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The New Solar Farms: Growing a Fertile Policy Environment for Agrivoltaics

By Sarah Brunswick and Danika Marzillier*

ABSTRACT

Global population growth and climate change increasingly put efforts to provide basic needs—food, water, energy, and housing—in competition with each other. One manifestation of this is the rapid development of agricultural land for urban uses or solar energy projects. Agrivoltaics have emerged as one promising way to preserve farmland while still accommodating new solar energy development. Agrivoltaics projects co-locate food crops or livestock operations with solar photovoltaics in synergistic ways. When properly designed and sited, agrivoltaics projects can simultaneously enhance crop yields, generate renewable power, conserve water, preserve agricultural lands, and bring new economic development and tax revenue to rural communities. However, a greater policy focus at the federal, state, and local level is needed to accelerate the deployment of agrivoltaics technologies across the country. This Article describes how information gaps, externality problems, and local opposition are hindering agrivoltaics development in the United States and identifies specific laws and policies capable of enabling agrivoltaics to flourish.

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INTRODUCTION

The Knowlton Farm in Grafton, Massachusetts, has been in the Knowlton family for over 150 years.[1] Despite the growing difficulties of farming in the Northeast, Paul Knowlton, the farm's current manager, loves his work and has quipped that he

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[1] Drew Pierson, *Making Solar and Agriculture Work Together*, BLUEWAVE (Nov. 26, 2019), https://bluewave.energy/bw-resources/making-solar-and-agriculture-work-together-at-knowlton-farms.

"would rather tend to his fields than take a vacation . . . "[2] Unfortunately, the Knowltons have had to increasingly let portions of their acreage fallow in recent years as cultivating it has grown increasingly unprofitable.[3]

The Knowltons' fortunes thankfully started to improve in 2015 when a solar developer installed 2.5 megawatts (MW) of solar photovoltaic capacity onsite.[4] The developer then added an additional 3.7 MW in 2017 with solar panels spanning nineteen acres that brought a new source of revenue to the Knowlton farm.[5] Members of the local community, ranging from individuals to a neighboring city government, became community solar subscribers in the project.[6] Over the project's lifetime, these subscribers will save a collective $10 million in electricity costs—with no out-of-pocket expense.[7]

When he looked to expand his farm's solar generating capacity again in 2019, Paul Knowlton opted to do so by adding ground-mounted solar panels on his land while still farming the soil below.[8] The farm's new panels are installed at least eight feet above the ground in a staggered design that provides enough direct sunlight for the crops to grow and also enables workers to access the growing crops.[9] Such innovative dual use of land—called agrivoltaics—will enable the Knowltons to continue cultivating their land and also to generate carbon-free renewable energy.[10]

Twelve acres of the new agrivoltaics project at Knowlton Farm will be used for grazing, and two additional acres will be used for food crops including strawberries, pumpkins, and leafy greens.[11] The project's bifacial panels will collect solar energy that reflects from the ground in addition to the direct sunlight

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[2] *Id.*

[3] *Id.*

[4] *Id.*

[5] *Id.*; Bruce Gellerman, *Farms Will Harvest Food and the Sun, as Mass. Pioneers 'Dual-Use' Solar*, WBUR (Nov. 10, 2020), https://www.wbur.org/news/2020/11/10/dual-use-solar-farms-agrivoltaics-massachusetts.

[6] Pierson, *supra* note 1.

[7] *Id.*

[8] Pierson, *supra* note 1; Gellerman, *supra* note 5.

[9] Gellerman, *supra* note 5.

[10] *Id.* Agrivoltaics has also been called agriphotovoltaics (APV).

[11] Tina Casey, *After COVID-19, Here Comes More & Better Farming with Solar Panels*, CLEANTECHNICA (Apr. 9, 2020), https://cleantechnica.com/2020/04/09/after-covid-19-here-comes-more-better-farming-with-solar-panels/.

from above.[12] By the time the project is fully operational in 2024, the Knowltons will once again harvest crops from land that has been fallow for twenty years.[13] Meanwhile, younger generations within the Knowlton family are increasingly showing interest in continuing the family farm well into the future.[14]

Projects like the one at Knowlton Farm are appearing across the United States as farmers begin to recognize agrivoltaics' promising potential. In Maine, a wild blueberry farm now hosts a project with 4.2 MW in solar generating capacity spread over ten acres.[15] Most such projects today still involve a research component as farmers and solar developers work with their land-grant university's farm extension programs to gather and generate data to aid further agrivoltaics development.[16] As one Maine official commented, these projects "help support . . . heritage industries, expand clean energy generation, and create new economic opportunities."[17]

Agrivoltaics technologies are emerging at a crucial time for agricultural lands across the United States. Global population growth and climate change are increasingly putting basic human needs—food, water, energy, and housing—in competition with one another.[18] Rising temperatures, severe weather events, and worsening drought conditions due in part to climate change

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[12] Gellerman, *supra* note 5.

[13] Pierson, *supra* note 1. The panels have been installed, and agricultural operations will be fully underway by 2024. *See* Meg Wilcox, *Solar Solutions: Clean Energy, Climate Resilience, and Conservation on U.S. Farmland*, LINCOLN INST. OF LAND POL'Y (Jan. 19, 2022), https://www.lincolninst.edu/publication/articles/2022-01-solar-solutions-us-farmland ("In a year or two, . . . Knowlton Farm will produce not only hay, but berries, pumpkins, leafy greens, and grass-fed beef. . . .").

[14] Pierson, *supra* note 1.

[15] *BlueWave Solar Announces Sale of Innovative Maine Agrivoltaic Solar Project to Navisun,* CISION PR NEWSWIRE (Mar. 25, 2021), https://www.prnewswire.com/news-releases/bluewave-solar-announces-sale-of-innovative-main-agrivoltaic-solar-project-to-navisun-301255414.html [hereinafter *BlueWave Solar Announces Sale*].

[16] *Id.* ("We will be closely monitoring soil quality and moisture in addition to crop production throughout the course of our work in hopes of ultimately creating a new playbook for today's wild blueberry farmer."); Casey, *supra* note 11.

[17] *BlueWave Solar Announces Sale*, *supra* note 15.

[18] Jessica Forcello, *BlueWave and Navisun Celebrate 4.2 MW Agrivoltaic Solar Project on Maine Wild Blueberry Farm*, BLUEWAVE (Nov. 10, 2021), https://bluewave.energy/bw-resources/bluewave-and-navisun-celebrate-4-2-mw-agrivoltaic-solar-project-on-maine-wild-blueberry-farm.

all threaten agriculture and the nation's food and water supplies.[19] The U.S. agricultural industry is facing growing pressure to reduce its water consumption and its broader environmental impacts, but it remains critically necessary to the country's survival.[20]

Renewable energy technologies have a vital role to play in fighting climate change and limiting its ill effects on humankind.[21] Renewable energy development can also create new jobs, promote energy independence, expand energy access, and reduce energy bills.[22] President Biden has characterized the clean energy transition as an opportunity "to build a modern and sustainable infrastructure" and "deliver an equitable, clean energy future," with the goal of achieving "net-zero emissions, economy-wide" by 2050.[23] State governments across the country are requiring utilities to rapidly transition to a more renewable energy mix,[24] and some communities have already successfully converted to using 100% renewable sources.[25] As of 2020, renewable energy sources accounted for roughly 20% of

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[19] *Climate Change and Agriculture*, UNION OF CONCERNED SCIENTISTS (Mar. 20, 2019), https://www.ucsusa.org/resources/climate-change-and-agriculture.

[20] *Cf.* Diana Kruzman, *US Southwest, Already Parched, Sees "Virtual Water" Drain Abroad*, GRIST (June 5, 2021), https://grist.org/agriculture/u-s-southwest-already-parched-sees-virtual-water-drain-abroad/ (describing one area of criticism of industrial agriculture in the U.S., the practice of exporting crops and the water within to foreign countries), *with* Courtney Lindwall, *Industrial Agricultural Pollution 101*, NAT. RES. DEF. COUNCIL (July 21, 2022), https://www.nrdc.org/stories/industrial-agricultural-pollution-101 (detailing a particular problem with industrial agriculture, how agriculture contaminates the environment).

