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Institute for Energy Economics and Financial Analysis

# Agrivoltaics

## An Economic Option for Farmers and Rural Development

Asher Salkin, Research Intern, IEEFA

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# Figures and Tables

## Key Findings

**Agrivoltaics can reduce local opposition to solar projects on farmland and create new income streams across rural stakeholder groups.**

**Agrivoltaics significantly reduces water usage and increases yields in arid regions.**

**Agrivoltaics broadens participation in the rural economy, and can contribute meaningfully to both the renewable energy transition and the long-term viability of U.S. agriculture.**

**With continued research, supportive policy, and adaptive financial models, agrivoltaics has the potential to align farmer needs, developer interests, and community priorities.**

# Introduction

Across the United States, the race to secure affordable, reliable energy is transforming the rural landscape. Fueled by data centers, artificial intelligence, electrification, and industrial reshoring, electricity demand is increasing after decades of little to no growth. Continued increases in power demand are expected through the 2020s, prompting a rush to build new generation resources.

Notwithstanding current political headwinds, economics are in renewables' favor. Studies show solar and wind are the cheapest sources of new power, consistently outcompeting gas and coal on price.[1] However, the ongoing solar boom comes with a challenge: The flat, sunny, and accessible land ideal for the solar industry's expansion is, in many cases, already in use for agriculture.[2] By 2050, the National Renewable Energy Laboratory (NREL) projects photovoltaic (PV) installations could require as much as 10 million acres of land, or between 0.5% and 1.1% of U.S. farmland.[3,4] Given that farmland conversion is an important social and political issue in agricultural communities, agrivoltaics represents an opportunity to produce both food and energy at the same time.

The Institute for Energy Economics and Financial Analysis (IEEFA) views this challenge as a land-use opportunity rather than a crisis. Agrivoltaics—the dual-use integration of solar panels and active farming on the same land—offers a solution that benefits all three core stakeholders. Landowners gain a new, steady revenue stream in an incredibly volatile industry, all while maintaining their land's agricultural productivity; solar project developers get access to viable sites with fewer permitting battles; and communities retain agricultural land in production while enjoying local investment and tax revenue. In short, agrivoltaics is a winning solution.

Although still nascent, agrivoltaics installations have expanded rapidly since 2020, growing from 27,000 acres with 4.5 gigawatts (GW) of capacity in 2020 to more than 62,000 acres and 10 GW in 2024—enough to power about 1.5 million homes.[5,6] Studies suggest that converting just 1% of U.S. farmland into agrivoltaics could meet a significant portion of the country's renewable energy goals without sacrificing food production.[7]

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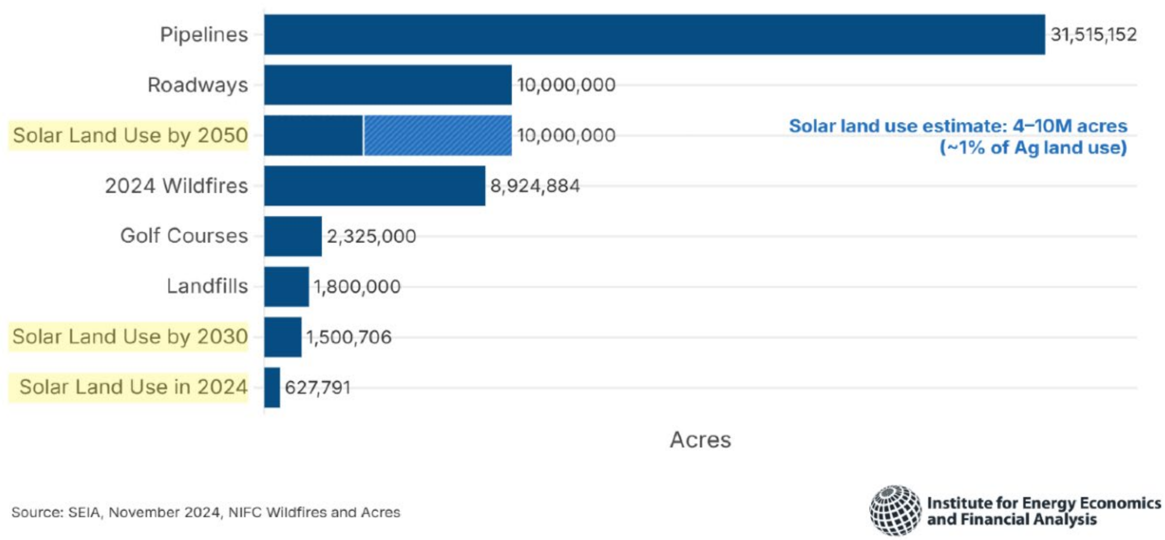
[1] Lazard. 2025 Levelized Cost of Energy+ Report. June 16, 2025.
[2] Reuters. Renewable energy remains cheapest power as new gas plants get pricier. June 16, 2025.
[3] National Renewable Energy Laboratory (NREL). Growing Plants, Power, and Partnerships. August 18, 2022.
[4] United States Department of Agriculture, National Agricultural Statistics Service (USDA NASS). Farms and Farmland, 2022 Census of Agriculture Highlights. March 2024.
[5] National Renewable Energy Laboratory (NREL). Lighting the Way for Agrivoltaics. November 21, 2024.
[6] Carbon Collective. Gigawatt (GW). January 9, 2024.
[7] Sustainability. Agrivoltaics Align with Green New Deal Goals While Supporting Investment in the US' Rural Economy. December 25, 2020.

