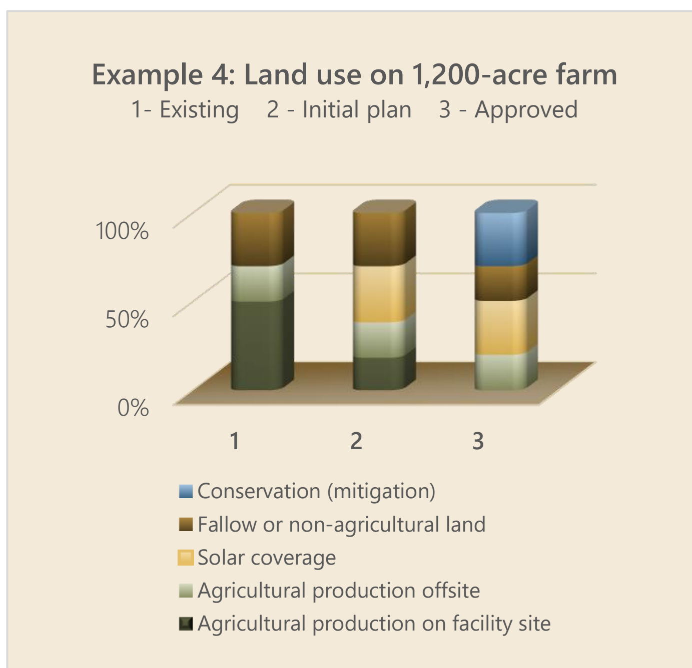


Figure 7: Example 4 - Land use on a 1,200-acre farm with solar development

The farmer also rents 70 acres offsite, but this acreage is not included in the calculations below.

Of those 830 acres, about 600 acres were in active production as of 2018, with the rest fallow, wooded, or otherwise not used for agriculture at that time.

Area	Existing	Initially proposed	Approved	Final land use changes
Agricultural production on facility site	600	220	0	-600 acres
Solar coverage	0	380	365	+365 acres
Fallow or nonagricultural land on and off site	230	230	100	-125 acres
Conservation (mitigation)	0	0	360	+360 acres
Facility site	830	830	830	unchanged

Table 4: Example 4 – Land-use on a 1,200-acre farm with solar development

The developer describes agricultural impacts in terms of helping to save the family farm: "This project will help sustain a family farm for the next generation." [38] The farm operator echoes this sentiment early in the project approval process:

"[The solar development] proposal, which would only use about one-third of our 1,200-acre property, will sustain our family farm for future generations while cultivating the growth of green power." [39]

As initially proposed, the plant was expected to use 380 acres of active farmland within the 830-acre site for solar development and use 220 acres (27%) for continued agricultural production.

Large portions of cultivated land were composed of environmentally sensitive areas such as wetlands, along with habitat for protected species. The developer will be required to mitigate these, using 365 additional acres outside the fenceline (but within the 830-acre facility area). This land would be placed in conservation and would no longer be available for agriculture or other uses. ***Error! Reference source not found.*** shows the final land use for the 1,200-acre family farm that was expected to be sustained by solar development on one third of it. Originally, about 600 acres of the site was in active production; most agricultural use is expected to cease on the project site. So, while the direct area (footprint) uses 7.6 acres per MW, the combined solar coverage and mitigation land effectively increases that amount to 14.6 acres per MW.

[38] Hecate Energy, Greene County Solar website FAQ, "How will it affect farmland?" http://www.greenecountysolar.info/faqs/, accessed 5 August 2023.

[39] New York State Department of Public Service, DMM Case no. 17-F-0619, https://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=17-F-0619. All details are included in this proceeding; out of courtesy to the landowners, details have not been provided here.

Example 5: Larger Grid-Scale Solar Facility Showing Fragmentation of Agricultural Land

(layout overview and detail)

This larger facility in area with a high concentration of agricultural land use provides an overview of the level of fragmentation that usually occurs with grid-scale projects. As discussed previously, such projects commonly involve multiple parcels and owners.

Over 60% of the facility footprint consists of prime farmland. The full site layout shows the fragmentation of agricultural land and areas where farming is unlikely to continue.

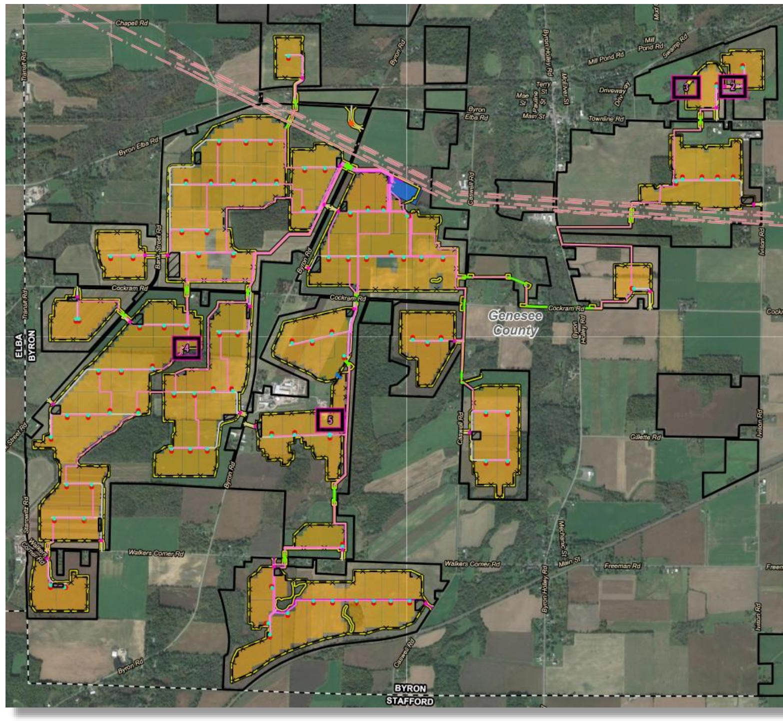


Figure 8: Example 5 – Layout of larger grid-scale solar facility showing fragmentation of agricultural land (overview)

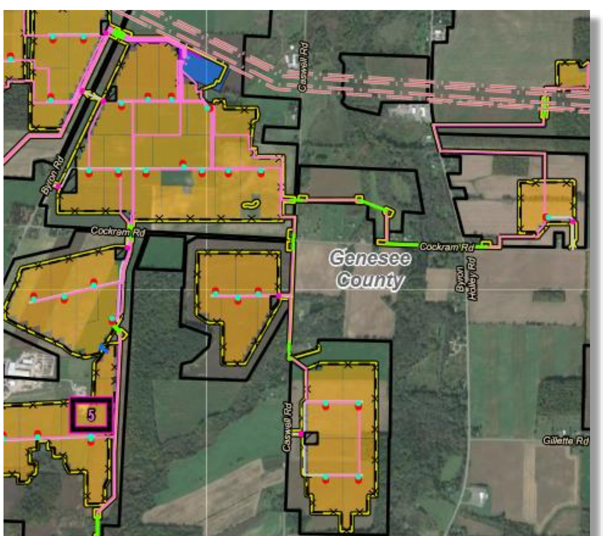


Figure 9: Example 5 - detail

The detailed view further clarifies how areas around the fenced arrays in orange can affect surrounding agricultural land. Note that much of the land immediately around proposed arrays is in production; these areas include setbacks and screening elements. Some of this land will be difficult to access in the future.

As farms grow larger and more productive, many acquire equipment featuring a wider turning radius than a typical farm tractor. Rather than switch equipment, many operations would tend to abandon some of these smaller or more difficult-to-access areas. These areas are also unlikely to be improved by irrigation or drainage structures.

SUMMARY: ACREAGE REQUIRED FOR SOLAR

"The land belongs to the future."

— Willa Cather

This chapter

- Selects an estimate for of acres per MW for a plant footprint
- Reviews the assumptions used to estimate acreage needed for solar development and summarizes the results.
- Summarizes land requirements for solar buildout

ACRES PER MW

This paper uses **6 acres per MW** of direct area (project footprint), which covers a range from 4 to 8 acres per MW. This amount per MW is near the low end of the acreage ranges listed previously, but ongoing improvements in panel efficiency and other technology should result in smaller plant footprints over the coming decades. This number includes most of the areas previously described under "Additional acreage," apart from mitigation and conservation acreage.

As the discussion and examples here suggest, 6 acres per MW does not represent the full amount of farmland that will be taken out of production or otherwise lost. This paper presents an optimistic estimate with the caveat that additional farmland is almost certain to be lost.

At this point, it is difficult—if not impossible—to determine exactly how much additional land will be lost outside the plant footprint. For example, dairy operations that lose access to rental land may be forced to downsize, resulting in additional farmland being lost.

ASSUMPTIONS USED TO ESTIMATE SOLAR ACREAGE REQUIREMENTS

The list below summarizes what we've discussed about solar capacity and land use. A table at the end of this chapter provides estimates of how much land solar buildout in upstate New York will require.

ENERGY AND CAPACITY

1. We need 50,000 MW of solar capacity by 2040.
2. This need increases to at least 65,000 MW by 2050.
3. Most of this capacity takes the form of grid-scale solar, but about a quarter will be distributed generation, consisting mostly of community solar plants.

4. Electric demand does not increase beyond maximum predicted amounts.
5. Energy demand shifts to a higher demand in winter than in summer around 2035.
6. Emission reductions occur as planned.
7. DEFRs and/or economical, scalable long-duration storage are widely available before 2040.

Solar Technology and Construction

1. State renewable energy siting mandates remain unchanged.
2. Solar buildout, battery installation, and transmission upgrades move forward on schedule.
3. Solar facilities produce the amount of energy expected.
4. Incremental improvements in solar technology and reductions in cost continue.
5. Solar-related supply chains are not interrupted, and skilled labor is readily available.

Economic Factors

1. Federal, state, and local incentives for solar development remain unchanged or increase.
2. No new incentives are added for brownfield/landfill siting.
3. Market-based agrivoltaics on grid-scale projects are unlikely.
4. Agricultural mitigation payments and related incentives remain at present levels or increase.

Agriculture and Land Use

1. New York has 6.9 million acres of farmland and 4.3 million acres of cropland, with prime farmland/priority soils representing roughly half of cropland.

2. The loss of farmland from non-solar causes continues at the same rate from 2017 through 2050 as it did from 1925 through 2017, with an initial reduction in acreage by 15% to account for any changes in terminology and methodology that may have inadvertently decreased recent totals. Note that it is possible that 15% is an excessive reduction, or that no reduction has occurred at all.

3. Solar land use averages 6 acres per MW (4-8 MW per acre), with adjacent farmland sometimes taken out of production but not included in these estimates.

4. Demand for farmland does not increase.

5. The rates paid by developers for leased or purchased land remain the same or increase, as demand may outstrip supply, and new demands may arise.

6. Farm ownership remains in transition, and cropland is readily available for sale or lease.

7. Eighty-four percent of utility-scale solar development takes place on farmland.

8. Of this amount, about 85% of development uses cropland.

9. Opportunities for agrivoltaics emerge slowly for projects with >200 acres of panel coverage.

10. Agrivoltaics do not directly replace the current agricultural use of land; hay and corn are relatively difficult to grow and harvest under panels, and spreading manure at the rates dairy farms need to is impractical.

11. Clear-cutting forests for solar projects remains unpopular.

12. No other siting options for large projects are widely available.

SOLAR DEVELOPMENT ACREAGE REQUIREMENTS

The table here summarizes the acreage of New York State farmland as of 2017 and the acreage required by 2040 and 2050 for solar development.[41]

NY Land areas		2050 Land required for solar development	
Land category	**Acres**	**Acres required**	**Percent of category required**
Total state land area	30,160,896	390,000	**1.3%**
Farmland	6,866,171	327,600	**4.8%**
Cropland	4,291,388	278,460	**6.5%**
Prime farmland[40]	2,330,000	139,230	**6%**

Table 5: NY land required for solar in 2050 (projected)

The claim that solar development will require only 1% of New York State's land is roughly correct. On the other hand, solar buildout will require more than 1% of the state's farmland. Note that these numbers reflect acreage on the facility site; they do not include

- Land used for mitigation
- Land taken out of production around facilities because it is less accessible or abandoned for other reasons.

Many people will find these numbers quite acceptable; others may be alarmed by them—in particular, by the amounts of land used most intensively for food production.

What has not been discussed here is the rate at which we are already losing farmland in New York State. The next chapter looks at this topic.

[40] Cropland comprising prime farmland; does not include forested and developed land.

[41] Some of these numbers may appear slightly inconsistent due to rounding.

LOSING GROUND

This chapter considers the loss of farmland that has been occurring over the last century and speculates on the reasons for farmland conversion over that period.