[21] *See* UNITED NATIONS, AFFORDABLE AND CLEAN ENERGY: WHY IT MATTERS (2018), https://www.un.org/sustainabledevelopment/wp-content/uploads/2018/09/Goal-7.pdf.

[22] Christina Nunez, *Renewable Energy, Explained*, NAT'L GEOGRAPHIC (Jan. 30, 2019), https://www.nationalgeographic.com/environment/article/renewable-energy.

[23] Exec. Order No. 14,008, 3 C.F.R. 477 (2022).

[24] *Renewable Energy Explained: Portfolio Standards*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/renewable-sources/portfolio-standards.php (last visited Nov. 7, 2022).

[25] *See, e.g.*, *Burlington: 100% Renewable Electricity City*, CDP, https://www.cdp.net/en/articles/cities/burlington-100-renewable-electricity-city (last visited Nov. 7, 2022).

electricity generation nationwide,[26] and the nation will need to continue its rapid pace of renewable energy development to achieve its goal of 100% clean energy by 2050.[27]

Unfortunately, today's most promising and cost-effective renewable energy strategy—large-scale solar photovoltaic projects—necessitates a large land footprint.[28] Rather than clearing undeveloped land,[29] solar project developers are increasingly seeking to build projects on large parcels of rural developed land, much of which is farm- and rangeland.[30] For the many farmers confronting severe economic pressures, solar energy developers' offers to purchase or lease land can be difficult to refuse. Meanwhile, some rural communities are resisting the influx of solar energy projects as a threat to their agrarian way of life.[31]

Agrivoltaics projects offer one potential means to preserve the nation's precious agricultural lands while also growing the nation's solar energy generating capacity. The ground-mounted solar panels in agrivoltaics projects shade crops, shelter them from the elements, and reduce their water demand, while the crops help cool the panels and thereby increase their productive efficiency.[32] Farmers with agrivoltaics projects can often generate new electricity and water savings without sacrificing crop yields, and the communities hosting these projects also benefit from new economic development and the preservation of

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[26] *How Much of U.S. Energy Consumption and Electricity Generation Comes from Renewable Sources?*, U.S. ENERGY INFO. ADMIN. (May 13, 2022), https://www.eia.gov/tools/faqs/faq.php?id=92&t=4.

[27] In addition to the Biden administration, twelve states have put forth this goal. U.S. ENERGY INFO. ADMIN., *supra* note 24.

[28] *See generally* Dave Merrill, *The U.S. Will Need a Lot of Land for a Zero-Carbon Economy*, BLOOMBERG (June 3, 2021), https://www.bloomberg.com/graphics/2021-energy-land-use-economy/ (showing that solar requires roughly eighteen times more land than coal to power a 100-watt television year-round).

[29] JOCELYN DURKAY & JENNIFER SCHULTZ, THE ROLE OF FORESTS IN CARBON SEQUESTRATION AND STORAGE (2016); A. M. Nahlik & M. S. Fennessy, *Carbon Storage in US Wetlands*, NATURE COMMC'NS, Dec. 13, 2016, at 1.

[30] Jonathan Foley, *A Five-Step Plan to Feed the World*, NAT'L GEOGRAPHIC, https://www.nationalgeographic.com/foodfeatures/feeding-9-billion/ (last visited Nov. 7, 2022).

[31] *E.g.*, *Rural Communities Push Back Against Solar Projects in Nevada*, AP NEWS (Nov. 30, 2021), https://apnews.com/article/business-environment-and-nature-las-vegas-nevada-environment-0c60ff102480ab06eac6cd0f13ade567.

[32] Greg A. Barron-Gafford et al., *Agrivoltaics Provide Mutual Benefits Across the Food-Energy-Water Nexus in Drylands*, 2 NATURE SUSTAINABILITY 848, 852 (2019).

vital farmland.[33] Large-scale agrivoltaics projects can even feed excess electricity into the local grid, providing new revenue streams for farmers and shoring up the grid resiliency in rural areas.[34] Unfortunately, agrivoltaics are currently more expensive than traditional ground-mounted solar projects, and much work remains to be done to understand how to optimally site and design these projects and to build support for them among farmers and host communities.

This Article highlights the great potential for agrivoltaics to advance food, energy, and water security in the United States; describes obstacles that presently limit the growth of these technologies; and identifies policy strategies capable of accelerating agrivoltaics growth across the country. Part I of this Article describes challenges facing the U.S. solar and agricultural industries and explains how agrivoltaics could potentially address many of these challenges. Part II frames the primary barriers to agrivoltaics' growth, including an underdeveloped body of scientific and technical knowledge about them, externality problems that deter optimal levels of investment in agrivoltaics technologies, and the reluctance of many rural communities to host agrivoltaics projects. Part III then identifies specific policy strategies that have effectively addressed similar barriers in the renewable energy and agricultural industries and could similarly accelerate agrivoltaics development across the country.

I. SOLAR SYNERGIES: THE GROWING POTENTIAL OF AGRIVOLTAICS

Climate change is increasingly compelling policymakers to confront the complex challenge of reducing greenhouse gas emissions while preserving water and food security on a warming planet. For example, chronic drought conditions in the Southwestern United States are requiring state governments in that region to adopt unprecedented measures to preserve water

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[33] *See* Kyle W. Proctor et al., *Agrivoltaics Align with Green New Deal Goals While Supporting Investment in the US' Rural Economy*, 13 SUSTAINABILITY 137, 7–9 (2021).

[34] *See Largest Agrivoltaic Research Project in U.S. Advances Renewable Energy While Empowering Local Farmers*, SOLAR POWER WORLD (June 10, 2021), https://www.solarpowerworldonline.com/2021/06/largest-agrivoltaic-research-project-in-u-s-advances-renewable-energy-while-empowering-local-farmers/.

supplies without unduly harming agricultural production or other water uses. Such challenges are likely to only intensify as the global population grows toward a projected 9.1 billion by 2050, with nearly 400 million living in the United States.[35] Although it is unclear how much global food production will need to increase to meet this rising demand, those required increases are likely to be substantial.[36] Unfortunately, the nation's agricultural land is increasingly being converted to other land uses such as residential or energy development.[37] As municipalities and farmers compete over increasingly scarce water resources, water systems designed primarily for agriculture are likewise being stretched like never before.[38] America's farmers are finding themselves at the epicenter of these tensions as the country struggles to transition to low-carbon energy sources and to adapt to the realities of a changing climate. The following materials highlight how solar energy development and agricultural land uses have clashed in recent years and how agrivoltaics offer one possible means of addressing these challenges.

A. Solar Energy Growth and Intensifying Competition for Rural Land

Solar photovoltaics ("PVs") are the fastest growing energy technology in the United States and are expected to meet 20 to 29% of the global electricity demand by 2100.[39] Panels comprised

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[35] JONATHAN VESPA ET AL., DEMOGRAPHIC TURNING POINTS FOR THE UNITED STATES: POPULATION PROJECTIONS FOR 2020 TO 2060 4 tbl.2 (2020).

[36] *See High Level Expert Forum-How to Feed the World in 2050*, AGRIC. DEV. ECON. DIV. (Oct. 12, 2009), https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf; Mitchell C. Hunter et al., *Agriculture in 2050: Recalibrating Targets for Sustainable Intensification*, 67 BIOSCIENCE 386, 386 (2017) (disputing common claim that 100% increase in food production is necessary).

[37] *See generally* JULIA FREEGOOD ET AL., FARMS UNDER THREAT: THE STATE OF THE STATES 3 (2020) ("Between 2001 and 2016, 11 million acres of farmland and ranchland were converted to urban and highly developed land use (4.1 million acres) or low-density residential land use (nearly 7 million acres). That's equal to all the U.S. farmland devoted to fruit, nut, and vegetable production in 2017. . . .").