**Figure 1: U.S. Land Use Comparisons (acres)**




*Source: National Interagency Fire Center*[8]

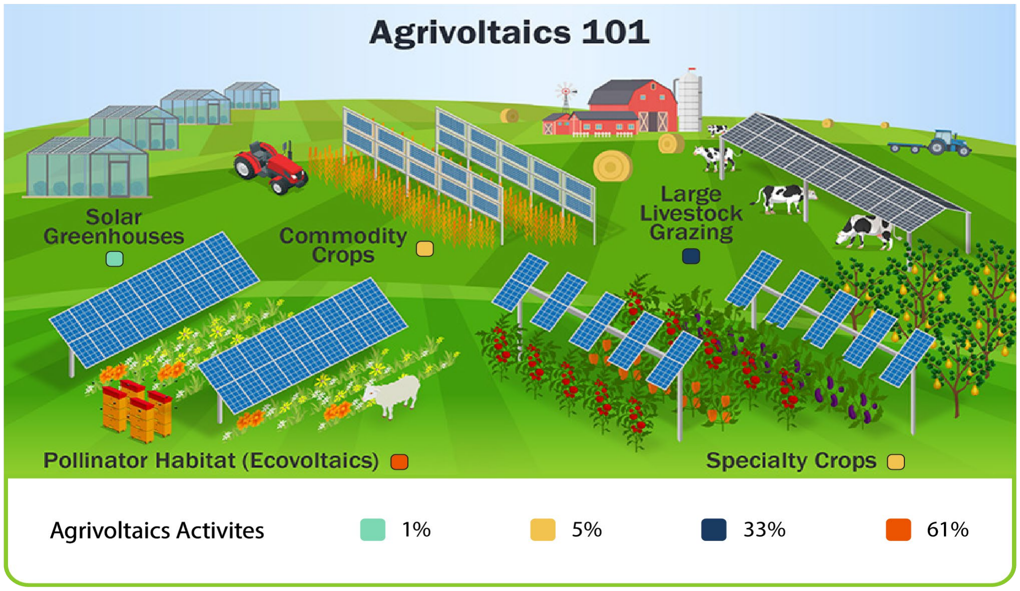
# The Basics of Agrivoltaics

Agrivoltaics can take many forms, each suited for different agricultural systems and regional conditions. The most widespread approach in the U.S. today is the pollinator habitat model. While less lucrative than other models, it is easily constructed by seeding native wildflowers and grasses between panels to boost biodiversity and public acceptance. The second most popular is solar grazing, where sheep or other small livestock graze beneath panels and maintain the solar site. In other regions, especially arid zones, crop-integrated systems are gaining ground, using solar arrays to shade specialty crops like leafy greens, peppers, and root vegetables that thrive in the shaded, cooler, and more moisture-retentive soils beneath the panels, where reduced radiation and wind exposure create a distinct microclimate.[9] Researchers abroad are testing a fourth model—greenhouse-integrated solar—in controlled environments, though it remains limited in rural U.S. applications.