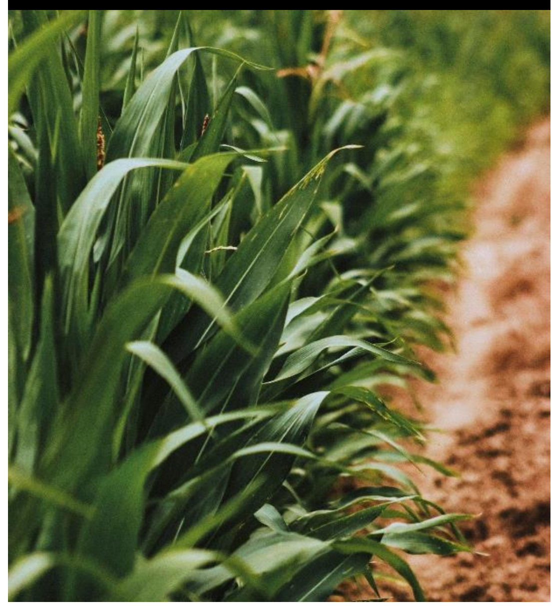
Every five years, the USDA compiles the US Census of Agriculture, a comprehensive collection of periodic data on American agriculture. In 1910, "land in farms" (in general, farmland) is listed as 22 million acres. In 2017, the most recent census available, New York State's farmland consisted of 6.9 million acres. This paper looks at historical data since 1925, when "cropland" data was collected as a discrete farmland category.

Figure 10: NY land in farms – 1925-2017 shows farmland losses between 1925[42] and 2017. To account for potential changes in definitions and methodology, an adjusted trendline for 85% of these losses is included (see sidebar below).

If data *did* remain fully comparable over that full period, the total loss of over 15 million acres would cover an area nearly the size of Connecticut, Massachusetts, and Vermont combined. On average, New York would have lost 141,722 acres of farmland every year between 1910 and 2017. Because definitions, data collection and processing, as well as methodologies, have varied over the last century, this paper assumes that the 1925 definition of farmland is less restrictive than 2017; in other words, land that might have been considered "farmland" in 1925 would not have been classified as such in 2017. At the risk of erring on the side of caution, acreage in farms was adjusted here, as discussed above.

"Perhaps it's time for planners, developers—all of us—to realize that farmland is already developed. Farmers prepare it through fertilization, tiling, and conservation structures over time.... But once it's gone, it's gone."

— Indiana Prairie Farmer



The 1925 Census of Agriculture collected some of the first specific data on cropland, reporting a total of 11.2 million acres. In 2017, that amount was 4.3 million. As described previously, cropland is the type of farmland best suited to siting utility-scale solar development.

[42] The amount of "land in farms" decreased by 2.8 million acres between 1910 and 1925. The rate of farmland loss has varied, but amounts have continued to decline in almost every census between 1910 and 2017.

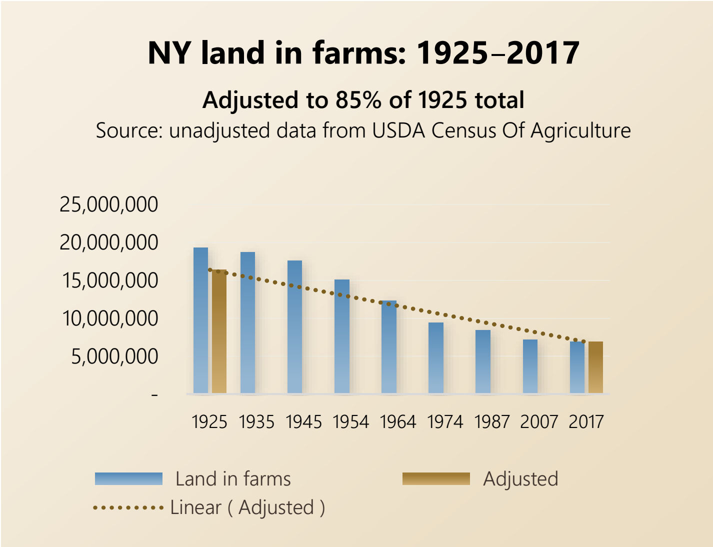


Figure 10: NY land in farms – 1925-2017

The overall number of farms declined from 215,597 in 1910 to 33,438 in 2017.[43] During this period, the size of farms approximately doubled. Farms have grown steadily in size since 1910, and they have grown more productive.[44] New York farms are still relatively small, with most falling between 10 and 179 acres, but 27% comprise 180 acres or more. Larger operations can make more efficient use of land, and this trend toward larger farms has been taking place over the same timeframe during which we have lost considerable farmland.

The increasing size of farms by no means offsets the ongoing loss of land in farms.

Farmland losses over the last century stem from a wide range of causes, including the rapid expansion of urban/suburban residential and commercial development while the state's population nearly doubled, from 10.4 million residents in 1920[45] to about over 20 million residents in 2020.[46] Hamlets became villages, villages became towns, and towns became cities. Associated commercial and industrial development accelerated this conversion.

Some farmers have idled land as they downsized operations, and historically many farms have been subdivided to provide family members with their own land for residential or commercial use. Additionally, farmland has been inherited by heirs who don't wish to keep it as agricultural land. Some has been purchased on speculation.

Land in farms

Published very five years, the Census of Agriculture supplies national, state, and county "land in farms" acreage, referred to in this document generically as farmland.

The definition of "land in farms" has changed many times since 1840, when the US Census collected agricultural data. More restrictive definitions reduced farmland acreage, but more inclusive ones increased the amount of.

This paper assumes that 15% of l farmland acreage since 1925 decreased due to changes in Census definitions and methodology. The 1925 adjusted value (85%) appears in Figure 10, along with a linear trendline.

[43] USDA, 2017 Census of Agriculture. and 1910 Census of Agriculture.

[44] USDA, 2017 Census of Agriculture. and 1910 Census of Agriculture (archived).

[45] US Census Bureau website, "Fourteenth Census of the United States: 1920: New York," https://www2.census.gov/library/publications/decennial/1920/bulletins/demographics/population-ny-number-of-inhabitants.pdf, accessed 25 October 2023.

[46] US Census Bureau website, https://data.census.gov/all?q=ny, accessed 25 October 2023.

Converting farmland to solar facilities doesn't take place in a vacuum. Millions of acres of New York farmland have already been consumed by residential, industrial, commercial, institutional, and other development. More will be converted in the future, and the scale of planned solar development will accelerate this conversion—not replace other forms of development.

While solar facilities may potentially impact farmland less than commercial/industrial or residential development does, we have no reason to think that it is more likely to be returned to farming in the foreseeable future.

NYS general farmland loss: 2017-2050 (projected) ***(NOT related to solar development)***			
Years (range)	**Farmland loss (acres)**	**Cropland loss (acres)**	**Prime farmland loss (acres)**
1997-2017	*-922,070*	*-670,150*	*-335,075*
2017- 2037	-823,941	-486,644	-243,322
2037-2050	-458,105	-286,318	-143,159
Change (acres): 2017-2050	-1,282,046	-772,962	-386,481

Table 6: NYS farmland loss not related to solar development (2017-2050)

What additional non-solar farmland and cropland loss should we expect by 2050? How much more land will solar development convert? Over the last 20 years, almost a million acres of farmland and over 670,000 acres of cropland were converted to industrial, residential, and other non-solar land uses. If this trend continues, the state will lose about 46,000 acres per year of land in farms and 33,500 acres per year of cropland to non-solar development. Land in farms decreased by about 12% between 1997 and 2017; if this trend continues, losses will increase to a cumulative total of 24%.

MISSING LAND

Development on productive farmland will not suddenly cease because we're installing solar facilities. People won't stop building homes, factories, commercial businesses, and warehouses on farmland. Building solar plants simply adds to the existing demand. Even if solar development were to stop now, the amount of land in farms would almost certainly continue to decline, for example, 253,500 acres of farmland underwent low-density residential or more intensive urban development between 2001 and 2016.[47]

But the state lost 922,000 acres of land in farms between 1997 and 2017, a period only slightly longer than 2001-2016. Subtracting 253,000 acres of low-density residential and intensive urban development still leaves a loss of 669,000 acres. Again, some of this loss might be attributed to changes in methodology or terminology, but it's also possible that the criteria used to define land

[47] American Farmland Trust website, "State of the States: Agricultural Land Conversion Highlight Summary - New York," https://storage.googleapis.com/csp-fut.appspot.com/reports/spatial/New_York_spatial.pdf, accessed 25 October 2023.

in farms grew *less* restrictive, resulting in a higher count of farms and indicating that even a loss of 922,000 acres might conceivably be less than would have occurred using earlier standards.[48]

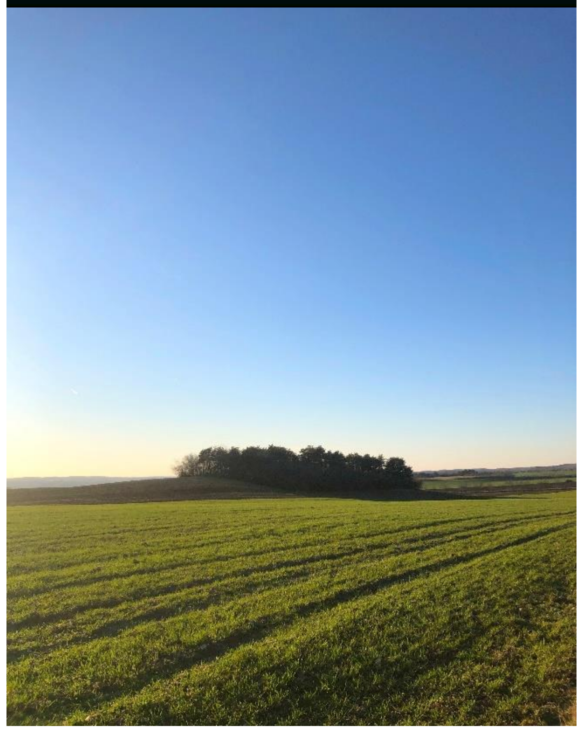
Where did the rest of this land go? Some of this land was probably idled due to the disability, retirement, or passing of the primary farm operator. Again, some farmland may have been purchased on speculation. On the whole, however, we are left with something of a mystery. Either the definition of farmland changed substantially, or more land was idled or developed than might be expected.

[48] The author tried repeatedly to contact the USDA by phone, email, and postal mail regarding this discrepancy but received no responses.

HOW MUCH LAND?

"Land is the only thing in the world that amounts to anything."

— Margaret Mitchell



This chapter assesses cumulative farmland losses from both solar and non-solar causes.

As we have seen, solar buildout to meet state goals requires 1.3% of New York State's land area by 2050, and about 5% (327,600 acres) of its farmland.

Is that a little, or a lot?

To many people, converting that much farmland—when we have almost 7 million acres of it—may seem like a reasonable exchange for the opportunity to produce clean energy. Others may be dismayed about converting this much land, especially when that total doesn't represent the full loss of available agricultural land due to fragmentation and decreased accessibility.

If we assume, for example, that the actual loss of farmland brings the average land per MW to 7 acres, the total loss of farmland rises to 455,000 acres. At 8 acres per MW, over half a million acres would be lost.

That begins to look like a lot.

As stated previously, though, we are limiting land losses to major facility elements: the area inside the fence, along with setbacks and landscaping, etc. Table 7: Cumulative NYS farmland losses estimates how much farmland will be lost to solar buildout and other causes if that loss continues at the rate that it did between 1910 and 2017. We saw in *Table 6: NYS farmland loss not related to solar development (2017-2050)* that non-solar losses are occurring at an alarming rate; Table 7 projects losses if we include solar buildout. Between 2017 and 2050, for example, over 1.2 million acres would be lost through residential and commercial development, idling, real estate speculation, and other causes. In addition, we can expect available farmland to be reduced by over 325,000 acres through solar development. The combined amount of farmland available for agricultural use would be reduced by a total of more than 1.6 million acres by 2050. The table breaks these numbers down into types of farmland to give a fuller picture of the overall consequences to agriculture.

Also, it is important to remember that 2050 is in many ways an arbitrary endpoint to this exercise. Solar development will not abruptly cease then. In fact, we will need electricity more than ever as we move forward with decarbonization.

Cumulative NYS farmland losses: 2017-2050 – projected *(from all sources)*						
Projected losses	Farmland lost (acres)	Percentage farmland lost	Cropland lost (acres)	Percentage cropland lost	Prime farmland lost (acres)	Percentage prime farm-land lost
Non-solar losses	1,282,046	-19%	-772,962	-18%	-386,48	-17%
Solar conversion	-327,600	-5%	-278,460	-6%	-139,230	-6%
Projected combined losses	**-1,609,646**	**-23%**	**-1,051,422**	**-25%**	**-525,711**	**-23%**

Table 7: Cumulative NYS farmland losses from all sources – 2017-2050 (projected)

According to the calculations here, a buildout of 2,819 MW of solar capacity *per year* would be required between 2023 and 2050. Table 8 breaks this down into how much land solar development will consume annually during this period

To look at these amounts even more closely, these estimates mean that every day for the next 27 years, solar development will consume about 40 acres of farmland.