[38] Matthew Brodahl & William A. Shutkin, *Exactly the Right Amount: Water Efficiency, Population Growth, and Climate Change*, 14 U. DENVER WATER L. REV. 337, 339–40 (2011).

[39] Chong Seok Choi et al., *Effects of Revegetation on Soil Physical and Chemical Properties in Solar Photovoltaic Infrastructure*, 8 FRONTIER ENV'T SCI., Aug. 11, 2020, at 1.

of numerous PV cells are usable in residential, commercial, and utility scale projects.[40] Utility-scale projects account for much of the United States' existing and projected solar generating capacity, with over 37,000 MW of existing operating capacity as of early 2022 and another 112,000 MW in development.[41] Solar development's explosive growth can be attributed in part to policies at all levels of government that encourage private solar investment by strengthening economic incentives for development and reducing soft costs.[42]

Although the growth of solar is helping the United States transition to a cleaner and more sustainable energy system, it is also placing new pressure on the nation's limited land resources. Energy sprawl—the expanding land footprint occupied by the nation's energy system—is a growing concern.[43] The pace of energy development today far exceeds that of urban or residential development.[44] In Massachusetts, a state with aggressive renewable energy policies, utility-scale solar arrays were responsible for 25% of new land development between 2012 and 2017.[45] Notably, 25% of that newly developed land was formerly cropland.[46] Based on current projects, reaching Massachusetts's 2050 energy goals using existing renewable

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[40] ALAN GOODRICH ET AL., RESIDENTIAL, COMMERCIAL, AND UTILITY-SCALE PHOTOVOLTAIC (PV) SYSTEM PRICES IN THE UNITED STATES: CURRENT DRIVERS AND COST-REDUCTION OPPORTUNITIES (2012).

[41] *Utility-Scale Solar*, SOLAR ENERGY INDUS. ASS'N, https://www.seia.org/initiatives/utility-scale-solar-power (last visited Feb. 5, 2022).

[42] For a description of successful solar incentives, see *Renewable Energy Explained: Incentives*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/renewable-sources/incentives.php (Nov. 20, 2020).

[43] MOLLY F. SHERLOCK, CONG. RSCH. SERV., R43452, THE RENEWABLE ELECTRICITY PRODUCTION TAX CREDIT: IN BRIEF (Apr. 29, 2020); *Organic Certification Cost Share Program (OCCSP)*, U.S. DEPT. OF AGRIC. FARM SERV. AGENCY, https://www.fsa.usda.gov/programs-and-services/occsp/index (last visited Oct. 15, 2021). To be carbon-free by 2050, the U.S. would need approximately 385,580 mi^2. Merrill, *supra* note 28.

[44] *See Organic Certification Cost Share Program*, *supra* note 43, at 1 (reporting that energy development in the US is occurring at "more than double the historic rate of urban and residential development").

[45] MASS AUDUBON, LOSING GROUND: NATURE'S VALUE IN A CHANGING CLIMATE 29 (2020), https://www.massaudubon.org/content/download/41477/1007612/file/Losing-Ground-VI_2020_final.pdf.

[46] Lisa Held, *Can Land Conservation and Dual-Use Solar on Farms Coexist?*, CIVIL EATS (June 29, 2021), https://civileats.com/2021/06/29/can-land-conservation-and-dual-use-solar-on-farms-coexist/amp/.

technologies could require another 150,000 acres of land.[47] Government efforts to install more solar on public lands, such as the Obama Administration's effort to open millions of acres of land in the Mojave Desert for solar energy development, also entail environmental costs.[48] While solar energy's land footprint today remains small relative to that of the nation's petroleum industry,[49] there are growing concerns about the potential harms of converting much more of the country's undeveloped land and farmland into solar projects.[50] Although PV panels can be mounted on the rooftops of existing structures,[51] most larger-scale solar PV projects involve the ground-mounting of panels over gravel or dirt lots.[52] This has historically made utility-scale solar development incompatible with other land uses.[53]

Limited land availability is increasingly prompting solar developers to seek to site projects on agricultural land. Utility-scale solar PV projects on undeveloped lands typically require the costly removal of native vegetation, land grading, and topsoil stripping,[54] which also contributes to heat islands, soil disturbances, and habitat loss.[55] By contrast, existing agricultural lands are often already relatively flat, unshaded, and designed for good drainage, making them an attractive

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[47] *See id.*; MASS AUDUBON, *supra* note 45, at 3.

[48] Adam Wilson, *The Future Looks Bright, or Does It? An Analysis of Solar Energy Law and Policy*, 22 J. ENV'T & SUSTAINABILITY L. 333, 344 (2016).

[49] SHERLOCK, *supra* note 43, at 3.

[50] *Id.*

[51] GOODRICH ET AL., *supra* note 40, at 4. Both rooftop and ground-mounted PV can be either fixed, i.e., stationary, or tracking, i.e., able to follow the sun. Jacob Marsh, *Solar Tracking Systems*, ENERGYSAGE (last visited Feb. 19, 2021), https://news.energysage.com/solar-trackers-everything-need-know/.

[52] PEGGY KIRK HALL ET AL., U.S. DEP'T OF AGRIC., FARMLAND OWNER'S GUIDE TO SOLAR LEASING (2019), https://farmoffice.osu.edu/sites/aglaw/files/site-library/Farmland_Owner's_Guide_to_Solar_Leasing.pdf.

[53] Teodoro Semeraro et al., *Planning Ground Based Utility Scale Solar Energy as Green Infrastructure to Enhance Ecosystem Services*, 117 ENERGY POL'Y 218 (2018); Jessica Owley & Amy Wilson Morris, *The New Agriculture: From Food Farms to Solar Farms*, 44 COLUM. J. ENV'T L. 409 (2019).

[54] *See generally* BRENDA BEATTY ET AL., NAT'L RENEWABLE ENERGY LAB., NATIVE VEGETATION PERFORMANCE UNDER A SOLAR PV ARRAY AT THE NATIONAL WIND TECHNOLOGY CENTER 1 (2017).

[55] *See generally* JORDAN MACKNICK ET AL., NAT'L RENEWABLE ENERGY LAB., OVERVIEW OF OPPORTUNITIES FOR CO-LOCATION OF SOLAR ENERGY TECHNOLOGIES AND VEGETATION (2013); Barron-Gafford et al., *supra* note 32.

option for solar projects.[56] Farmland is often also relatively well-situated for transmission line access and is abundant in much of the country,[57] comprising over half of the country's total land.[58] Developing solar projects on agriculturally-zoned land likewise typically involves fewer permitting obstacles and tends to create fewer conflicts with cultural resources or threatened or endangered species than undeveloped land.[59] Moreover, negotiating solar leases with private landowners is often faster and easier than the laborious process of leasing federal or state lands.[60] Even securing land use approvals from municipal officials tends to be less difficult than navigating the permitting and environmental review requirements associated with solar leasing on federal public land.[61]

Although the accelerating conversion of agricultural land to solar energy uses can bring economic benefits to rural regions, in some instances this land conversion can also have disproportionate adverse effects on impoverished communities.[62] For this reason and others, even as the demand for large-scale solar increases, proposed solar energy projects on formerly agricultural lands often encounter significant local resistance.[63] Because solar development can be profitable for farmers and developers alike,[64] farmers are increasingly opting

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[56] KELSEY HOROWITZ ET AL., NAT'L RENEWABLE ENERGY LAB'Y, CAPITAL COSTS FOR DUAL–USE PHOTOVOLTAIC INSTALLATIONS: 2020 BENCHMARK FOR GROUND-MOUNTED PV SYSTEMS WITH POLLINATOR-FRIENDLY VEGETATION, GRAZING, AND CROPS (2020).

[57] HALL ET AL., *supra* note 52, at 4.

[58] Merrill, *supra* note 28; *see also* Foley, *supra* note 30 (showing agricultural land as almost 40% of global ice-free land and roughly 70% of developed land).