Together, these systems showcase that agrivoltaics is not a single solution, but a flexible, adaptable, and scalable approach to dual land use. While not a silver bullet, its ability to enhance farm economics while also delivering benefits for land use and climate mitigation makes it a potential strategy for rural development.

[8] National Interagency Fire Center (NIFC). Wildfires and Acres. 2024.
[9] Agronomy. The Early Effects of an Agrivoltaic System within a Different Crop Cultivation on Soil Quality in Dry–Hot Valley Eco-Fragile Areas. March 14, 2024.

**Figure 2: The Different Agrivoltaics Applications**




*Source: National Renewable Energy Laboratory*

Agrivoltaics may also help address one of the most persistent challenges facing solar energy deployment: community opposition. For example, a 2022 study found strong concerns regarding solar's impact on land values and the local environment.[10] However, a more recent study found significantly less opposition when solar project proposals included agriculture.[11] More research is needed on community perceptions and priorities, but early evidence suggests that agrivoltaics can build local support by demonstrating shared economic and ecological benefits, aligning with community values, and advancing a more integrated land-use model.

[10] ScienceDirect. Sources of opposition to renewable energy projects in the United States. April 12, 2022.
[11] Energy Research & Social Science. Integrating Solar Energy with Agriculture: Industry Perspectives on the Market, Community, and Socio-Political Dimensions of Agrivoltaics. 2021.

# The Economics

Where it is able to ease local opposition, agrivoltaics has the potential to revitalize struggling small and mid-sized farms—defined as having a revenue or annual gross cash farm income (GCFI) of less than $350,000 and between $350,000 and $999,999, respectively.[12] Since 1987, the ownership of U.S. cropland has consolidated steadily, with farms between 100 and 999 acres shrinking from 57% to 33% of total cropland acreage by 2017, while large farms (2000+ acres) expanded from 15% to 41% over the same period.[13]

Between 2012 and 2017 alone, more than 100,000 small and mid-size farms transitioned out of farming.[14] Agrivoltaics offers a path forward for the non-industrial American farm. By introducing new, reliable revenue streams and ecological resilience, it can help small rural farms remain viable in a rapidly changing economy by making the most of every acre.

For specialty crop farmers, agrivoltaics unlocks a new income stream by pairing solar panels with shade-tolerant crops such as kale, lettuce, broccoli, and sweet potatoes. Solar leases range from $450-$2,500 per acre per year, with contracts lasting 25-30 years, meaning up to three decades of guaranteed income.[15] For farmers in such a volatile industry, this income stream is a key means of providing financial stability. Furthermore, contracts often stipulate that developers restore land to its prior condition, supporting its long-term agricultural value. In addition, studies show that low-density, shade-crop agrivoltaics systems have a short three-year break-even period and can increase overall farm value by 30%.[16,17]

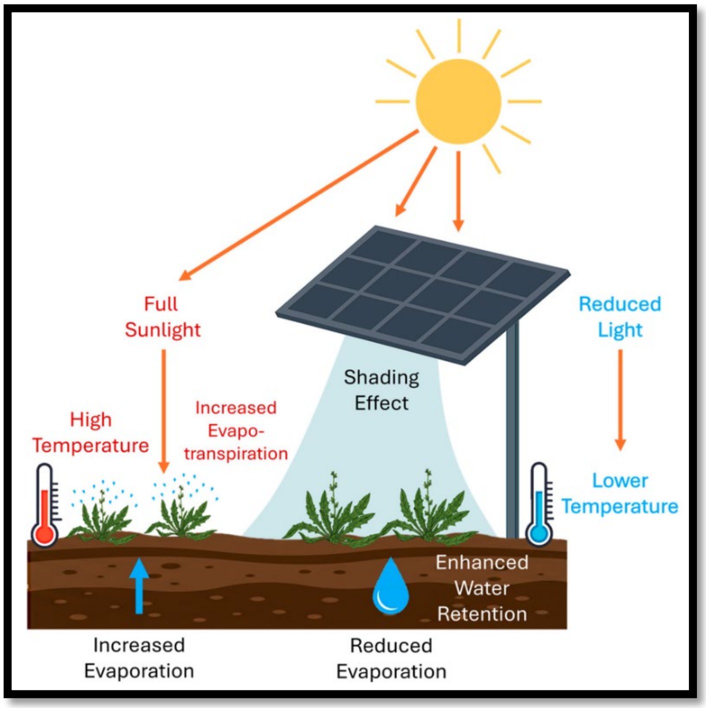
In arid regions, the benefits are even greater. In regions such as the Mountain West, where farms face harsher drought conditions, crop agrivoltaics has shown dramatically higher yields, doubling or even tripling yields from cherry tomatoes and chiltepin peppers respectively, while requiring as little as half of the normal irrigation water.[18]