Annual solar acreage requirements by 2050	
Acres	Type of land
16,915	State land area
14,210	Farmland
8,810	Cropland
4,405	Prime farmland

Table 8: Annual solar acreage requirements by 2050

Once again: is that a little, or a lot?

By itself, solar development has some measurable and distinct impacts on the availability of farmland. Some will consider it minimal, and others will find it concerning.

Let us consider some of the factors relating to our current and future land use, and their relationship to solar development.

SOLAR DEVELOPMENT IN A CHANGING WORLD

The context for solar development in relation to agriculture is constantly changing. This chapter looks at the following issues in New York State:

- Climate change and agriculture
- Farmland values in New York and other states
- Farming and farmers
- Concentrations of solar development, with examples
- Agrivoltaic solutions

> *"Destiny is not a matter of chance; it is a matter of choice. It is not a thing to be waited for, it is a thing to be achieved."*
>
> —William Jennings Bryan

CLIMATE CHANGE AND AGRICULTURE

When we assess the impacts of solar development on farmland, we should look first at the effects of climate change on New York State agriculture to determine what quantities and types of farmland should be used for solar or preserved. Crops, yields, and weather patterns will change. If climate change alters the crops we grow and livestock we raise, we need to replace our current agricultural production levels, and we don't know whether these changes will require more land or less. Ideally, we should be able to combine agricultural production through the co-location of agricultural activity and solar production (agrivoltaics). This subject is covered below.

The specific effects of solar buildout on the state's economy and food supply are beyond the scope of this paper. One subject that may have been overlooked, however, is how our potential need for agricultural land may *increase* in response to climate change and other factors. Given the state's agricultural diversity and food processing capability, the pertinent question here may be whether solar buildout may limit New York's ability to *expand* agricultural production.

Of the 50 states, New York is second only to California in having the most food processing facilities. This abundance means we can take food directly from the farm, process it in various facilities, and sell it directly to consumers or distributors, all within the state.[49] New York products are sold all over the world, of course, and we import a good deal of food from other states and countries, but New York has the rare potential to produce many of its most important food products in-state.

[49] Stephen Martinez (USDA Economic Research Service), "Number of Food and Beverage Processing Plants Varies Across the United States," 6 November 2017, https://www.ers.usda.gov/amber-waves/2017/november/number-of-food-and-beverage-processing-plants-varies-across-the-united-states/,accessed 26 October 2023.

Given the state's existing agricultural diversity and the fact that somewhat less devastating climate impacts are expected here than in other parts of the country, New York may be positioned to expand and further diversify agricultural production, and certainly to increase its own resiliency and ability to be self-sufficient. The increasing demand for locally and regionally produced foods offers new opportunities both for current farmers and those interested in going into farming.

Farming will become both riskier and potentially more profitable, depending on what can be produced easily during longer growing seasons, milder winters, and hotter summers, with more extremes of precipitation. How does increased risk from changing weather patterns figure into all of this? As we have seen, farmland conversion for solar facilities is about quality as well as quantity. Do we have the most versatile land available to handle more challenging growing conditions?

The New York Department of Agriculture and Markets (AGM) describes how future climate patterns will affect farming operations:

> While New York State is projected to see increased precipitation overall, it is expected to come in short, extreme precipitation events in between mild droughts. This represents a major risk to farms, particularly those in low-lying or flood prone areas. Even very local downpours and cloud bursts can cause substantial damage to farms.[50]

According to Cornell University's Climate Smart Farming initiative,[51] climate change will lengthen growing seasons and make it possible to produce new crops, but invasive species that have troubled warmer climates will become more common here and threaten native and other vulnerable species. Dairy and other livestock operations will need to provide more cooling for animals as temperatures rise. Planting may be delayed by wet winter and spring weather, or re-planting may be needed, with resulting lower yields and higher costs to farm operators. Summer and fall droughts will be more common, as will seasonal flooding and other extreme weather events.[52, 53]

The Northeast is expected to experience somewhat fewer climate-related disruptions to farming than western areas of the country, where droughts are expected to be more widespread and prolonged. Production shortfalls in other regions may give the Northeast a better opportunity to produce more of the nation's food supply.

If we continue to maintain current production levels, diversify, and possibly even increase agricultural activity, the state's most versatile and productive soils will be needed. For instance, intense precipitation requires soils that drain well to avoid flooding—and are at the same time drought-resistant. Some of these challenges may be overcome by planting new crops and varieties, or by employing new technologies and practices. One element can't be changed: farm soils. In an era when changes in our climate are making agriculture even more challenging, the state's best farmland is under intense development pressure.

Prime farmland represents the state's most capable agricultural land. Given the increases in precipitation intensity and possibility of flooding, New York will need this type of farmland more than

---

[50]AGM website, Soil and Water Conservation Committee, "Climate Resilient Farming," https://agriculture.ny.gov/soil-and-water/climate-resilient-farming, accessed 25 October 2023.

[51] Cornell University: Climate Smart Farming website, http://climatesmartfarming.org/, accessed 25 October 2023.

[52] Cornell Cooperative Extension website, "Climate Change Facts," https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/8/4308/files/2015/02/CornellClimateChange_NYs_Changing_Climate-FINAL-28kcqiy.pdf, accessed 25 October 2023.

[53] Cornell University, "Intensity Duration Frequency Curves for New York State: Future Projections for a changing climate" (fact sheet), https://ny-idf-projections.nrcc.cornell.edu/#dialog_box, accessed 25 October 2023.

ever in the future, as climate change affects multiple aspects of the food supply. If agricultural use is shifted onto less capable land, yields may decrease, certain crops may no longer thrive, and the possibility of catastrophic losses from severe storms or drought is likely to increase.

FOR SALE OR RENT: CHEAP CROPLAND

What makes New York State farmland so appealing to developers? One factor is the sale price of the state's cropland in comparison to other states in the Northeast.[54] In 2022, the sale value per acre was about half of the Northeast's average: $3,150/acre compared to $7,060/acre, and well below the national average of $5,050. In fact, farmland and cropland values in New York State were the lowest of any state east of the Great Plains.

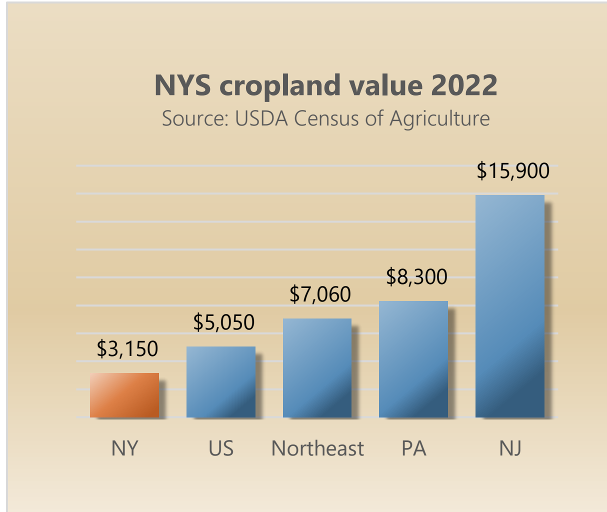


Figure 11: NYS Cropland values - 2022

Farmland cash rents in New York are also low, at $61/acre in comparison to a national average of $136/acre in 2020.[55] Cropland rent is only slightly higher. If long-term solar lease rates average $1,000-1,500 per acre, it becomes clear why many farmers would prefer to lease land for solar development. In some cases, available farmland is owned by investors and other "absentee" owners, who seldom have a reason to keep the land in production by renting it out as farmland. Leasing to a solar developer is clearly more profitable, although conversion penalties and other expenses must be considered. Leases must be drawn up and reviewed with great care. For example, if a solar developer fails to pay a contractor, will the landowner be open to having mechanics' liens placed on the property?

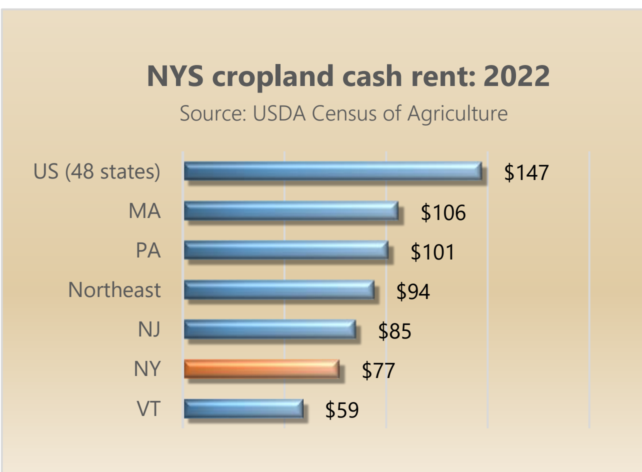


Figure 12: NYS cropland cash rent - 2022

Few landowners or their lawyers are likely to have much experience with leasing land for solar projects, and most solar developers have a great deal of it. Landowners would be wise to proceed with caution and try to reduce their exposure to legal action over the life of the solar project, including the cost of returning the land to its desired state.

---

[54] USDA NASS, https://quickstats.nass.usda.gov/results/4F2E1D91-9784-3B06-92F9-7826E3E6944A, accessed 27 October 2023.

[55] USDA NASS, https://quickstats.nass.usda.gov/results/54849026-0E3C-398B-B80D-43FD99047B6E, accessed 27 2023

FARMING AND FARMERS

The solar industry has used a standard set of assumptions in describing the effects of solar development on farmers and farming. These state that leasing or selling farms for solar development:

- Helps struggling operators keep their family farms
- Provides a stable source of income to offset volatile yields and prices
- Gives farmers additional income to invest in their operations
- Allows older farmers to retire with a stable income
- Helps to prevent higher-impact residential or commercial development

The industry also states that solar coverage lets the soil "rest" and improve. This assumption is discussed in the next chapter.

The statements above are unquestionably appealing—perhaps more so to the general public than to actual farmers, as we will see below. If we assume that many of these statements above are true, we are still left with a few that are questionable.

FEEDING THE MULTITUDES

We want to support the underdog, and we claim to hold farmers in high esteem. Of course, we complain bitterly when food prices rise, even though Americans spend the lowest percentage of their income on food than the citizens of any country in the world and yet have access to some of the highest-quality foods.[56]

The graphic in *Figure 13* shows the percentage of income spent on food around the world. As you can see, Americans spend only 6.8% of their income on food—and have one of the lowest malnutrition rates in the world. By contrast, citizens of Pakistan spend over 45% of their income on food but have one of the highest rates of malnutrition.

As part of supporting the underdog, we also tend to view farmers with smaller operations more sympathetically than those with larger, more productive ones. Small farm operations are often more financially precarious and vulnerable to industry and market trends. In the dairy industry, for instance, distributors have cut routes, leaving some smaller-scale dairy farmers without buyers for their milk. These farmers are sometimes left with the choice between selling their herds or investing in their own dairy processing operations.

---

[56] Washington State Magazine, "Billions served, August 2011," https://s3.wp.wsu.edu/uploads/sites/902/2011/07/WSMaug11_billions.pdf, accessed 25 October 2023.