[59] *See* Owley & Morris, *supra* note 53, at 425–26 ("Agricultural land is of interest to PV solar developers due to its level terrain, existing land disturbance, decreased likelihood of hosting species of concern, and proximity to transmission lines or substations.").

[60] *Id.* at 426.

[61] *Id.*

[62] Owley & Morris, *supra* note 53, at 424–25.

[63] Alexis S. Pascaris et al., *Integrating Solar Energy with Agriculture: Industry Perspectives on the Market, Community, and Socio-political Dimensions of Agrivoltaics*, 75 ENERGY RSCH. & SOC. SCI. 1 (2021).

[64] *See* KATIE SIEGNER ET AL., MAXIMIZING LAND USE BENEFITS FROM UTILITY-SCALE SOLAR: A COST-BENEFIT ANALYSIS OF POLLINATOR-FRIENDLY SOLAR IN MINNESOTA 18 (2019) ("The monetary value of the private and social benefits for conventional solar is 30 times greater than that of a corn farm and 160 times greater than that of a soy farm[,]" and "[t]he monetary value of the

to sell land to solar developers.[65] However, agricultural communities concerned about potential broader impacts of this new form of development are increasingly hesitant to welcome large solar projects.[66]

B. Mounting Pressures on American Farmers

The U.S. farming industry has long enjoyed substantial government support and is highly profitable today,[67] but many smaller farms have faced severe economic and other challenges in recent years. For a variety of reasons, small and mid-sized farms—farms that play a crucial role in the country's food production and in the economic stability of rural communities—are often susceptible to the new difficulties presented by climate change and growing competition for land. As climate change increases temperatures, it also increases heat stress that can further tax food crops and field workers.[68] These and other challenges are causing many smaller farms to struggle in new and threatening ways.

1. Climate Change and Urban Sprawl

Climate change presents newfound challenges for farmers, as chronic drought conditions increasingly plague some of the nation's most productive growing areas.[69] Worsening droughts

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private and social benefits for a pollinator-friendly solar project is 32 times than that of a corn farm and 184 times greater than that of a soy farm.").

[65] *See* Gellerman, *supra* note 5. A quarter of Massachusetts farmland and forests have been converted to ground-mounted solar arrays. *Id.* (amounting to 6,000 acres). A 2020 study found that "meeting the state's [renewable energy] targets could require clearing up to an additional 150,000 acres." *Id.*; *see also* MASS AUDUBON, *supra* note 45.

[66] *See* Ellen Rosen, *As Demand for Green Energy Grows, Solar Farms Face Local Resistance*, N.Y. TIMES (Nov. 2, 2021), https://www.nytimes.com/2021/11/02/business/solar-farms-resistance.html ("[L]ocals are fighting back against what they see as an encroachment on their pastoral settings, the loss of agricultural land and a decline in property values.").

[67] *Farm Sector Income & Finances: Highlights from the December 2021 Farm Income Forecast*, U.S. DEP'T OF AGRIC. (Dec. 1, 2021), https://www.ers.usda.gov/topics/farm-economy/farm-sector-income-finances/highlights-from-the-farm-income-forecast/ (reporting that net farm income increased by $15.7 billion year-over-year in 2020 and is forecasted to increase by another $22.0 billion in 2021).

[68] ELLEN HANAK ET AL., WATER AND THE FUTURE OF THE SAN JOAQUIN VALLEY 3 (2019).

[69] NAT'L RENEWABLE ENERGY LAB., *Benefits of Agrivoltaics Across the Food-Energy-Water Nexus*, NREL (Sept. 11, 2019), https://www.nrel.gov/news/pr

coupled with growing municipal water demand have stressed water supplies in states like California and led to more stringent water conservation laws.[70] Stress on surface and groundwater supplies is requiring many communities to augment their water supplies or search for ways to reduce water consumption.[71] Farmers are among the first to feel these effects and many are already being forced to decrease their water usage.[72] For example, California's San Joaquin Valley—one of the country's most productive growing regions—will need to take more than half a million acres out of agricultural production to meet the requirements of the State's Groundwater Management Act.[73] Unfortunately, taking land out of food production not only weakens food security;[74] it can also lead to problems with dust, invasive species, and nutrient depletion.[75]

The agricultural industry is also facing pressure from urban sprawl, which further contributes to farmland conversion.[76] From 2001 to 2016, 11 million acres of domestic agricultural land were paved over, fragmented, or converted to uses that

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ogram/2019/benefits-of-agrivoltaics-across-the-food-energy-water-nexus.html ("Across the globe, reductions in precipitation and rising air temperatures are increasing vulnerabilities in both the agricultural and energy sectors. Water scarcity concerns are shaping conversations and driving action in the agricultural sector while extreme weather events are impacting energy systems worldwide.").

[70] HANAK ET AL., *supra* note 68, at 3.

[71] *Id.*

[72] *Sustainable Farm Agrivoltaic*, OR. STATE UNIV., https://agsci.oregonstate.edu/newsroom/sustainable-farm-agrivoltaic (last visited Jan. 1, 2022); *see, e.g.*, Stephen Robert Miller, *Extreme Drought Creates Unlikely Farming Allies in the Arizona Desert*, NAT'L GEOGRAPHIC (Jan. 28, 2022), https://www.nationalgeographic.com/environment/article/extreme-drought-creates-unlikely-farming-allies-in-the-arizona-desert ("[T]he United States Bureau of Reclamation will slash the amount of river water most central Arizona growers receive in 2022 by more than half—and eliminate it entirely in 2023.").

[73] Sammy Roth, *California Farmers are Planting Solar Panels as Water Supplies Dry Up*, L.A. TIMES (July 31, 2019), https://www.latimes.com/business/la-fi-agriculture-farmlands-solar-power-20190703-story.html?msclkid=03818b24aef111eca5a94ed617b808cc ("Agricultural water use exceeds likely sustainable supplies [in California's San Joaquin Valley] by nearly 2 million acre-feet per year or 11% of net water use.").

[74] *Sustainable Farm Agrivoltaic*, *supra* note 72.

[75] HANAK ET AL., *supra* note 68, at 3.

[76] *Welcome to Farms Under Threat: The State of the States*, AM. FARMLAND TR., https://csp-fut.appspot.com/ (last visited Sept. 16, 2021).

jeopardize agriculture.[77] Land scarcity near developed areas drives up lease rates, making the leasing of land an attractive option for farmers struggling to make ends meet.[78] These pressures can be especially palpable in rural communities, which face ongoing economic stagnation[79] with more than 22% of children living in poverty.[80] As the nation's farmer population ages and such economic disparities continue to grow, small farmers are increasingly getting pinched out of the market.[81]

2. Agricultural Subsidies' Role in Pushing Out Small and Mid-Sized Farms

Because of agriculture's social value and the volatility of agricultural commodity markets, the U.S. agricultural industry has long been heavily dependent on various forms of federal government support.[82] In particular, federal subsidies and price supports help to protect farmers from fluctuations in prices, revenues, and yields, encourage conservation efforts, and provide support for marketing, exports, research, and other activities.[83]

With U.S. agricultural subsidies reaching an all-time high in 2020, the federal government has the power to greatly influence agricultural activities.[84] That year, farmers received $45.5 billion in subsidies, of which $31.4 billion was dedicated to disaster programs (including COVID-19 relief) and $3.8 billion

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[77] *Id.*

[78] FRAUNHOFER INST. FOR SOLAR ENERGY SYS. ISE, AGRIVOLTAICS: OPPORTUNITIES FOR AGRICULTURE AND THE ENERGY TRANSITION 4–5 (2020).

[79] J. PENDER ET AL., U.S. DEPT. OF AGRIC., RURAL AMERICA AT A GLANCE, 2019 EDITION (2019).

[80] Tracey Farrigan & Dennis Vilorio, *Poverty Rates in 2017 Were Highest for Children, Particularly Among Those Living in Rural Areas*, U.S. DEP'T OF AGRIC. ECON. RSCH. SERV, https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=95298 (last visited Nov. 7, 2022).