On top of this, crop agrivoltaics lessens the heat stress suffered by solar panels, leading to a 2% annual generation increase.[19] By reducing heat stress and retaining soil moisture in both plants and panels, agrivoltaics reduces drought effects that impose significant costs on farmers each year. Researchers have also found that soils under solar panels are richer in organic carbon, nutrients, and

[12] United States Department of Agriculture, Economic Research Service (USDA ERS). Farm Structure and Organization. January 5, 2025.
[13] United States Department of Agriculture, Economic Research Service (USDA ERS). Consolidation in U.S. Agriculture Continues. February 3, 2020.
[14] National Sustainable Agriculture Coalition (NSAC). Examining the Latest Agricultural Census Data. March 8, 2024.
[15] Solar Land Lease. Lease Rates for Solar Farms: How Valuable Is My Land?
[16] Schweiger, Andreas H. and Lisa Pataczek. "How to Reconcile Renewable Energy and Agricultural Production in a Drying World." Plants, People, Planet. 2023, 650-661.
[17] Dinesh, H., & Pearce, J. M. The potential of agrivoltaic systems. Renewable and Sustainable Energy Reviews. 2016, 299–308.
[18] National Renewable Energy Laboratory (NREL). Agrivoltaics Research and Development Report. November 2023.
[19] Ibid.

microbial activity, leading to improved fertility while protecting against erosion and desertification.[20] In practice, this means agrivoltaics can help farms remain productive and resilient even in hotter, drier conditions, diversify revenue streams, and improve long-term value.

**Figure 3: Water Saving Benefits of Agrivoltaics**




*Source: Agrivoltaics as a Sustainable Strategy to Enhance Food Security Under Water Scarcity, Scarano et. Al.*

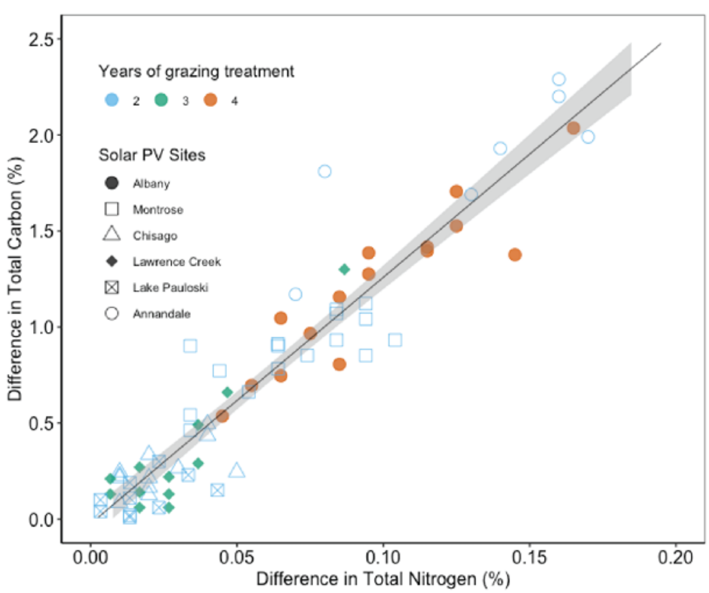
For livestock producers, grazing sheep under solar panels offers an opportunity to stack complementary enterprises. The animals benefit from shade and shelter, while developers cut one of their largest ongoing expenses—mowing and vegetation management—by up to 50%.[21] Two primary business structures illustrate how these arrangements can operate. In one model, panels are installed on existing pasture, and the landowner receives a solar lease payment while continuing to graze animals beneath the solar array. In the second model, a solar company directly contracts with a livestock farmer to bring their flock onto the site. Here, the farmer gains a new revenue stream through the grazing contract while also reducing feeding costs by utilizing the vegetation. In either structure, livestock herders typically earn between $244 and $262 per acre in net income from vegetation management.[22]