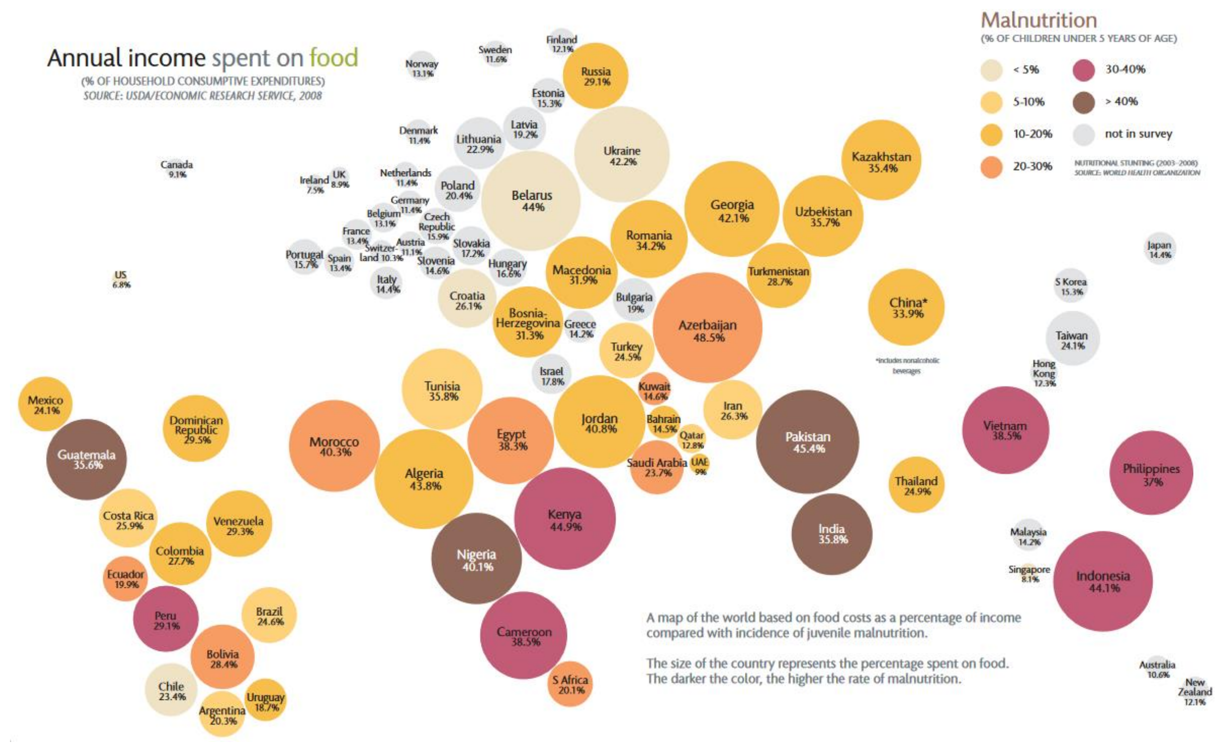


Figure 13: Food as a percentage of annual income - map from Washington State Magazine (August 2011)

There also seems to be a perception that small farms are more important to providing the food we need to survive. Small farms do indeed support biodiversity and are less likely to grow crops for non-food uses, such as ethanol production. Yet while most of us want to see small operations survive and succeed, our social and emotional attachment to small farms seems worth examining. Why don't we attach more value to larger, more profitable operations? Is our societal goal to keep as many farms in operation as possible, or to ensure that production remains adequate to meet our needs?

Farmers' Perceptions of Solar

American Farmland Trust's *Smart Solar Siting on Farmland: Achieving Climate Goals While Strengthening the Future for Farming in New York* report[57] surveyed farmers and others about their views on solar development on farmland. Interestingly, when municipal officials and farmers were asked how they expected solar to affect the viability of farms, farmers responded much more negatively than the officials; a full 52% expected negative impacts, while municipal officials expected only 32% negative impacts. Likewise, 22% of officials expected positive impacts, compared with 14% of farmers. These numbers suggest that municipal officials, who make decisions on permitting

[57] AFT, "Smart Solar."

smaller solar projects, view the effects of solar development more favorably than do farmers. These results call into question the widespread assumption that farmers are fighting for the right to host solar projects amid communities who are insensitive to their needs. Based on anecdotal evidence, many residents perceive solar as helpful to farmers and encourage their town officials to approve projects. Obviously, issues such as climate change play into this process, but it begs the question: are we trying to "save" farmers through a means that many farmers perceive negatively?

Of those farmers who were hosting projects, 25% reported that their operations would shrink or that they would stop farming, while 22% saw no impact, and 39% indicated that their operations would continue.

Perhaps the most striking responses involved farmers who rent land. Some of the comments from farmers who rent:

"The highest farm leases are $150/acre… the solar company is paying $1,800/acre to rent the land. How can local farms compete with that? They can't." –Farmer in the Southern Tier.

"When landlords choose to rent their farmland to solar companies instead of a farmer, that farmer will lose rental ground. This will be bad for farmers. But when a solar farm rents land from a farmer, that farmer will have income from that land that will (presumably) be higher than the contribution from growing crops, so it will make that farm more viable." –Farmer in western NY.

"The land being developed isn't owned by farmers, so it is being taken away from farmers because we can't compete with the prices they offer." –Farmer in the Finger Lakes.

Note that the last two responses refer to farmland that isn't owned by farmers. No data seems to be available on the occupations of those who own farmland being leased or sold to solar developers, but clearly it isn't just farmers who own farmland. Solar development is an attractive option for "absentee" landowners who have little immediate use for the land in question; these situations do not appear to be uncommon.

Dairy operations have specific needs that may require renting farmland. For example, those who grow feed for their herds may not have appropriate acreage of their own for that purpose. Related to that issue is the need to spread manure at relatively high rates. Without fields available for this purpose, dairy operations' critical need to process manure is in jeopardy.

To conclude, in the words of a farmer in the Southern Tier:

Farmers who are nearing retirement age with no one to continue farming are looking for retirement investment with solar…are pleased that these projects are available to them. Those with farms that have generations to pass on [to] are unhappy [with that] because they always have the need for more land.

Concentrations of Solar Development

Of particular concern is the uneven distribution of solar development across the state. For example, solar development in counties such as Herkimer, Genesee, and Montgomery, is planned on an especially intensive scale, leading to the high concentration of solar buildout in areas where local economies are disproportionately affected:

"Taking farmland out of production creates a trickle-down effect. All the other businesses losing business. For example, it takes a minimum of $200 an acre for crop support per acre. This includes seed and fertilizer sales, fuel, equipment repairs and payments on new equipment, tires, sprays, twine and bale wrap, dairy supplies, fencing… the list goes on and on." – Farmer in the Mohawk Valley.

This statement reflects what researchers have found:

Given the land-use trend so far and the characteristics of identified good- and medium-suitability lands, agricultural land will likely remain the prime target for future USSE [utility-scale solar energy] development. Preventing the local concentration of solar farms could help to mitigate the negative impacts of USSE development on local agriculture and economic activities dependent on it. During one of the interviews that was conducted for this analysis, an expert conveyed that concentration of USSE installations on agricultural land… initiates a chain reaction through all the businesses that depend upon the operation of farms.[58]

Example of Concentration: Genesee County

What happens when several grid-scale solar projects are concentrated in one agricultural area? Let's look at an area of Genesee County in western New York that will host the approved 500-MW Cider Solar project. The facility will impact 2,159 acres of active agricultural land within a 2,452-acre total footprint. The developers point out that this one facility only displaces 1.2% of Genesee County agriculture. But two other large facilities are located within a radius of three miles: the 280-MW Excelsior Energy Center and 200-MW Orleans Solar Project. Smaller projects are proposed as well.

In such cases, farmers who have previously rented land that will be converted to solar may find it extremely difficult to find new rental prospects:

For the 65 percent of upstate farmers who rent some or all of the land, there is concern over how to support their farm operations. More than half of farmer-renters surveyed reported negative impacts, including increased competition for land, higher lease rates for rented land, or loss of access to farmland. This is an especially challenging issue for dairy farmers.[59]

The owners of a farm near the future Excelsior Energy Center site put it clearly:

[Our farm] generates roughly $14 million in farm gate sales of milk per year. Past studies by the PA Center for Dairy Excellence of the multiplier effect of dairy farms on a community range between two and four times the economic impact of the farm. For [our farm] in Genesee County, this would mean $28 to $56 million in economic impact on the community. Land availability in close proximity to active dairy farms is critical to their success. As both a source of forage crops for feed, and as a place for manure to be spread at agronomic rates, a loss of 500 acres of farmland will likely result in [our farm] being forced to downsize by at least a third if the solar project is approved.[60]

Example of Concentration: Montgomery County

At a mere 403 square miles, Montgomery County is the fifth smallest upstate county; it has a population of about 50,000, and agriculture plays a major role in its economy and social structure. As in several other parts of the state, many Amish families have settled there to farm, and conflicts are arising between solar developers and the Amish community, which not only relies on existing land to survive, but requires additional land as families grow and expand their farming.

---

[58] Venktesh et al., 2021.

[59] AFT, "Smart Solar."

[60] NY DPS DMM, Excelsior Energy Center Article 10 proceeding public comment, 5 April 2022, https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={6DA0045C-FC88-4F5A-83BE-711A76B7A5BD}.

According to utility and state interconnection queues, about 220 solar projects are planned for the county, including 665 MW of community solar and 1,500 MW of grid-scale solar for the highest total proposed capacity of any upstate county as of this writing: 2,200 MW, which will require at least 20 square miles of land—presumably most of it being farmland.

Amish families have expressed strong concerns that their children will have little land available for farming. Note that farming may be on the decline in some parts of New York, but Amish use of farmland has consistently expanded and is necessary to maintaining their way of life. An interview with one Amish farmer provides insights:

> Members of the Amish community understand the reasoning of their neighbors who have accepted offers from [a solar developer] especially aging farmers who will be afforded the opportunity to relax. But the majority of the more than 77 families agree they will leave the area and the state if the project is built…. Despite the reliance of the community on agriculture, the farmer said he would prefer to compete with a big farm operation covering the same amount of land than see the space covered with solar panels. Aside from the concerns about the view of the solar panels, the large-scale project would take up otherwise useful farmland, meaning it would be unavailable to future generations of Amish farmers who already have rapidly growing families.[61]

Agrivoltaics: Preserving Food

Perhaps the best option for keeping farmland in production is agrivoltaics/the co-location of agricultural production and solar development. There is increasing interest in this approach from both solar developers and farmers. It offers the opportunity to grow food and generate electricity at the same time, an extremely attractive option to many. Some solar developers are even offering agrivoltaic solutions to interested farmers.

It is understandable that solar developers and host landowners may wish to maintain some kind of agricultural operation. Thus far, however, most meaningful agrivoltaic production has been limited to fewer than 50 acres and has been expensive to integrate even on a small scale. It is especially difficult to introduce agrivoltaics after a large facility has been designed and constructed.

The agrivoltaics market is likely to be a $9.3 billion business by 2031.[62] As of this writing, agrivoltaics is receiving enormous media attention, but very little progress seems to have been made apart from a few small projects. Eventually it should offer a viable means of using land for both agriculture and solar production. Unfortunately, grid-scale plants being designed and constructed in New

[61] Ashley Onyon, "Solar project proposed in Glen eyed to help state meet energy goals," The Daily Gazette, 8 August 2021, https://dailygazette.com/2021/08/08/solar-project-proposed-in-glen-eyed-to-help-state-meet-energy-goals/.

[62] Allied Market Research, "Agrivoltaics Market by System Design (Fixed Solar Panels, Dynamic), by Cell Type (Monocrystalline, Polycrystalline), by Crop (Vegetables, Fruits, Crops, Others): Global Opportunity Analysis and Industry Forecast, 2021-2031," 2023, https://www.alliedmarketresearch.com/agrivoltaics-market-A47446, accessed 25 October 2023.

York State now and in the near future are unlikely to pursue agrivoltaics. As mentioned previously, our goals for solar buildout are too aggressive to incorporate agrivoltaics.

Additionally, agrivoltaics must at some point address specific, market-driven needs for food. Grazing sheep, for instance, is of limited agricultural value and isn't always viewed as an agrivoltaic solution.

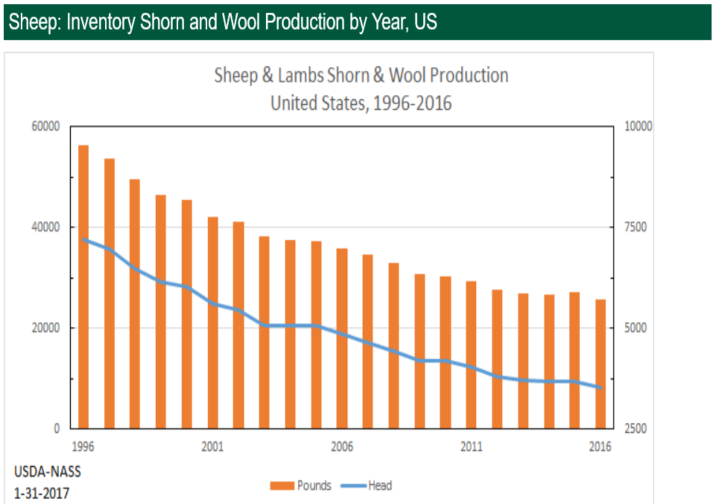


Figure 14: Sheep: Inventory shorn and wool production by year – graphic from USDA-NASS

ABOUT THOSE SHEEP

Grazing sheep under panels can be an inexpensive, appealing, low-emissions alternative to mechanical mowing. While it generates interest, saves money, and produces some agricultural products, sheep grazing does not address a current market demand. There is some concern, in fact, that large-scale solar grazing operations might compete with existing sheep farms.