[81] Liz Carlisle et al., *Securing the Future of US Agriculture: The Case for Investing in New Entry Sustainable Farmers*, 7 ELEMENTA SCI. ANTHROPOCENE, 2019, at 1, 7.

[82] *See generally* Nathan R.R. Watson, *Federal Farm Subsidies: A History of Government Control, Recent Attempts at a Free Market Approach, The Current Backlash, and Suggestions for Future Action*, 9 DRAKE J. AGRIC. L. 281, 286–92 (2005).

[83] Chris Edwards, *Agricultural Subsidies*, DOWNSIZING THE FED. GOV'T (Apr. 16, 2018), https://www.downsizinggovernment.org/agriculture/subsidies.

[84] *See Government Payments by Program*, U.S. DEP'T OF AGRIC. ECON. RSCH. SERV., https://data.ers.usda.gov/reports.aspx?ID=17833 (last visited Feb. 4, 2022) (reporting from 1933).

to conservation programs.[85] Another $10 billion went to programs that predominately rely on traditional crop-based subsidies, which favor crops such as corn and soy.[86] USDA direct payments comprised 39% of on-farm revenue—the largest share in twenty years.[87] Collectively, these subsidy programs mitigate farmers' risks but can also disincentivize crop diversity and inflate land prices.[88]

Notably, most of the heavy federal subsidies earmarked for farmers go to large corporate farming operations, making it even more difficult for many smaller farms to remain profitable. Only about 31% of farmers—the majority of which own large, specialized farming operations—reported using subsidies in the USDA's most recent Census of Agriculture.[89] Meanwhile, nearly 90% of farms bring in less than $350,000 each year,[90] and over half of farmers typically report losses that require them to rely on off-farm sources of income.[91] As farmers increasingly base economic decisions on subsidy programs and land prices, large farms continue to grow and small- and mid-sized farming operations become increasingly less common.[92] Given the worsening impacts of climate change and mounting pressures on

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[85] *Id.*; *see generally* CONG. RSCH. SERV., R40763, AGRICULTURAL CONSERVATION: A GUIDE TO PROGRAMS (2020) (listing conservation subsidy programs).

[86] *See id.*; Edwards, *supra* note 83.

[87] RANDY SCHNEPF & STEPHANIE ROSCH, CONG. RSCH. SERV., R46676, U.S. FARM INCOME OUTLOOK: DECEMBER 2020 FORECAST 9 (2021).

[88] Lori Sanders, *The Shrinking Market of Midsized Farms*, R ST. SHORTS, Sept. 2016, at 3.

[89] *See* U.S. DEP'T OF AGRIC. & NAT'L AGRIC. STATS. SERV., 2017 CENSUS OF AGRICULTURE: U.S. SUMMARY AND STATE DATA 16 tbl.5 (2019), https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf [hereinafter 2017 CENSUS OF AGRICULTURE].

[90] *Farming and Farm Income*, U.S. DEP'T OF AGRIC. ECON. RSCH. SERV., https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/farming-and-farm-income/ (last visited Dec. 1, 2022).

[91] *Id.*; 2017 CENSUS OF AGRICULTURE, *supra* note 89, at 16 tbls.5–6 (reporting 56% of farms having net losses in 2017 and 54% in 2012). In 2019, 3.2% of farms accounted for 51% of the total value of United States' agricultural production. Carlisle et al., *supra* note 81, at 3.

[92] *Bigger Farms, Bigger Problems*, UNION OF CONCERNED SCIENTISTS (Apr. 14, 2021), https://www.ucsusa.org/resources/bigger-farms-bigger-problems ("[L]arge crop farms are getting larger, small crop farms are getting smaller, and midsize crop farms are disappearing.").

farmers to convert or consolidate farmland,[93] additional policy action will likely be needed to enable the next generation of farms and ranches to be sustainable and economically viable.[94]

C. Agrivoltaics as a Potential Win-Win for Agriculture and Solar Energy

In recent years, agrivoltaic technologies have emerged as one potential strategy for increasing solar energy development and preserving small- and mid-sized farms in the face of unprecedented challenges. Agrivoltaics projects co-locate food crops or livestock with ground-mounted solar PV in a manner that simultaneously allows for energy production and continued agricultural activities.[95] While co-location of solar panels and agriculture is a relatively new concept, the technologies involved are already well-established. Agrivoltaics projects are innovative in the ways that they place panels and plant species into specific design schemes to optimize land-use efficiency. When designed and sited effectively, agrivoltaics projects can result in enhanced crop yields, greater energy production, lower water demand, reduced carbon emissions, and new economic development and tax revenue for rural communities.[96] Hence, agrivoltaics defy the traditional narrative that land-use conflicts between energy and food production are inherently a zero-sum game.[97] Agrivoltaics can simultaneously create environmental, economic, educational, and recreational benefits at multiple

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[93] *See* FREEGOOD ET AL., *supra* note 37, at 6 ("When farms and ranches consolidate or go out of business, it becomes harder for the remaining operations to thrive.").

[94] *Id.* ("States need policies to support agricultural viability and to facilitate the transfer of land to a new, more diverse generation of farmers and ranchers.").

[95] U.S. DEPT. OF AGRIC. FARM SERV. AGENCY, CONSERVATION RSRV. PROGRAM (2019), https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/2019/conservation-reserve_program-fact_sheet.pdf; Emiliano Bellini, *Where Appropriate, Agrivoltaics Can Certainly Be a Viable and Meaningful Alternative to Large-Scale Solar*, PV MAG. (June 11, 2021), https://www.pv-magazine.com/2021/06/11/where-appropriate-agrivoltaics-can-certainly-be-a-viable-and-meaningful-alternative-to-large-scale-solar/.

[96] David Wagman, *Could Agrivoltaics Feed Our Demand for Clean Energy?*, PV MAG. (Jan. 6, 2021), https://pv-magazine-usa.com/2021/01/06/could-agrivoltaics-feed-our-demand-for-clean-energy/.

[97] *See* Barron-Gafford et al., *supra* note 32, at 285.

scales.[98] First conceived in Japan in the early 2000s,[99] agrivoltaics' installed peak capacity reached 2.8 GW globally in 2020.[100] Domestically, agrivoltaic pilot projects are operating in several states, with more projects on the horizon. Although most existing agrivoltaics projects were installed in conjunction with public universities, the concept is also gaining interest within the private sector.

1. Agrivoltaics' Multiple Benefits

Early projects have demonstrated agrivoltaics' potential to increase land-use efficiency through distinct practical, economic, and community benefits. Among other things, agrivoltaics can improve crop yields, conserve water, and enhance solar panel efficiency. Agrivoltaics projects can also benefit farmers economically through dual-revenue streams and higher crop yields. An emerging body of research suggests that farmers and solar developers across the United States may benefit from the synergies that agrivoltaics provide. By benefiting individual farms, agrivoltaics can also potentially revitalize struggling rural communities, improve food security, and accelerate the nation's transition to a sustainable, carbon-free energy system.

a. On-Farm

In a variety of settings, farmers can increase their overall profitability by installing solar PV over their crops. Solar panels provide shading to plants, which can decrease both water demand and heat stress.[101] PV panels also provide physical protection to plants from inclement weather. Accordingly,

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[98] Semeraro et al., *supra* note 53, at 225.

[99] Stephan Schindele et al., *Implementation of Agrophotovoltaics: Techno-Economic Analysis of the Price-Performance Ratio and its Policy Implications*, 265 APPLIED ENERGY 1 (2020).

[100] FRAUNHOFER INST. FOR SOLAR ENERGY SYS., *supra* note 78. One successful example includes an agrivoltaics installation in a rural Chilean community, where an off-grid project is seeing positive results for both agriculture and electricity generation—despite a hotter, drier climate, a lot of sun, and less wind. *Agrivoltaics—Solar Panels on Top, Potatoes Down Below*, EN:FORMER (Nov. 22, 2019), https://www.en-former.com/en/agrivoltaics/.