[20] Agronomy. The Early Effects of an Agrivoltaic System within a Different Crop Cultivation on Soil Quality in Dry–Hot Valley Eco-Fragile Areas. March 14, 2024.
[21] American Solar Grazing Association. Solar Grazing Practices: 2022–2023 Report. 2023.
[22] Southern Illinois University Law Journal. Renewable Energy in Illinois: The Agrivoltaics Contribution. 2024.

Managed grazing not only keeps sites clear but also improves soil health through sustainable manure cycling and reduced mechanical disturbance.[23] Recent field data (Figure 4 below) shows that solar grazing can significantly increase soil carbon and nitrogen levels over time, demonstrating measurable ecological gains in addition to farm income. In fact, sites with multiple years of grazing treatment displayed the strongest improvements, linking economic and environmental benefits in a single system.[24]

As one Wisconsin farmer put it while grazing his flock at a Dane County solar site, agrivoltaics is "a great partnership" that provides steady work for farmers, healthy forage for sheep, and cost savings for developers.[25] Among the various agrivoltaics applications, these two models stand out as the most economically viable: Crop agrivoltaics in arid, underproductive regions such as the southwest United States, where shading can boost yields while cutting water use; and solar grazing in the Midwest, where livestock integration offsets major maintenance costs, boosts farm incomes, improves soil quality, and retains key pastureland in rural regions.

**Figure 4: Positive Impact of Sheep Grazing on Soil Health at Solar Sites**




*Source: NREL*

Emerging research is also pushing the boundaries of what agrivoltaics can mean in practice. Research at the University of Minnesota is experimenting with grazing cows, traditionally believed to be too large and destructive to co-exist with photovoltaics. The research team found that with panels elevated to eight feet, cows quickly adapted, using them for shade on hot days without causing significant damage. Pasture beneath the panels recovered more quickly during the dry summer of

[23] Ibid.
[24] National Renewable Energy Laboratory (NREL). Agrivoltaics Research and Development Report. November 2023.
[25] Wisconsin Public Radio (WPR). 'A Great Partnership': Fitchburg Farm Grazing Sheep at Dane County Solar Site. September 6, 2024.

2023, with grasses like orchard grass, meadow fescue, and red clover thriving in partial shade.[26] While installation costs and farmer concerns about panel damage pose potential challenges, the University of Minnesota's five years of research suggests that cattle-solar integration can be done with little to no harm and with meaningful benefits for both animal welfare and pasture productivity.[27]

This early work highlights the potential for agrivoltaics to extend beyond sheep grazing to larger livestock. Still, more research is needed to understand long-term impacts on herd behavior, forage management, and system economics at scale. It is already clear that crop agrivoltaics in the arid West and solar grazing in the Midwest offers scalable, mutually beneficial pathways that reframe solar development as an asset—not a threat—to agriculture.

# Development Models

Realizing the full potential of agrivoltaics depends not only on the technology but also on the financial models that determine who shares the benefits. The most common approach today is the solar lease, where developers pay landowners between $450 and $2,500 per acre each year to host panels, usually guaranteed for 25 or 30 years.[28] As the farmer still has access to the land beneath the panels, they can secure two sources of income through any type of agrivoltaics system. This model is the simplest, but other development approaches may have far greater and more widespread effects. Lessons from the Midwest wind sector show that ownership structures matter.