According to one industry representative, sheep are not used under tracking panels (moving panels that follow the sun's angle across the sky during the day):

NextEra will not plan to incorporate sheep as they have identified that with moving panels sheep have been hurt if caught under the panel when it moves.[63]

The market for wool and lamb meat has been declining for decades, and promoting lamb consumption runs contrary to our present emphasis on plant-based diets. In 1910, New York's inventory of sheep and lambs totaled 930,300. By 1959, that number had dropped to 188,566, and in 2017 it was 80,195. Lamb meat appears to have lost popularity after World War II, and wool producers must compete with cheaper imports. The USDA's Agriculture Economic Research Service tells us:

[E]ach American consumed about 0.6 pound of lamb yearly in 2011. The highest lamb consumption in the past 100 years was 5 pounds per person in 1912.[64]

The trend away from raising sheep for meat is reflected as well in the production of wool, as shown in *Figure 14: Sheep: Inventory shorn and wool production by year – graphic from USDA-NASS*. New York farmers produced a little over 250,000 lbs. of wool in 2017. Canadian farmers, on the other hand, produced 1.9 million lbs.,[65] and Australia produced 626 million lbs.[66] Often, sheep farmers

[63] Eden Renewables/NextEra "Pre-Construction Meeting Minutes," 12 April 2022, Town of Glen, NY.

[64] USDA: Ask USDA website, "How much lamb is consumed per capita in the US," https://ask.usda.gov/s/article/How-much-lamb-is-consumed-per-capita-in-the-US, accessed 21 October 2023.

[65] Statistics Canada, "Wool disposition and farm value, 2020," https://www150.statcan.gc.ca/n1/daily-quotidien/220422/dq220422d-eng.htm.

[66] The World Atlas website, "The World's Top 10 Wool Producing Countries," https://www.worldatlas.com/articles/the-world-s-top-wool-producing-countries.html, accessed 21 October 2023. Note that US production is far below any of these.

contract for shearing, so their net proceeds are further reduced.

Note also that general meat consumption in the US is becoming less popular as the public views a plant-based diet as healthier and more sustainable. There may be a secondary market, however, for lamb as animal feed.

As a means of maintaining solar sites, though, sheep seem an excellent solution, assuming water sources are available, and that winter feed and shelter are available in some location. While it is easy to endorse solar grazing in general, it is more difficult to view temporary grazing as a replacement for full-time agricultural use. Cynics argue it is an attempt to keep or gain agricultural tax incentives for land acquired by solar developers.

These remarks are by no means intended to discourage grazing sheep on solar facilities. Lamb and sheep-related products may be attractive to niche or local markets as locally raised meat, specialty yarns, cheeses, and so on. These markets could very well expand in the future.

At issue is whether sheep grazing currently represents a true co-location of solar facilities and agriculture. The same holds for using pollinator-friendly plantings under panels. Such plantings are a welcome adjunct to farming or conservation efforts, but they do not appear to address an existing primary need for food or fiber.

In short, sheep grazing is an excellent use of solar sites, but it fails to provide the full benefits of planned, well-designed agrivoltaic solutions.

BEYOND SHEEP

Ideally, agrivoltaic solutions should

- Extend or adapt the characteristics and production of an existing operation
- Incorporate agricultural best practices and promising innovations
- Account for climate-related changes to upstate agriculture
- Not require major investment in new structures or machinery
- Receive ongoing guidance from experienced and knowledgeable professionals
- Offer scalability, allowing the operation to expand (or downsize)
- Continue to provide rental land for other farmers
- Be incorporated into the earliest stages of solar project design
- Alternatively, allow for retrofitting on existing grid-scale sites of 500+ acres

Of course, federal, state, and local incentives for agrivoltaics would have to account more fully for the expense of full-scale agricultural adaptation.

To be truly useful, agrivoltaic solutions need to produce New York State's present major crops and products, including those that are high in national rankings, as shown in *Table 9: New York agricultural products* in national rankings.

New York State's main crops (by market value) include:

- Milk from cows
- Grains, oilseeds, dry beans, dry peas
- Cattle and calves
- Fruits, tree nuts, and berries

Product	Rank in nation
Apples	2
Maple syrup	2
Milk (from cows)	3
Grapes	3
Corn silage	3
Tart cherries	3
Cabbage	3
Fresh market produce	4
Sweet corn	4

Table 9: New York agricultural products in national rankings

Few of these crops are well-suited to growing under conventional panels, with the possible exception of some low-growing bean crops and fruit such as strawberries. The task of retrofitting thousands of acres of solar facilities to grow New York State's most economically important crops seems nearly impossible at this point.

A more helpful approach might be to consider what agricultural products we need to grow, and then adapt solar structures to accommodate their production. At present, we are primarily experimenting with what grows well under or between panels. While this is a useful start, it often focuses on raised-panel technology without researching what needs to be grown.

Many crops and livestock require raising panels high enough and spacing rows widely enough to produce crops under them. There might be some resistance on the part of neighbors and communities who do not want to view hundreds or thousands of acres of panels elevated eight feet off the ground, even if they are performing a useful agricultural purpose.

Developers of grid-scale solar facilities sometimes mention solar grazing, but most do not plan for expensive and complex agrivoltaic operations that would require raising panels to produce everything from low-growing vegetable and fruit crops to small trees. Reinforced, raised panels can be used for cows and cattle, and fencelike, vertical panels allow farmers to continue growing hay and row crops. Goats are not good candidates for agrivoltaics, as they tend to jump on the panels and chew on wires. Cows and cattle require reinforced racking supports, as they may lean on the panels or attempt to scratch themselves on the supports. Unfortunately, pigs—among the least fussy grazers—are apt to dig up wires and can be difficult to contain. Hens and meat chickens appear to thrive under ordinary panels, on the other hand.

In the future, agrivoltaics represents a very promising direction—and perhaps the only sensible one when we site solar on farmland. But progress on a large scale is likely to be slow and expensive. More incentives are needed, along with more research and practical experience on the part of growers.

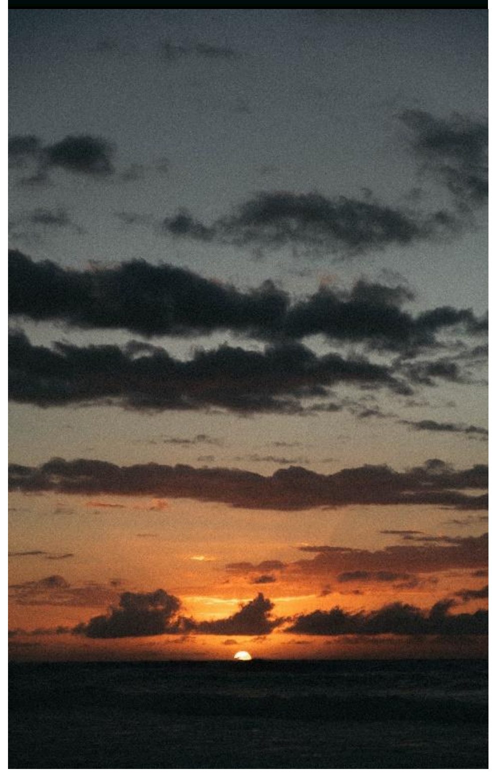
UNDOING SOLAR

In this chapter, we consider whether

- Decommissioning is likely
- Facilities are temporary or permanent
- Soil under panels actually improves

"The past never returns, what returns is not the past, but a present that has distant roots."

— Luigina Sgarro



Solar developers often dismiss concerns about agricultural land use as a "perceived" problem and argue that the land required for solar is a tiny percentage of NYS farmland. They sometimes engage in a deflection of land-consumption issues by claiming that solar facilities are a beneficial form of development; solar development will "preserve" farmland from other types of development. Solar plants can be co-located with agriculture by grazing sheep, keeping bees, and planting "pollinator meadows" under the solar panels. When solar facilities are decommissioned, developers assure us that agricultural use may resume on the land simply by removing the solar facility components. The soil will have "rested" and will be more productive than it was before the solar plant was constructed.

What is the basis for making such assumptions?

Of course, many of these statements are speculative by nature, as no research has examined the effects of solar facilities on soil over a 20–30-year period. In fact, as of this writing, no large solar project has been decommissioned after its "useful lifetime" and returned to agricultural use.

At this point, no one knows exactly what work will be required to return land to agricultural use after 30-50 years of hosting a solar plant. Stormwater runoff patterns change, for example, and wet areas may no longer be tillable. Will zinc levels in acidic soils increase from years of contact with galvanized piles? How does solar coverage affect the water-holding properties of soil? What are the effects of different ground covers?

The longest research study to date took place over a seven-year period and reported moderately deteriorating conditions under the panels, including much lower levels of organic matter and decreased water-holding qualities in soil directly under the panels, in comparison to an adjacent field used as a control, along with the soil between the panels.[67] There is no obvious reason why this situation would improve in the coming decades. Because the soils between rows were not improved by the presence of solar panels, it appears that statements that solar projects are "improving soil

---

[67] Moscatelli, Maria & Marabottini, Rosita & Massaccesi, Luisa & Marinari, Sara, "Soil properties changes after seven years of ground mounted photovoltaic panels in Central Italy coastal area," 2022, Geoderma Regional. 29. e00500, https://www.sciencedirect.com/science/article/abs/pii/S2352009422000207. Note that these changes to date, while significant, did not preclude returning the land to agricultural use at some point.

Well-rested soil

Solar developers often counter land-consumption issues by claiming that building solar facilities is beneficial to future agricultural use. This argument assumes that solar coverage doesn't affect soil; on the contrary, it leaves land fallow for a long period, during which nutrients are replaced. In other words, it allows the soil to "rest" and improve:

"The [solar] project essentially provides a form of preservation for agricultural land by maintaining permeable land surface and improving soil quality over the project life."

— Avangrid website, about its Mohawk Solar project

"This is just a different way of using the sun and it has no impact on soil. We can let the soil rest for 25 or 30 years and it can easily be returned to farming."

—Landowners leasing agricultural property for solar development

quality" may be premature, at the very least, and should probably be avoided.

DECOMMISSIONING VS. REPOWERING

Older wind turbines in New York State are being repowered; the process may also provide an opportunity to upgrade a project to increase output. Repowering makes much more financial sense than decommissioning, assuming the landowners are amenable to lease extensions or new leases—keeping in mind that after 30 years, the property may have new owners. As long as lease rates remain competitive, there is little reason for the owners to use the land for another purpose:

> The project's economics provide assurance of its long-term operation. Most of the project costs are incurred in developing, siting, and building the facility. Once the solar facility is up and running, maintenance costs are relatively minor. To recover start-up costs and earn a profit requires that the facility produce power for the full term of the 25-35 years of its planned life.[68]

If this is true, why would a developer decommission the facility after 25-35 years? While repowering a renewable energy resource has substantial costs, they are likely to be far lower than initial start-up costs on a new site. While it is true that solar panel production decreases over time, it is reasonable to assume that degrading panels will be replaced as more efficient models and technology become available. Several years ago, 300–350-watt panels were common; now 600-610-watt panels are available. New panel efficiency continues to improve.[69] Further innovations such as bifacial panels and tracking systems are already bringing about changes in the industry. It may be more economical for developers to replace older panels with higher-efficiency ones well before the "life of the project" ends.

There seems, however, to be little chance that a successful solar site will be decommissioned for many decades to come. By regularly upgrading solar component technology, the developer can maintain or increase the solar facility's value and productivity.

The average age of a farmer in New York State is 57. [70] Realistically, a family member—who may or may not be a farmer—will own the farm when the lease expires. If the site is owned by a farmer at

[68] Hecate Energy, "Greene County Solar Facility FAQs," https://www.greenecountysolar.info/faqs/, accessed 25 October 2023

[69] Renogy website, "How efficient are solar panels: a brief guide," https://www.renogy.com/blog/how-efficient-are-solar-panels-a-brief-guide/, accessed 20 October 2023. Today's most efficient models reach 22% or more efficiency, compared with only 15% a few years ago. Research models are reaching efficiencies of over 47%.

[70] Office of the NYS Comptroller, "A Profile of Agriculture in New York State," 2019, https://www.osc.state.ny.us/files/reports/special-topics/pdf/agriculture-report-2019.pdf.

that point, it would be surprising if s/he decided to return the land to agricultural use. More land would require more equipment, more labor, and more extensive facilities.

TEMPORARY OR PERMANENT?

As we just saw, some farmland owners are under the impression that land used for solar may be tilled and returned to agriculture as soon as the racking piles are out of the ground. Is this the case?

The idea that solar facilities may be removed at any time is true in theory, but we want to make sure that the land can then be returned to agricultural use when plants are decommissioned before reaching more widespread conclusions such as:

"By leasing land to solar companies, you contribute to sustaining the farming industry for future generations." —Landowners leasing to a solar developer.[71]

The New York State Department of Agriculture and Markets (AGM) considers farmland conversion lasting 30 years or more to be permanent. The solar industry insists that this conversion is temporary and often implies that such land is likely to be returned to agricultural use.