[101] Cookson Beecher, *Power Food – Agrivoltaics Scores Impressive Triple Win, But Some Food Safety Concerns Remain*, FOOD SAFETY NEWS (Mar. 22, 2021), https://www.foodsafetynews.com/2021/03/agrivoltaics-scores-impressive-triple-win-but-some-food-safety-concerns-remain/ ("Too much sun can be bad for plants when they get past the point of light saturation, which does not increase their photosynthetic production, but instead makes them thirstier.").

studies reveal that many types of crops grown in agrivoltaic systems produce similar or increased yields yet require fewer water resources.[102] Moreover, transpiration from the crops cools the panels above them, allowing for more efficient solar energy production. Farmers further benefit from onsite electricity savings and additional revenue from excess energy sales.

One of the most promising benefits of agrivoltaics is their potential to increase crop yields. Existing studies suggest that this positive effect on yields tends to be most significant for crops that are shade tolerant, heat sensitive, and able to adapt to changing conditions. For example, although a University of Arizona study reported increased yields throughout its agrivoltaics study area, tomato fruit production doubled (a very heat-sensitive plant), while chiltepin fruit production tripled.[103] This study also found general improvements in crops' CO_2 uptake and water-use efficiency.[104] In a separate study, a lettuce crop experienced no yield decrease when grown in the shaded areas under solar panels and the surface area of the crops' leaves increased as an adaptation to lower light conditions.[105] Even in study areas where yields have remained unchanged or slightly decreased, crop quality has remained high.[106] Other successful crops include certain pepper varieties, potatoes, cranberries, and grapes; and more research is ongoing to study agrivoltaics'

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[102] Further, a German project found that even in years where crop yield decreased, very dry years led to increases for wheat, potatoes, and celery. FRAUNHOFER INST. FOR SOLAR ENERGY SYS., *supra* note 78.

[103] Barron-Gafford et al., *supra* note 32. The University of Arizona study focused on three vegetables: jalapeños, tomatoes, and chiltepin fruit. *Id.* Tomato plants had doubled fruit production, with a 65% increase in CO_2 uptake and 65% increase in water-use efficiency. *Id.* While jalapeño production did not change significantly, water-use efficiency increased by 157%. *Id.* The soil at the study suit also required less frequent watering than at the control area. *Id.* Chiltepin pepper fruit production tripled, with a 33% increase in CO_2 uptake, but no change in water-use efficiency. *Id.*

[104] *Id.*

[105] Harshavardhan Dinesh & Joshua M. Pearce, *The Potential of Agrivoltaic Systems*, 54 RENEWABLE & SUSTAINABLE ENERGY REVS. 299, 300 (2016). In another study, lettuce produced 81–99% of the yield compared to the full-sun control plot, with a 20% reduction in water consumption. Proctor et al., *supra* note 33.

[106] *Agrivoltaics—Solar Panels on Top, Potatoes Down Below*, *supra* note 100.

feasibility in other regions and with other crops.[107] While studies on "cash crops" such as corn and soybeans have been limited to date because of their requirements for full sun and the large machinery needed to harvest them, early studies have likewise shown promising results and more research is already underway.[108] Agrivoltaics systems are also compatible with mushroom farming, beekeeping, and animal husbandry—all of which can benefit from additional shading.[109]

The solar panels installed in agrivoltaics projects can also provide valuable physical protection for sensitive plant crops.[110] Panels situated directly above crops protect them from physical damage from rain, hail, or wind.[111] Panels' support systems may even be integrable with conventional protective barriers such as hail nets or be able to replace the protective plastic tunnels that often cover some berry crops.[112] Weather protection lowers the volatility inherent in food production, increasing net revenues.[113] The shaded areas created under PV panels can even provide cooler conditions for farm workers, reducing heat stroke and other health risks in hot climates.

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[107] In Germany, projects have successfully grown winter wheat, potatoes, celery, grass, and clover leys. *Id.* The panels are mounted high enough to allow tractors to drive underneath them.

[108] Proctor et al., *supra* note 33, at 2. Corn grown in Japan in agrivoltaic conditions showed a 4.9% increase in biomass and 5.6% higher yields than corn grown in full sun. *Id.*; *see also* Press Release, Univ. of Ill. Urbana-Champaign Inst. for Sustainability, Energy, & Env't, USDA Funds 'Agrivoltaics' Project Led by iSEE, Univ. of Ill. Researchers (Oct. 20, 2021), https://sustainability.illinois.edu/usda-funds-agrivoltaics-project/.

[109] *See, e.g.*, Jonathan Klavens et al., *Solar Project Development: The Special Case of Agrivoltaic Projects*, 64 BOS. BAR J. 1, 13 (2020) ("For example, mushroom cultivation, beekeeping and animal husbandry are all farming activities that might benefit from shade reduction greater than 50%.").

[110] FRAUNHOFER INST. FOR SOLAR ENERGY SYS. ISE, *supra* note 78, at 18.

[111] *Id.* at 20 ("Agrivoltaics likely offers the greatest potential for synergy effects with special crops in the areas of wine growing, orchards, and vegetable cultivation."); Chris Crowell, *Growth Industry: Agrivoltaics gives new life to solar energy values such as harvest, yield, and connection*, SOLAR BUILDER (May 12, 2021), https://solarbuildermag.com/news/growth-industry-agrivoltaics-gives-new-life-to-solar-energy-values-such-as-harvest-yield-and-connection/.

[112] Gwénaëlle Deboutte, *Transparent solar panels for agrivoltaics*, PV MAG. (July 2, 2021), https://www.pv-magazine.com/2021/07/02/transparent-solar-panels-for-agrivoltaics/; FRAUNHOFER INST. FOR SOLAR ENERGY SYS. ISE, *supra* note 78, at 21.

[113] *See* Rosa I. Cuppari et al., *Agrivoltaics and Weather Risk: A Diversification Strategy for Landowners*, APPLIED ENERGY, 2021, at 1 (noting co-location can increase annual net revenues by 300-5000%).

By naturally cooling the PV panels above them, crops grown in agrivoltaics projects can also increase panels' productive efficiency, reduce overheating risk,[114] and mitigate heat island effects that often result from ordinary utility-scale solar farms.[115] Solar panels become less efficient as their temperatures rise: one study found that for every one-degree Celsius increase over twenty-five degrees (seventy-seven degrees Fahrenheit), panel efficiency decreases by about 0.6%.[116] The same study found that placing solar panels within an agrivoltaics system enabled them to stay roughly nine degrees Celsius (forty-eight degrees Fahrenheit) cooler during a three-month growing season in Arizona.[117] As a result, the panels were 3% more productive over that period.[118] In a separate study, researchers saw increases in panel productivity of up to 10% in agrivoltaics systems.[119]

Agrivoltaics installations may also benefit ranchers. Grasses, like those commonly used to graze range animals, are some of the most effective plants at cooling panels, offering a potential win-win for ranchers and solar energy generators.[120] Ranchers in agrivoltaics test sites have reported increases in water efficiency and biomass yield, and the panels have also provided valuable shade for animals.[121] While relying on grazing animals to assist in a solar farm's vegetation management has not been shown to directly increase solar developers' profits, it can reduce mowing costs and other maintenance and site preparation costs that often accompany ground-mounted solar

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[114] Barron-Gafford et al., *supra* note 32, at 849.

[115] *Id.*

[116] *Id.*

[117] *Id.* at 851.

[118] *Id.*

[119] *Sustainable Farm Agrivoltaic*, *supra* note 72.

[120] Harrison Dreves, *Beneath Solar Panels, the Seeds of Opportunity Sprout*, NAT'L RENEWABLE ENERGY LAB'Y (Apr. 1, 2019), https://www.nrel.gov/news/features/2019/beneath-solar-panels-the-seeds-of-opportunity-sprout.html.