The Community Wind North Co-op in Lake Benton, Minn., is not an agrivoltaics project, but this community-owned wind farm demonstrates how local ownership transformed renewable energy from an outside development into a genuinely local development strategy. While corporate wind farms brought lease income and tax revenue, the community-owned wind farm delivered additional, widely shared benefits. About 120 local owner-investors invested $20,000 each and earned roughly $5,000 each per year, totaling $600,000 in community profits not realized in the other ownership models.[29] Residents also described a greater sense of local accountability, community pride, and a strong identity around wind energy development.[30] There currently are no agrivoltaics cooperatives in operation, but the Lake Benton case underscores the potential power of cooperative ownership to spread revenues, build local capacity, and strengthen community buy-in. A similar cooperative ownership financial model for agrivoltaics could result in significant profits for local communities and investors alike.

In the meantime, community-scale agrivoltaics projects are beginning to fill that role, delivering shared benefits without upfront costs and demonstrating across the U.S. how agrivoltaics can extend value beyond individual farms to entire communities. One example is the 3.2-megawatt (MW) Lime

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[26] AgUpdate, Agri-View. Solar Plus Cows: Green Dairy. December 26, 2023.
[27] Journal of Dairy Science. Evaluation of Solar Photovoltaic Systems to Shade Cows in a Pasture-Based Dairy Herd. March 2021.
[28] Solar Land Lease. Lease Rates for Solar Farms: How Valuable Is My Land.
[29] Journal of Rural and Community Development (JRCD). The Vertical Patterns of Wind Energy: The Effects of Wind Farm Ownership on Rural Communities in the Prairie Pothole Region of the United States. 2018.
[30] Ibid.

Kiln solar project in Fulton, Md., developed by Chaberton Energy and Pivot Energy.[31] The project powers 500 households and businesses, with subscribers saving around 10% annually on their electricity bills while also supporting sheep grazing and 15 acres of pollinator habitat.[32] Integrating clean energy production, farm integration, and ecological restoration, the Lime Kiln project illustrates how agrivoltaics can deliver broad-based benefits that prop up a community, rather than an individual farmer. Without such inclusive structures, new cash inflows risk concentrating benefits among a few landowners—an outcome that research on wind development has shown can create divisions in rural areas.[33]

At the other end of the spectrum, some farmers are directly purchasing or financing their own solar systems, capturing the highest long-term rewards in the form of cheaper electricity, energy security, and full autonomy. However, this farmer-owned model is capital-intensive and risky, and for most small and mid-sized operations, it is only viable with targeted support such as low-interest loans, tax incentives, or rural energy grants that are currently being curtailed by federal policymakers.

While farmer-owned systems maximize independence and long-term rewards for producers, they do little to align with the needs of developers or utilities. To address this gap and encourage farmers to embrace agrivoltaics, companies are turning to partnership models that provide clear benefits to both sides. One model—solar grazing, discussed earlier—contracts livestock producers to manage vegetation with sheep, cutting costs for utilities while providing farmers with steady income. A second model offers crop farmers access to low-rent land beneath and around panels, often with fencing, parking, or equipment support included. In a 2022 survey by the National Young Farmers Coalition, 59% of young farmers reported that finding affordable land was “very or extremely challenging,” underscoring why agrivoltaics partnerships that lower land costs are especially valuable.[34]

Agrivoltaics offers distinct benefits to different groups in rural America, reaching landowners, renters, livestock producers, and crop growers, as well as the broader community. Landowners gain stable and often superior returns compared to commodity crops while preserving long-term land value. Renters, particularly beginning farmers, gain rare opportunities to access land, earn a steady income through grazing or site management, and establish a foothold in agriculture at minimal cost. Communities benefit as well, with shared projects like Lime Kiln delivering affordable energy and ecological restoration. Ultimately, agrivoltaics has the potential to significantly expand who can participate in and benefit from agriculture *and* the energy transition.

[31] PV Magazine USA. Agrivoltaic community solar facility is now operational in Maryland. July 15, 2025.
[32] Ibid.
[33] Sarah Mills. Wind Energy and Rural Community Sustainability. 2018.
[34] Agrarian Trust. “Key Findings From National Young Farmers Coalition’s 2022 Farmer Survey.” September 29, 2022.