In fact, we simply do not know the effects of solar coverage on farmland over 30 years or more. To claim the land can be returned to agricultural use immediately is premature at best. For example:

- Adjacent land use and conditions may have changed significantly after three or more decades. For example, adjacent land may have begun to drain onto the solar site.
- Climate change itself may have resulted in new weather patterns, longer growing seasons, higher soil temperatures, and increased stormwater runoff, requiring the farmer to make changes to a reestablished operation
- Markets for agricultural products may have changed, leaving farmers unprepared for new market conditions
- New equipment and knowledge may be required for maximum productivity; common agricultural practices and techniques may have changed

Some of these considerations will be true whether the land was used for solar or not. If the land is being farmed actively over that same period, though, farmers will be familiar with changes and have had a chance to adapt to them more gradually.

Let's look at this more closely using whatever present resources are available.

[71] Unbound Solar website, "Pros and cons of leasing land to solar companies," accessed 28 April 2023 (Update: website down for maintenance as of this writing)

WHAT HAPPENS TO SOIL ON A SOLAR SITE?

Farmers usually test their soil regularly and amend it as needed. Many operators periodically leave land fallow for a few years at a time—not for 30 years. With proper care, actively used soil need not become less productive over such a period. Should solar developers promote their facilities as beneficial to soil quality—or at least not detrimental to it? Why would they make such a claim without research and evidence to show it is accurate?

No one knows yet what happens to soil under the panels, and these scenarios of returning land to agricultural use appear speculative. Solar developers have no experience with restoring sites to agricultural use; it remains uncertain how complex, expensive, or in certain cases even feasible it may be to resume farming operations. Consequently we must weigh the appeal of the "resting" scenario against the reality that no one has direct physical evidence of the effects of solar development on farm soils after that length of time.

What yields can a farmer expect from re-converted solar land? How do pH and water-holding capability compare between soils under panels and in the rows between them? If differences occur, how is this "striping" effect best remedied? How long will it take to return land to former production levels? Will drainage modifications be required? Will the solar company install any drainage structures that are needed? Will they repair or modify damaged ones?

Returning a grid-scale facility to agricultural use is probably quite a bit more complicated than removing racking and panels and tilling the soil. Extensive soil testing will be needed, and amendments applied. If wetlands were previously cultivated previously, they may no longer be available for agriculture, and wet areas that cannot be farmed may have been created.

Some level of compaction from construction is inevitable. Deep ripping may help with areas affected by construction or stormwater runoff in some cases, but can it be relied on to relieve all compaction problems?

As of this writing, it appears that only one study has looked at soil conditions on an operating solar site for more than 2-3 years. The 7-year study, based in Italy, samples data from the soil underneath panels, from the rows between panels, and from an adjacent field used as a control:

> [S]even years of soil coverage modified soil fertility with the significant reduction of water holding capacity and soil temperature, while electrical conductivity (EC) and pH increased. Additionally, under the panels soil organic matter was dramatically reduced (−61% and − 50% for TOC and TN, respectively compared to [spaces between rows]) inducing a parallel decrease of microbial activity assessed either as respiration or enzymatic activities… As for the effect of land use change, the installation of the power plant induced significant changes in soils' physical, chemical and biochemical properties creating a striped pattern that may require some time to recover the necessary homogeneity of soil properties but shouldn't compromise the future re-conversion to agricultural land use after power plant decommissioning.[72]

[72] Moscatelli, et al., "Soil properties changes"

While it is reassuring that seven years of having panels installed has not done irreparable damage, soil is not simply "resting" under the panels but is actively undergoing changes. What additional changes may occur by the time a plant is decommissioned after 30 years? After 60?

Soil does not improve from being located on a solar site. Developers should avoid making unsupported claims, especially to host landowners.

Any solar project that takes more than 500 acres of farmland out of production should monitor changes in soils under and around panels over the life of the project. This approach may be the only way we can determine what measures will be required to restore solar land to full agricultural use—or agrivoltaic use if repowering incorporates this approach, as seems sensible.

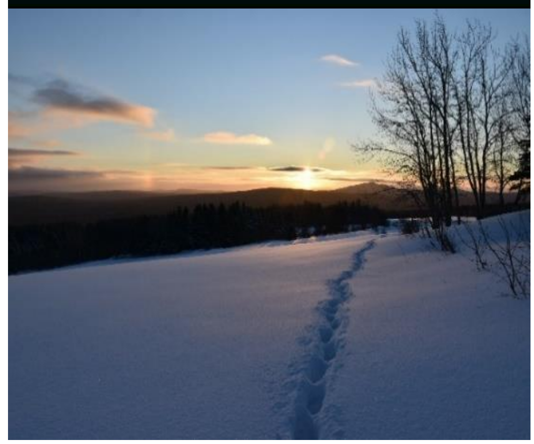
Concern has been raised about thin-film solar panels (a fairly small proportion of panels installed in the US) and the heavy metals they contain leaching into the soil. There seems to be no evidence that simple runoff on the panel surfaces causes leaching of these metals, but one study used the straightforward approach of crushing thin-film panels and mixing them with a variety of acidic substances.[73] When leaching occurred, researchers documented the uptake of heavy metals into plants grown in contaminated media. Panels seldom break, but damage is certainly not unheard-of, with broken panels sometimes remaining on the ground for months. It would seem entirely reasonable—if uncommon—that under certain conditions, thin-film panels could leach heavy metals into soil (and presumably groundwater). Additional research is needed.

Similarly, the extent to which PFAS may be introduced into farm soils (with resulting uptake into vegetation) needs more study. Panels are often treated with "anti-reflective" coatings that need to be reapplied periodically. There are questions about whether these contain PFAS, as in this case the coatings gradually slough off. The same is true of hydrophobic and anti-soil coatings. We need well researched information from transparent sources on these topics.

[73] Su, L.C., Chen, J.J., Ruan, H.D., Ballantine, D.J. and Lee, C., "Metal Uptake by Plants from Soil Contaminated by Thin-Film Solar Panel Material," (2019) Journal of Environmental Protection, 10, 221-240, https://doi.org/10.4236/jep.2019.102013.

ENOUGH LAND

> *"You never know what is enough unless you know what is more than enough."*
>
> —William Blake



This chapter concludes the main body of this paper by asking wether we have enough land for agriculture and solar buildout. It includes suggestions for the parties involved in siting solar plants.

As we have seen, solar development isn't the sole source of pressure on our supply of farmland. If we are serious about preserving farmland, we need to look at ongoing losses and determine how to minimize them, whether through land-use planning, zoning, or other measures to limit low-density residential and industrial/commercial development on highly productive farmland.

Opponents of solar projects on farmland will probably see these losses as an important reason to limit solar expansion. It would seem at least equally important, though, to limit low-density residential expansion, which also uses large amounts of high-quality farmland. This is not an either-or proposition; both pose a potential threat to agriculture in the state. Opponents of building solar on farmland need to expand their fight to include residential and other development on our best farmland. It is difficult to justify preserving farmland from one type of development when others are just as destructive, if not more so.

Ultimately, we may be facing a conflict between the rights of landowners to use farmland for any legal purpose and our collective need for farmland as a vital resource. Because most of us do respect the long hours, hard work, and inherent risks that farmers take, we naturally sympathize with their decisions to take farmland out of production or change the focus of their operations by leasing or selling land for solar development.

Farming is not an altogether benevolent activity. It can reduce biological diversity, introduce harmful chemicals into the environment, and consume massive subsidies that fail to improve life for many farmers or increase the production of affordable, healthy food and other agricultural products.

Do we have enough farmland for solar buildout on the scale required to meet Climate Act goals? Keep in mind that the Climate Act is a law, not simple policy. Its success depends on our having more farmland than we need in order to produce food, fiber, and fuel.

The answer to this question may be somewhat subjective. We may not even know the answers until it is too late to do much about the issue.

For now, though, the following suggestions apply:

<u>State policymakers</u>

- Acknowledge that prioritizing solar development over agricultural use may be short-sighted in the context of ongoing farmland loss

- Provide national leadership in agrivoltaic projects and work w/AGM to define a detailed, long-term agrivoltaic strategy and framework for grid-scale projects
- Continue to fund and incentivize agrivoltaic research and pilot programs
- Expand and fund farmland conservation efforts
- Promote much greater incentives for avoiding priority soils, and/or disincentives for building on them; use these funds directly to benefit the preservation of farmland (e.g., by funding land trusts)
- Consider the effects of solar development concentration in agricultural areas and find alternatives to siting grid-scale facilities close to one another
- Review NYSERDA's farmland mapping to ensure that concentrated areas of development have been identified and alleviated
- Acknowledge that re-conversion isn't a likely outcome and plan accordingly

Solar developers

- Take responsibility for development on farmland; stop implying that all solar land will be re-converted to agricultural use
- Acknowledge that sheep grazing and "pollinator meadows" are not replacements for most previous agricultural uses; highly productive soils should not be used to grow fescue, ryegrass, and wildflowers
- Do not use sheep grazing as an example of co-location unless definite plans are underway; do not say "if economically feasible" if it isn't, and do not claim to have plans to graze lands that are clearly inappropriate (e.g., wetlands and some sensitive habitat areas)
- Work directly with neighbors and nearby farmers to minimize the impacts of planned facilities
- Use industry best practices to prevent erosion and stormwater runoff onto neighboring properties
- Use local processes to site facilities on farmland and listen to local concerns rather than dismissing them out of hand
- Recognize and respect public concerns about food production and address them with real information about agricultural land loss
- Cease using the completely unsupported claim that solar development improves farmland
- Stop using the unproven claim that farmland can and will be returned easily to agricultural use
- Pursue real, market-driven agrivoltaic solutions
- Dedicate more research and development funding to agrivoltaics and agricultural land use
- Maintain transparency with communities about plans and how they may affect farmland

Community leaders

- Require all project documentation to be made available in an online repository so developers, town officials and residents; this arrangement helps to avoid confusion about which documents are up to date and reduces the need for FOIL submissions

- Listen to community members and make sure their project questions are answered thoroughly and accurately by developers
- Address agrivoltaics in local laws
- Maintain complete transparency in the permitting process and ensure that community members concerns are understood and addressed at thoroughly as possible
- Be aware that solar developers focus on business; they are answering to investors, not engaging in altruism
- Make sure FOIL responses are answered promptly and Open Government requirements are met

Other individuals

- Avoid converting farmland to commercial or low-density residential use and make sure farmland protections are incorporated into protections into all local laws
- Oppose any non-agricultural use of prime farmland
- Work toward supporting farmers through farmland trusts, new-farmer partnerships, and other alternatives that provide more flexibility in meeting their financial obligations
- Participate in making voluntary decisions about solar siting locations

Host landowners

- If properties may be attractive to solar developers, work with neighbors and other community members toward a mutual understanding of issues such as property values, environmental concerns, and financial hardships. Most landowners agree not to disclose developers' plans, so these are prudent conversations to have *before* pursuing leasing or selling land for solar development
- Always have an attorney review solar leases and other documents signed with developers; make sure to retain the right to keep solar development off the most valuable land and avoid plans that may cause areas of farmland to be abandoned.
- When negotiating solar leases, insist on agrivoltaic solutions beyond sheep grazing and "pollinator meadows"
- Be aware of liabilities and potential scenarios that might negatively impact finances. For instance, if the developer fails to pay contractors, ensure that they cannot file mechanics' liens against farm property, as sometimes happens now
- Consult with family and legal advisors about the consequences of property changing hands
- Consider the wishes of those who may inherit farmland; do they support siting solar on the land in question? Might they prefer to farm the property or rent it to nearby farmers?
- Require ongoing soil testing
- Work w/developers, farmland conservation organizations, and towns to preserve the best farmland
- Consider working with a new farmer, selling development rights and/or working with a land trust to preserve farmland from development

- Recognize that reconversion of farmland is unlikely

Members of the public oppose and support solar development on farmland for a variety of reasons. With the possible —but not definitive—exception of agrivoltaics, there are no broad, sweeping solutions to balancing the consumption of farmland against the need to preserve it. And for many community members, the industrialization of farmland is an undermining of rural identity, not simply an aesthetic consideration or concern about property values.

There are no easy answers here; conflicts are inevitable. The best we can do is begin engaging in an open, transparent conversation about our needs, preferences, and desires for solar development on farmland. We need to find a way to engage in productive discussion; this may require both opponents and supporters of solar development to acquire and share information from credible sources. Opponents of solar on farmland are often under the impression that heavy metals such as cadmium telluride are used in most solar panels. They need to understand that multiple kinds of panels are used, and the thin-film panels that use cadmium and other heavy metals only account for about 10% of panels used worldwide.[74]

Opponents also need to understand that residential and commercial ("rooftop") solar pose the same general risks as utility-scale solar panels. A surprising number of people who oppose utility-scale solar have residential arrays and/or support solar in less visually intrusive settings but seem unaware that the same concerns about environmental impacts and decommissioning apply to those systems as well. This is not intended as a criticism of smaller-scale solar installations, but people need to be aware that they use the same technologies that are used in utility-scale systems.