[121] HOROWITZ ET AL., *supra* note 56, at 1. Early agrivoltaics installations have shown more than 90% production for grasses and other forage plants that can support grazing animals. Sarah Shemkus, *Agrivoltaics: Solar Panels on Farms Could Be a Win-Win*, CIVIL EATS (Jan. 22, 2019), https://civileats.com/2019/01/22/agrivoltaics-solar-panels-on-farms-could-be-a-win-win/.

installations.[122] Farmers have even successfully reared sheep and poultry below traditional ground-mounted solar arrays.[123] In short, combining animal-rearing with solar energy production can potentially generate greater total land productivity and synergistic benefits in many settings. Moreover, "PV+" systems—which involve the co-location of pollinator habitats with photovoltaics—produce benefits as well and can help to restore endemic plant communities.[124] Such PV+ techniques likewise reduce topsoil impacts and dust on the panels, and provide native vegetation for pollinators, the latter having the potential to substantially benefit nearby farms.[125]

In addition to the prospective farming-related benefits of agrivoltaics, farmers involved in such projects also often profit from the electricity generated. As most small farms operate in a fiscal deficit,[126] this additional revenue is often much needed. In some cases, lease payments or sales of electricity directly compensate farmers.[127] In other instances, the electricity generated through agrivoltaic systems may remain onsite for use on the farm itself,[128] lowering electricity bills.[129]

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[122] Semeraro et al., *supra* note 53, at 223 (noting a German facility saved €18,000 in mowing costs in three years); *see also* HOROWITZ ET AL., *supra* note 56.

[123] CLEAN ENERGY EXTENSION, UMASSAMHERST, FACT SHEET: DUAL-USE: CROP AND LIVESTOCK CONSIDERATIONS (2018), https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/crop_and_livestock_considerations_110118.pdf.

[124] Off. of Sustainability, *Active Research Begins on ENR2's PV+ Project*, UNIV. OF ARIZ., https://sustainability.arizona.edu/projects/enr2-rooftop-photovoltaic-pv-project (last visited Mar. 11, 2022); *see also* Barron-Gafford et al., *supra* note 32, at 852 ("[U]ninvestigated for agrivoltaics are the potential for the restoration of endemic plant communities to provide increases in solar panel efficiencies").

[125] Semeraro et al., *supra* note 53, at 218, 225; BEATTY ET AL., *supra* note 54, at 29.

[126] *See supra* notes 90–93 and accompanying text (providing background on U.S. farm sizes and incomes, and trends on how they are changing).

[127] *See infra* notes 276–280 and accompanying text (discussing the statewide solar incentive program).

[128] *Agrivoltaics—Solar Panels on Top, Potatoes Down Below*, *supra* note 100. This project in Heggelbach, Germany generates enough electricity to power all of the farm's operations and feed enough extra power into the grid to provide power to sixty-two families of four. *Id.* Electricity produced on the farm could be used to "run irrigation pumps, dry grain, power cold storage, create nitrogen-based fertilizers, and charge electric tractors, reducing overall emissions and providing a form of distributed energy storage." Proctor et al., *supra* note 33, at 8.

[129] Barron-Gafford et al., *supra* note 32.

b. Nationwide Potential for Agrivoltaics

The mutual benefits of agrivoltaics increase land-use efficiency, making agrivoltaics potentially viable in a broad range of geographic areas. Admittedly, traditional solar systems generally have lower capital costs[130] and greater panel density than most agrivoltaics projects, resulting in greater electricity output per acre.[131] In dual-use systems, however, the combined value of food and electricity production is greater than if the land was used solely for either agriculture or solar production.[132] Researchers measure the effectiveness of agrivoltaic systems using the Land Equivalent Ratio ("LER").[133] An LER higher than one indicates that two elements work more efficiently together than they do apart, so for example, an LER of 1.3 means that either 30% more food production or 30% more solar panels would need to be added to the same land to achieve the same value as a dual-use.[134] In any agrivoltaics situation, the LER is higher than one, meaning dual-use is more advantageous than installing solar alone—regardless of location and crop type.[135] This figure also does not account for all of agrivoltaics' benefits, including leaving ecosystems intact and preserving topsoil.

The variety in states exploring agrivoltaics—including Colorado, Oregon, Massachusetts, Arizona, Michigan, and Illinois—shows that they have nationwide potential. Successful implementation of agrivoltaic systems requires choosing region-specific crops that are also well-suited for agrivoltaics. The Midwest's reliance on cash crops has thus far prevented Midwestern states from becoming a hotspot for agrivoltaics

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[130] BEATTY ET AL., *supra* note 54, at 29.

[131] Clean Energy Extension, *Dual-Use: Agriculture and Solar Photovoltaics*, UNIV. MASS. AMHERST, https://ag.umass.edu/clean-energy/fact-sheets/dual-use-agriculture-solar-photovoltaics (last visited Mar. 11, 2022).

[132] *Id.*

[133] Stefano Amaducci et al., *Agrivoltaic Systems to Optimize Land Use for Electric Energy Production*, 220 APPLIED ENERGY 545, 550 (2018).

[134] *Id.* at 557.

[135] *Id.* Any agrivoltaics scenario is more advantageous for production of maize for biogas and electric energy from ground-mounted PV systems. LER increased with panel density and was higher with sun tracking panels than with static panels. *Id.; see also* FRAUNHOFER INST. FOR SOLAR ENERGY SYS. ISE, *supra* note 78("[D]ual use of land for agriculture and solar power generation has the potential to counteract the scarcity of usable space and to contribute to the sustainable development of rural areas.").

development.[136] Still, the region also grows crops, such as blueberries, potatoes, and tomatoes,[137] and cultivators of these crops may be able to supplement their income through agrivoltaics on their farms. In fact, Illinois will join Colorado and Arizona in 2022 as a test state for optimizing agrivoltaics across an array of crop species—including traditional row crops.[138]

Unsurprisingly, the quality of a region's solar resources can impact its viability for agrivoltaics installations. For example, much of the nation's early agrivoltaics research has originated in Arizona, where there are 300 days of annual sunshine and a strong agricultural industry.[139] Still, a relative lack of solar potential has not prevented states such as Maine and Michigan from exploring agrivoltaics as well.[140] In fact, the microclimates created underneath the panels in agrivoltaic systems can sustain plant species that are normally not viable in a region, which may allow farmers to diversify their crops.[141] As a potential weapon against desertification,[142] agrivoltaics can enable new and continued farming in a time when the industry

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[136] *Agriculture in the Midwest*, U.S. DEP'T AGRIC., https://www.climatehubs.usda.gov/hubs/midwest/topic/agriculture-midwest (last visited Jan. 2, 2022) (citing 75% of "over 127 million acres of agricultural land" as corn and soybeans); *see supra* note 109 and accompanying text.

[137] *Agriculture in the Midwest, supra* note 136.

[138] Inst. for Sustainability, Energy, & Env't, Univ. of Ill. Urbana-Champaign, *supra* note 108.

[139] *Arizona: State Profile and Energy Estimates*, EIA, https://www.eia.gov/state/analysis.php?sid=AZ (last updated Apr. 21, 2022) ("[P]lentiful sunshine gives the entire state some of the nation's greatest solar energy resources."); *Guide to Arizona Agriculture*, ARIZ. DEP'T. AGRIC. (Dec. 2018), https://agriculture.az.gov/sites/default/files/AZDA_GuideToAZAg-R5.pdf; *The 5 C's,* ARIZ. STATE LIBR., https://azlibrary.gov/collections/digital-arizona-library-dazl/arizona-almanac/5-cs (last visited Nov. 13, 2022) ("Arizona consistently experiences over 300 days of sunshine a year . . . ").

[140] *Global Horizontal Solar Irradiance*, NREL, https://www.nrel.gov/gis/assets/images/solar-annual-ghi-2018-usa-scale-01.jpg (last visited Jan. 2, 2022) (mapping solar potential in United States); *see, e.g.*, Lisa DeMarco, *Agrivoltaic pilot program on Maine blueberry farm set to provide critical dual-use insights*, SOLAR POWER WORLD (Nov. 15, 2021), https://www.solarpowerworldonline.com/2021/11/agrivoltaic-pilot-program-set-to-provide-critical-insights/ (describing agrivoltaic pilot program in Maine).