**Figure 5: Potential Agrivoltaics Benefits by Stakeholder Group**

| Farmer Benefits | Community Benefits | Industry Benefits |
|---|---|---|
| Enhanced farm viability (economic and climate resilience) | Local food-energy resilience through distributed resources | Improved community acceptance and company reputation |
| Revenue diversification | Economic and workforce development | Savings on O&M (site-specific) |
| Maximized land use, innovative dual-uses | Reduced pressure on farmland | Increased land access |
| Water and energy savings (region-specific) | Protect cultural heritage and local interest | Maximized system co-benefits |

*Source: NREL*

## Development Barriers

Realizing agrivoltaics' potential is not without challenges. Significant barriers still limit its widespread adoption.

A recent decision by the U.S. Department of Agriculture illustrates the challenge: In August 2025, the department announced it would discontinue funding solar and wind projects through the Rural Energy for America Program (REAP). For years, REAP grants covered as much as half of the costs for these small-scale projects. Between 2023 and 2025 alone, 6,822 projects received more than $1 billion in funding, generating an estimated $2.75 billion in rural economic development and often making farmer-owned solar financially viable.[35]

At Bowers Farms in Arkansas, for example, a 455-kilowatt (kW) solar installation now saves the farm about $4,100 each month and reached a one- to two-year payback period due to REAP funding, federal tax credits, and depreciation incentives that reduced system costs by more than 90%.[36] Without REAP, small-scale projects like this likely would not be feasible.

Other obstacles can be eased, if not eliminated, via additional research and information dissemination. NREL surveys have shown consistently that farmer engagement and autonomy, as well as cross-sector collaboration between solar developers and agriculturalists, are the major hurdles for the industry.[37] Information and data sharing, both through the growing field of agrivoltaics consulting and the broader sharing of success stories, can help bridge the trust gap with farmers who remain cautious, particularly by giving farmers the tools to better understand the cost structures, site layout, and agricultural compatibility.

[35] PV Magazine. USDA announces it will discontinue funding solar projects. August 19, 2025.
[36] APC Solar. REAP Grant Success. January 2, 2024.
[37] National Renewable Energy Laboratory (NREL). Agrivoltaics Research and Development Report. November, 2023.

Institutional barriers also play a major role. Farmland projects face tough permitting battles due to public opposition, as well as persistent concerns around liability and grid interconnection. Ultimately, overcoming these challenges will require continued research, supportive policies, and raising awareness of agrivoltaics' benefits to build farmer trust and make agrivoltaics broadly viable in all forms of agriculture.

The American Farmland Trust (AFT) suggests that establishing a clear definition of agrivoltaics is the key intervention needed to scale the technology—a point also emphasized by researchers and others in the sector. A standardized definition of agrivoltaics will help spur the development of needed insurance structures as well as site- and farm-specific templates. AFT also recommends an incentive proposal that preserves agricultural function, supports flexibility, and rewards conservation.[38] There is no need to invent new incentives; just align the ones already in place, whether those are tax abatements, feed-in tariffs, or rural energy grants. Strengthening these policies will not only reduce uncertainty but also accelerate adoption, setting the stage for agrivoltaics to become a mainstream tool for rural resilience and the energy transition.

# Conclusion

Agrivoltaics demonstrates that agricultural production and solar development can be complementary rather than competing options for land use. It can stabilize farm income through long-term solar leases and grazing contracts, increase crop yields in water-stressed regions, lower operating costs for developers and farmers, and improve soil and ecosystem health.

With thoughtful design, agrivoltaics systems have the potential to redefine solar development as a tool for rural prosperity, rather than a threat to it. While barriers such as financing gaps, permitting hurdles, and the recent loss of USDA funds remain, the technology offers clear economic and ecological value when properly designed. For rural communities facing farm consolidation, rising costs, and climate stress, agrivoltaics is a viable tool in a broader strategy for resilience. With continued research, supportive policy, and adaptive financial models, it has the potential to align farmer needs, developer interests, and community priorities. In this way, agrivoltaics can contribute meaningfully to both the renewable energy transition and the long-term viability of U.S. agriculture.

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[38] American Farmland Trust (AFT). Final Policy Recommendations to Increase Agrivoltaic Development: Definition and Incentives. February 28, 2025.

# About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

# About the Author

**Asher Salkin**

Asher is currently studying agriculture and applied economics at the University of Wisconsin-Madison with a minor in sustainability and public policy. At IEEFA, Asher worked as a research intern during the summer of 2025.



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