Supporters of large solar facilities should understand that people who oppose these projects are not simply complaining that they don't "look pretty." Even when issues such as decommissioning and stormwater runoff have been addressed, the appearance of solar plants—which frankly cannot be screened all that effectively—industrializes the rural landscapes that form a part of many rural residents' identities. This scale of industrialization is daunting to those who have given up shorter commutes, higher wages, better access to healthcare, and more educational opportunities to live among these landscapes. Even these residents are sometimes unable to articulate that their rural surroundings shape who they are and what they value.

Does the derogative "NIMBY" label adequately capture the opposition of rural populations to perceived industrialization? The opposition of local residents to solar buildout is increasingly blamed on fossil-fuel corporations' influence and funding. These suggested schemes teeter on the edge of conspiracy theories, as their proponents offer little in the way of evidence. What about the many, many local opposition groups who have no ties to any central organization, let alone fossil fuel companies?

Supporters of solar buildout often criticize opponents for their lack of knowledge of solar technology, and yet many are no more informed. Both opponents and supporters need more education about solar technology and New York State's buildout goals: the role of solar in fighting climate change, the safety of equipment being used, and the effects on farmland.

Solar supporters and opponents should both understand that the solar divide runs the risk of becoming partisan; in the context of today's hyperpartisan political environment. It is no more

[74] Solar Magazine, "Thin-Film Solar Panels: An In-Depth Guide | Types, Pros & Cons," 12 March 2022, https://solarmagazine.com/solar-panels/thin-film-solar-panels/.

helpful for opponents to refer to "green fascists" as it is for supporters to call opponents "anti-farmer." Neither side can afford to engage in such histrionics.

Developers must comply with local laws, and local officials must hold them firmly to the community's regulations. Too many solar projects have been rushed through the approval process—especially early in the process of reviewing solar projects—only to encounter serious problems later. Projects change hands with head-spinning frequency, and town officials must realize that commitments made by one developer may not be binding unless well documented, and even then may prove impossible to enforce.

It is also important for developers and municipal officials to acknowledge that screening is of limited use in blocking views of solar projects. Even in best-case scenarios, differences in elevation may lead to visibility issues. Screening plantings often take at least 5-10 years to become effective. If screening vegetation is inadequate, towns need to take action and require more effective efforts. Code enforcement officers may lack the training or confidence to ensure compliance with local and state laws. Unless a fully qualified environmental monitor (EM) is working on the project, specific concerns about agricultural land (e.g., stormwater runoff, grading, and compaction) may not be addressed effectively.

We cannot afford to make bad decisions about farmland *or* energy production. Today's priorities may become tomorrow's regrets. The conflicts identified here will require all our efforts, open-mindedness, and thoughtful engagement to negotiate.

Appendix A: Solar Basics

This appendix introduces basic concepts and terminology used in this paper. Many people have heard references to these subjects but don't have a clear idea what they mean. There is much more to learn about solar, but the information here should help in better understanding this document.

The Electric Grid

The state's electric grid carries energy between the place where it is generated, such as a solar plant, to the place where it is used, such as your home.

Electricity flows through transmission and distribution lines. Transmission lines carry large amounts electricity between parts of the state. They make up the basic structure of the state's electric grid. Distribution lines draw energy from the grid or local sources so your utility company can deliver electricity to your home through the wires that run along streets and roads.

Capacity and Energy

"Capacity" (sometimes "nameplate capacity") describes the amount of energy that a solar installation can produce under ideal circumstances. This paper uses megawatts (MWs) as the main unit for measuring capacity.

"Energy" refers to what an installation produces and is available to the grid. It is commonly measured in megawatt-hours (MWh). A MWh refers to one MW of energy generated over the period of one hour.

In 2021, each of the 7.5 million households in New York State used an average of roughly 9 MWh of energy a year. Of course, residences aren't the only things that use electricity. The transportation and commercial/industrial sectors, for example, use significant amounts of energy as well.

While a 100-MW solar plant can theoretically generate 100 MW under perfect conditions, it may produce less—and it produces nothing at night.

Often output from a solar plant is confusingly stated as the number of households it can serve. A developer might claim that a 100 MW plant will serve 20,000 households. Because obviously solar plants can't generate electricity at night, you may be wondering what happens to those 20,000 households at night.

Measuring capacity

Capacity is usually measured in watts (W), kilowatts (kW), and megawatts (MW). A megawatt is a million watts. The capacity of large solar installations is usually measured in MW. For instance, a community solar project often has a capacity of 5 MW.

To complicate this, MW may be measured in two ways. MWdc (direct current) measures capacity between the panels and the inverter. MWac measures capacity from the inverters (before they connect to the grid). Because some power is lost during inversion, MWdc is always higher than MWac for the same facility. A 10 MWdc plant might be 8 MWac.

Don't worry, they still get electricity through the grid. Primarily, that energy comes from natural gas, nuclear, and hydroelectric resources.

Households aren't the only things that require electricity. So do the industrial and transportation sectors, for example. The claimed number of "households served" is usually mathematically correct in theory, but it paints a potentially misleading, meaningless picture.

Different types of solar energy installations

These terms describe the most common types of solar energy systems. This paper focuses on grid-scale solar, which uses large amounts of land (usually over 100 acres).

Residential: Home rooftop and ground-mounted systems (commonly 0.15 MW or less). Energy from most rooftop installations is sold to the local utility company at retail rates: the amount that any residential customer would pay for it. This arrangement is called "net metering."[75] As you can imagine, utilities aren't eager to offer this arrangement to all customers. They want to buy wholesale energy from grid-scale resources and sell it to customers at a profit. Consequently, opportunities to expand residential and commercial solar under net metering agreements are limited, and they are carefully regulated.

Utility-scale: Any solar plant over 1 MW

Commercial: Businesses (e.g., rooftops) and surrounding area (often 0.1 to 2.0 MW)

Community solar: A project that is assumed to collect and distribute solar energy in a local area; subscribers receive a discount for buying energy from a community solar plant. The actual energy that subscribers use may come from other sources as well. In New York State, these plants are limited to 10 MW, but they may be built in pairs (often 5 MW each). There appears to be no limit on the number of individual plants that can be placed on adjacent sites.

Grid-scale: A solar installation that supplies electricity directly to the state's transmission grid. In New York State, these are typically 20 MW to 500 MW.

The term "solar farm" serves as a euphemistic marketing term and is not consistently used within the solar industry. The terms **solar project**, **solar power plant**, and **solar facility** are more common and descriptive. "Solar farm" tends to be used by media outlets, lobbyists, and solar marketers.

Industrial solar is used occasionally within the solar industry and increasingly as a somewhat derogatory—but accurate—term by people who oppose utility-scale solar projects.

Components of a solar plant

When we talk about solar energy, we usually mean photovoltaic (PV) solar, which uses **panels** (also called **modules**) that collect sunlight and turn it into electricity. A solar project has one or more **arrays:** collections of panels that function as a unit and share infrastructure. The term isn't synonymous with "solar

[75] For more about how net metering works, see the EnergySage article "What is net metering and how does it work?" https://www.energysage.com/solar/solar-101/net-metering/?rc=seia, accessed 23 October 2023.

Manufacturer	Trina Solar
Model	TSM-DEG21.C20 (bifacial)
Output	Up to 665 W
Size	7′ 10″ x 4′ 3″ (portrait orientation)
Weight	85 lbs.
Color	Black (monocrystalline)
Frame	Aluminum alloy
Operating temperature range	-40° F—185° F
Warranty	30 years, assuming 100% output when installed and 85% after 30 years
Country of manufacture	China

farm" or solar project; some media outlets use the terms interchangeably. An array is the largest part of a solar project, not the entire project.

PANELS AND SUPPORTS (RACKING)

A panel for industrial use might have a maximum output of 665 watts, weigh about 85 lbs., and measure close to 8' by 4', with an area of about 33 square feet. The table in this appendix specifies the details of a panel used in 2023 for industrial solar projects.[76]

Panels are mounted on **racking**: steel frames that support their weight and hold them at a certain angle. Some racking includes motorized tilting to take advantage of the sun's changing angle through the day (**tracker panels**).

INVERTERS

Solar panels produce DC (direct current) electricity, like a battery. The grid that supplies electricity where it's needed uses AC (alternating current), like your household outlets. An **inverter** turns DC electricity from solar panels into AC electricity before it is injected into the grid.

OTHER COMPONENTS

Wires attach panels to inverters and connect inverters to other parts of the installation. Sometimes these are overhead wires, and sometimes they are buried. Depending on the scale of the solar installation, a solar project may include transformers and other equipment to help deliver electricity to the grid.

STATE SUMMARY: NEW YORK BY THE NUMBERS

New York pursues solar development aggressively compared with many states, but there's plenty of room for improvement, especially given the state's ambitious climate goals:[77]

National ranking in installed solar: 9th (was 4th in 2022)
Percentage of state's electricity: 4.41%
Total solar investment in the state: $9.8 billion

[76] Based on Trina 665 W bifacial TSM-DEB21C.20. Datasheet, https://static.trinasolar.com/sites/default/files/DT-M-0013%20BDatasheet_Vertex_DEG21C.20_EN_2022_A_web_DEG21C.20_2022A_EN_20221103.pdf, accessed 25 October 2023.

[77] Solar Energy Industries Association (SEIA®) website, https://www.seia.org/states-map, accessed 25 October 2023.

APPENDIX B: UPSTATE, DOWNSTATE

This appendix helps people understand some of the conflicts surrounding the solar divide.

> *"When truth divides, errors multiply."*
>
> — Eli Siegel

When solar projects are announced in rural upstate communities, many residents tend to drift into groups: those who oppose projects and those who support them.

Solar developers have heard the full range of concerns about solar energy before and are experienced in addressing them. They may suggest that people who oppose solar are getting misinformation from NIMBYs and weigh in with a consistent narrative: solar energy is safe, cheap, and quiet. These projects help farmers and provide financial benefits for communities. Solar will keep electricity prices low and cut emissions. Solar plants do not reduce property values but may increase them. PILOT and host community agreement (HCA) funds will bring in more revenue for schools, towns, and counties. The project will create jobs—all while helping to address an existential crisis.

Seldom mentioned is the fact that most developers state they cannot build their projects without PILOTs, and that they require sales tax and mortgage recording tax exemptions as well.

Residents who favor utility-scale solar projects agree with these statements. They often add that

- The project under consideration doesn't pose a threat to state agriculture
- The need to counter climate change through solar buildout is more pressing than the need to protect farmland
- PILOT funds and temporary construction jobs outweigh any negative socioeconomic effects of solar development.

Community members opposing projects tend to express concern that

- Farmland is a finite and essential resource; extensive solar development on farmland threatens the food supply
- PFAS chemicals and other hazardous substances that may be used in coatings, panels, and other electrical components may contaminate the soil and food products grown there
- Farm and agrotourism economies may be impaired
- Sacrificing farmland to meet New York City's renewable energy needs is short-sighted and not a valid reason to allow solar buildout.

Farmers in the community may support the right of other farmers to use their land as they wish. Dairy farmers in particular, though, may find it difficult to compete with solar developers for the land they need for forage, feed, and nutrient management through spreading manure on a large scale.[78]

Municipal officials tend to have a more positive or uncertain view of solar development on their communities. Because agricultural assessments result in lower tax revenues, PILOT and HCA funds provide welcome tax relief. One survey points to widespread uncertainty during interviews with town supervisors.[79] Increasingly, boards must act with care to avoid litigation. As one municipal official said to a group opposing a solar project: "We're more afraid of being sued by them [the solar developers] than by you."

PUBLIC OPINION VS. PUBLIC POLICY: WHEN BIGGER ISN'T BETTER

We often hear about the popularity of solar development. In a 2020 Pew Research national study, for example, 91% of Americans favored increasing solar development.[80] Does this favorable view reflect opinions everywhere? Does it change when large facilities are proposed in an area?

In a 2021 study on public support for solar development in upstate New York, researchers found that support and opposition—especially in certain rural regions—correlate closely with facility size and location.[81] It appears that support is weaker in areas where grid-scale projects are concentrated, such as western and northern New York. The popularity of solar development seems to depend on the project—especially on its scale and location. Across the upstate study region, rooftop support was a healthy 4.4/5, where 5=strong support. For grid-scale solar, it was only 3/5. In western New York, where renewable buildout will be especially concentrated, support for grid-scale projects, was even weaker, at 2.8/5.

Support for siting plants on landfills was about 4.3/5 overall, but, as has been pointed out, only 1.8/5 for siting solar projects on productive agricultural land or forest.[82]

---

78 AFT, "Smart solar."

79 Nilson Roberta S., Stedman, Richard C., "Are big and small solar separate things? The importance of scale in public support for solar energy development in upstate New York," Energy Research & Social Science, Volume 86, 2022, 102449, https://www.sciencedirect.com/science/article/pii/S2214629621005363).

80 Pew Research Center, "International Science Survey 2019-2020, September 2020 Release," https://www.pewresearch.org/science/wp-content/uploads/sites/16/2020/09/PS_2020.09.29_international-science_TOPLINE.pdf, accessed 25 October 2023.

81 Nilson et al., "Are big and small."

82 Nilson, et al., "Are bid and small."

The energy plantation

Over the course of the 20th century, New York City's water supply was created by flooding a million acres farmland, forests, and villages. This extraordinary feat of engineering, which allowed the city to flourish and expand, displaced over 5,700 upstate residents, and submerged about 25 communities.*

Although residents received compensation, they had no choice but to leave the homes that had remained in their families for generations, the farms that had sustained them, and the villages that had provided a sense of community.

Their sacrifices made it possible for millions to lead safer, healthier lives but left a generational memory of loss among some upstate residents. For some current residents, the use of upstate land represents a pattern of neocolonialism in which upstate New York now serves as an energy plantation for the downstate region.

*Catskill Watershed Corporation website, "History," https://cwconline.org/about/, accessed 1 July 2023.

DIVIDED HISTORY

The upstate region receives what amounts to $14 billion a year in tax relief from downstate New York.[83] In turn, upstate New York has historically provided the natural resources that sustain urban areas. Some upstate residents have parted with these resources willingly, and others have not.

Supporters and opponents of solar buildout on farmland tend to diverge in their personal and at times political ideologies. Urban/rural conflicts account for certain clashes over using upstate New York farmland. Note that urban areas may include both upstate cities and metropolitan New York.

Today, willing landowners are leasing or selling properties for utility-scale solar plants, but some of their neighbors and other residents oppose their decisions:

> [Forty-two] percent of residents oppose USS installations in or near their local communities, 14 percent neither support nor oppose, and 44 percent support.[84]

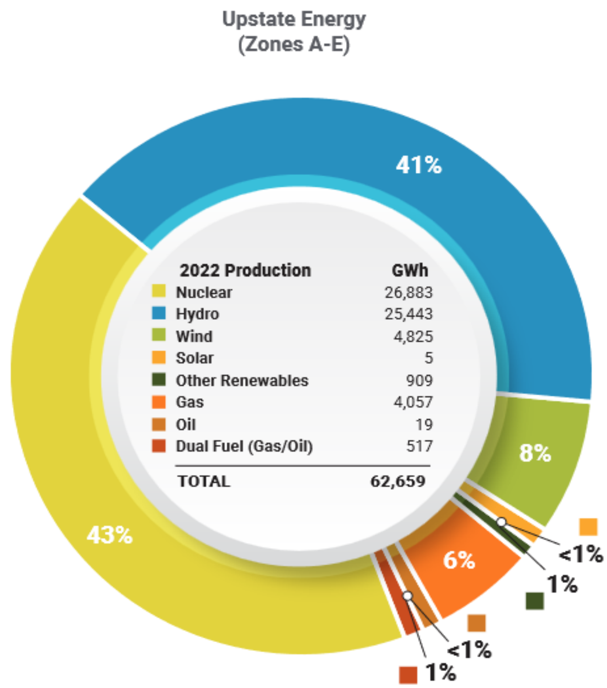
[83] Mark Weiner, "5 Reasons Why Splitting New York Would Be a Disaster for Upstate," *Syracuse*, 5 March 2019. https://www.syracuse.com/politics/2019/03/5-reasons-why-splitting-new-york-would-be-a-disaster-for-upstate.html.

[84] Nilson, R.S. and Stedman, R.C., "Reacting to the Rural Burden: Understanding Opposition to Utility-Scale Solar Development in Upstate New York," Rural Sociology, 88: 578-605, 16 March 2023, https://doi.org/10.1111/ruso.12486.

DOWNSTATE, UPSTATE

It's often pointed out that upstate New York already generates far more clean energy than the downstate region, and in the future, upstate counties will have to produce even more to offset New York City's dependence on fossil fuels.

About 92% of upstate energy is already generated by emissions-free resources. The downstate region, on the other hand, has had almost no zero-emissions energy generation since the Indian Point nuclear plant was taken out of service. As of this writing over 95% of downstate energy was generated by fossil fuel-based resources.



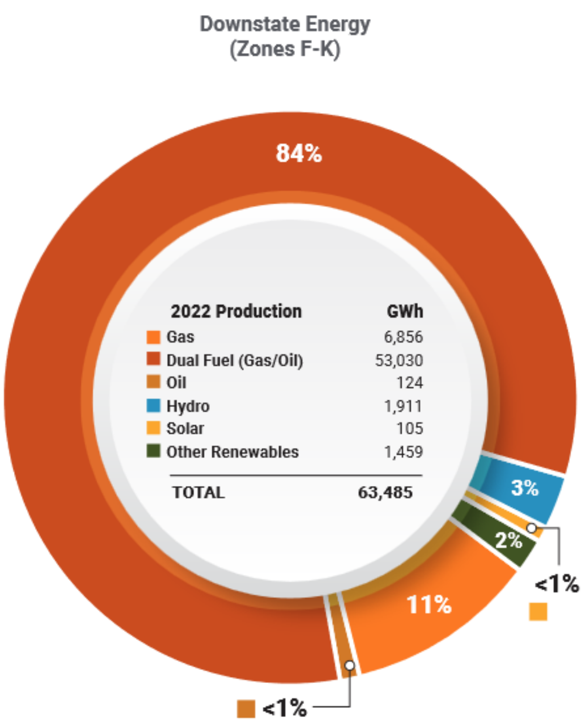


Figure 15: Upstate and downstate NY energy generation by fuel

Chart source:
The New York Independent System Operator (NYISO) "Power Trends 2023"

Downstate New York has three realistic options for decarbonizing in the required timeframe: a massive buildout of offshore wind, lithium-ion battery storage, and transmission projects to import hydroelectric power from Canada and to supply renewable energy from upstate facilities.

All these alternatives are planned or under consideration, but without upstate renewables, it is doubtful that New York City will be able to reach state emissions goals.

Siting Major Electric Generating Facilities in New York State

While smaller community solar plants have drawn some local opposition, most towns and counties appear to welcome the funds that may be provided through PILOTs as well as HCAs. Towns that refuse to approve solar plants face possible legal action.

Historically, New York has encountered strong opposition to building large power plants of any kind: gas, nuclear, wind, or solar. To make the siting process easier, the state has passed laws that prevent local communities from derailing planned facilities. What the state regards as a NIMBY problem has been addressed through state laws that prevent local opposition from stopping or significantly altering projects while streamlining the siting process for large renewable projects. Article 10 of the New York State Public Service Law ("Article 10") and Section 94-c of the New York State Executive Law ("Section 94-c") allow the state to override local laws and decision-making processes for power plants with a capacity >25 MW (optionally >20 MW for Section 94-c).

Projects taking large amounts of agricultural land out of production are typically sited under one of these mandates. Consequently, it is up to the state, solar developers, and farmland owners to decide to what extent they wish to protect agricultural land. The state uses mitigation payments and tax penalties to discourage development on productive land, but developers often find it more expensive and less convenient to use marginal or non-agricultural land.

Who Decides?

Solar developers often use the "decide-announce-defend" approach to siting facilities they believe may encounter local opposition.[85] While a practical and convenient approach, this belief may be something of a self-fulfilling prophecy, as the approach often appears to provoke some level of local resentment, especially when used in combination with state siting mandates such as Article 10 or Section 94-c.

Small "community solar" plants are being sited quickly, but the large facilities that are needed to meet state climate goals have been relatively slow to materialize. These projects use economies of scale to generate much larger amounts of energy than residential, or community solar installations do.

Communities are allowed some autonomy over small projects that consume relatively little land, while projects with much larger impacts proceed without local approval. The lack of autonomy under Article 10 and Section 94-c siting mandates may erode rural residents' trust in the state and almost guarantees some level of local opposition.

Collaborative Siting

State authorities now encourage communities to determine the best places to site solar facilities. It's a promising start to adopting a consensus-based approach that leads to a sense of local

---

[85] Nadejda Komendantova, Antonella Battaglini, "Beyond Decide-Announce-Defend (DAD) and Not-in-My-Backyard (NIMBY) models? Addressing the social and public acceptance of electric transmission lines in Germany," Energy Research & Social Science, Volume 22, 2016, https://doi.org/10.1016/j.erss.2016.10.001.

empowerment and lets communities plan for siting on previously disturbed lands, including capped landfills.

Unfortunately, collaborative siting only applies to small plants, not grid-scale installations. The projects that will most affect communities are beyond their control.

STATE-MANDATED SITING

The use of mandated siting processes reflects a sharp division between rural communities and what they perceive as an encroaching urban and authoritarian state government.[86] In the case of grid-scale solar projects, the state consistently uses Section 94-c (and Article 10) to override local laws that might discourage or limit solar development in any way.

The purpose of these mandates is to site renewable energy facilities, not protect communities or ensure that they thrive. According to the laws' written content and public hearing discussion, these mandates do not consider the following when approving facilities:

- Cumulative effects of multiple grid-scale facilities
- Socioeconomic well-being of the community
- Changes in real property values

Can residents trust these laws to protect their interests? Many residents would argue that climate change is an existential crisis, and towns should support the state's efforts to curb its worst effects. Without these laws, towns might choose not to support the state's climate agenda. Can the state trust communities that may want nothing to do with producing renewable energy, especially for the downstate region and for other states?[87]

Given the rising level of hostility between some rural communities and the state, it would seem reasonable to increase community involvement increasingly exclude it. Yet if authority is returned to the communities, there is a real chance that some towns will reject these projects or demand that they be downsized. If the state's primary goal is to build out solar energy, it cannot afford to address the concerns of those towns where they are sited.

Members of the CAC, which prepared the *Scoping Plan* for implementing the Climate Act, included policymakers, energy experts, and lobbyists—but no one representing rural upstate New York, which will be profoundly affected by proposed changes such as the eventual elimination of fossil fuel-based heating systems, the need to replace old cars and trucks with new EVs and the service upgrades required, along with the siting of large-scale renewable facilities. Some communities welcome the latter, while others complain that the scale or location are inappropriate, or that developers are acting unethically.

It remains to be seen how wealthy downstate communities will respond to the large-scale buildout of offshore wind, battery storage, and transmission projects. Wealthy communities may be no more open to large-scale solar development than underserved ones. The town of Chilmark MA on

---

[86] Eisenberg, Ann M., "Power and Powerlessness in Local Government: A Response to Professor Swan," Harvard Law Review, Volume 135, Issue 3, January 2022, https://harvardlawreview.org/archives/vol-135-no-3/.

[87] Some projects sited under Article 10 have power purchase agreements (PPAs) with states other than New York, including projects with contracts with NYSERDA that specifically prohibit it. Three recent examples include renewable facilities owned by developers who have signed PPAs with Connecticut utilities. These projects are sited on New York farmland; Connecticut has much more stringent farmland conversion restrictions. These facilities include Cassadaga Wind, the Coeymans Solar Farm, and the Greene County Solar Facility.

Martha's Vineyard, for instance—home of John Kerry, US Special Presidential Envoy for Climate—contains a single 11-acre parcel where large-scale solar systems may be located: the town landfill.[88]

It is uncertain if or how this impasse ends. State government and state law will always prevail, and there are no signs that future laws will protect communities from inappropriate or predatory siting. Opposition is a minor inconvenience—at best—in siting grid-scale solar facilities. With powerful entities such as Columbia Law School providing free assistance to host landowners and solar developers who feel their efforts are being hindered by local communities, it is nearly impossible for minimally funded upstate opposition groups to put up much of a fight.

The state has already invested billions in renewable energy buildout and is prepared to fund much more:

> A cornerstone of this transition is New York's unprecedented clean energy investments, including more than $55 billion in 145 large-scale renewable and transmission projects across the state, $6.8 billion to reduce building emissions, $3.3 billion to scale up solar, more than $1 billion for clean transportation initiatives, and over $2 billion in NY Green Bank commitments.[89]

There remains an upstate need for downstate tax revenue; perhaps farmland is the price to be paid for it. Is this short-sighted, or a good way to fight the effects of climate change? The answer depends: Are we losing a little farmland, or a lot? Do we have enough land for solar buildout and agricultural production? Numbers tell us surprisingly little, leaving us once again with opinions. If this document is helpful, though, at least these will be more informed opinions.

---

[88] Town of Chilmark 2020 zoning, GIS map: parcel 28: 013-028-00, 55 Tabor House Rd, Chilmark Town of/land fill, 11.3 acres, https://www.axisgis.com/chilmarkma/, accessed 29 October 2023.

[89] NYSERDA Newsroom press release, "America's Largest-Ever Investment in Renewable Energy is Moving Forward in New York," 24 October 2023, https://www.nyserda.ny.gov/About/Newsroom/2023-Announcements/2023-10-24-Governor-Hochul-Announces-Nations-Largest-Ever-State-Investment.