[141] *See, e.g.*, Emiliano Bellini, *Giant Agrivoltaic Project in China*, PV MAG. (Sept. 3, 2020), https://www.pv-magazine.com/2020/09/03/giant-agrivoltaic-project-in-china/ (discussing a 1 GW project in China aiming to "resume goji farming in the region, which in turn revived an otherwise dead expanse of desert . . . ").

[142] *See, e.g.*, *id.*

is readily losing both farmers and cropland. In short, agrivoltaics can potentially be beneficial in a wide range of regions and climates.

c. Off-Farm Benefits

Agrivoltaics also offer substantial societal benefits that extend beyond the four corners of a farm. Among other things, agrivoltaics can help to reduce the conversion of farmland and undeveloped land, further the transition to renewable energy, and protect rural communities. For instance, the Nature Conservancy estimates that 35 to 50% of ideal locations for solar installation in California are located on current cropland and about 50% of ideal wind and solar is sited on current rangelands.[143] Developing agrivoltaics projects on agricultural land can increase the land's overall productivity without removing it from crop rotation.[144] Siting such projects on abundant agricultural and grazing lands also preserves the nation's precious undeveloped land resources,[145] limiting intrusions into wildlife habitats.[146] Agrivoltaics can also be a valuable tool in combatting climate change and its effects. Agrivoltaics directly displace fossil fuel-powered electricity generation and can aid utilities in meeting clean energy standards and goals.[147] By enabling farmers to achieve similar or increased crop yields while reducing water consumption, they can simultaneously help to increase the water efficiency of the nation's agricultural industry.[148]

Agrivoltaics is also uniquely situated to benefit rural farming communities, which tend to have lower median

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[143] GRACE C. WU ET AL., POWER OF PLACE: LAND CONSERVATION AND CLEAN ENERGY PATHWAYS FOR CALIFORNIA 40 (2019).

[144] *Id.*

[145] Foley, *supra* note 30.

[146] *See* Scott Dance, *Go Solar, or Save the Trees? Georgetown University Solar Farm Would Clear 240-Acre Forest in Charles County*, BALT. SUN (Jan. 31, 2019, 9:55 PM), https://www.baltimoresun.com/news/environment/bs-md-georgetown-solar-trees-20190131-story.html (discussing a proposed solar project that would require clearing forest deemed important for birds).

[147] *See infra* notes 269–274 and accompanying text (discussing public utilities' use of renewable energy sources).

[148] *See supra* notes 104–106 and accompanying text (noting the improvement of crop yields with the use of agrivoltaics).

incomes[149] and greater exposure to climate change-related risks. These communities' distances from grid infrastructure can cause them to disproportionality bear the negative effects of power outages.[150] By introducing new localized generation sources, agrivoltaics may improve electricity reliability in some of these areas.[151] Agrivoltaics systems that generate excess power can also serve surrounding communities through co-operative purchase programs.[152] Their installation and maintenance likewise creates new operational and construction jobs.[153] In these and other ways, agrivoltaics can provide rural communities with much-needed economic development and more sustainable access to food and electricity.[154]

2. Inadequate Policy Support for Agrivoltaics

Despite promising pilot-scale research and a few state-level programs aimed at promoting agrivoltaics, agrivoltaics development remains cost-prohibitive throughout most of the country. It would require an initial investment of $1.12 trillion over a 35-year project lifespan—or approximately $31 billion annually—for a buildout of agrivoltaics capacity capable of generating 20% of U.S. electricity.[155] Agrivoltaic systems currently cost between $0.07 and $0.80 more per watt than

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[149] *See supra* notes 67–93 and accompanying text (discussing the unique threat to small and mid-sized farms posed by climate change, how urban sprawl leads to farmland conversion and harms the agricultural industry, and that most federal subsidies for farmers only go to large operations).

[150] Hannah J. Wiseman, *Localizing the Green Energy Revolution*, 70 EMORY L.J. ONLINE 59, 97 (2021).

[151] *See id.* ("[S]mall-scale green energy in the form of distributed solar and microgrids can enhance the reliability of power, thus allowing some rural customers (and others) to avoid outages to begin with or to maintain at least some amount of power despite a widespread outage.").

[152] *See, e.g.*, Pierson, *supra* note1(highlighting one farming family's participation in agrivoltaics and regenerative agriculture); *cf.* John Fialka, *How Co-ops Are Bringing Solar Power to Rural America*, E&E NEWS (Mar. 22, 2019), https://www.scientificamerican.com/article/how-co-ops-are-bringing-solar-power-to-rural-america/ (explaining the attitude shift in coal-dependent rural U.S. co-ops toward solar arrays due to the decline of solar costs).

[153] Proctor et al., *supra* note 33, at 8.

[154] *Id.* at 8–9.

[155] *Id.* These numbers are based on the United States' 2019 energy generation. *Id.* at 5; *see also* Chris Malloy, *Why Combining Farms and Solar Panels Could Transform How We Produce Both Food and Energy*, COUNTER (Mar. 30, 2021, 2:45PM), https://thecounter.org/agrivoltaics-farmland-solar-panels-clean-energy-crops/.

conventional ground-mounted solar.[156] Some of these additional costs are associated with the racking systems and mounting structures, but much of the added expense comes from planning and development.[157] There are also additional operation and maintenance costs associated with retaining functional farmland beneath the panels.[158] These costs currently make agrivoltaics impractical for many farmers, leading some to instead convert productive farmland into conventional solar farms.

In the face of these costs and the tension between conventional solar development and farmland preservation, in 2018, Massachusetts was the first state to specifically incentivize agrivoltaics.[159] While it has been at the forefront of solar development, Massachusetts is one of the smallest states in the country.[160] With such limited land resources, new solar development was increasingly encroaching on vulnerable farmland.[161] Thus, Massachusetts developed its agrivoltaics incentive in an effort to protect valuable farmland while still meeting the state's ambitious solar energy goals.[162]

As part of the Solar Massachusetts Renewable Target ("SMART") program, qualifying agrivoltaics projects are eligible

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[156] HOROWITZ ET AL., *supra* note 56, at vi, 2, 10–11; Schindele, *supra* 99, at 9. The lower estimate is for PV panels collocated with grazing; the upper estimate is for PV panels collocated with crops. Generally, the levelized cost of electricity in an agrivoltaics system is double that of a ground-mounted PV system, similar to that of a small rooftop system. However, the levelized cost of electricity drops to only about 1/3 higher than a ground-mounted system where agrivoltaics is used with permanent crops that only require low clearance. FRAUNHOFER INST. FOR SOLAR ENERGY SYS., *supra* note 78, at 24.

[157] FRAUNHOFER INST. FOR SOLAR ENERGY SYS., *supra* note 78, at 22–23. Installing enough agrivoltaics projects to meet 20% of the United States' 2019 total energy generation would cost about $338.8 billion over a 35-year project lifespan, or $9.4 billion annually, more than installing traditional PV.; Proctor, et al., *supra* note 33, at 6.

[158] Schindele, *supra* note 99, at 10.

[159] 225 MASS. CODE REGS. § 20.02 (2022).

[160] *Massachusetts: Profile Analysis*, U.S. ENERGY INFO. ADMIN. (Sept. 16, 2021), https://www.eia.gov/state/analysis.php?sid=MA (citing Massachusetts in top ten states for installed solar capacity); *see State Area Measurements and Internal Point Coordinates*, U.S. CENSUS BUREAU (Dec. 16, 2021), https://www.census.gov/geographies/reference-files/2010/geo-state-area.html.

[161] *See supra* notes 45–47 and accompanying text.

[162] *Id.*; Exec. Off. of Energy & Env't Affairs, *Clean Energy and Climate Plan for 2020*, MASS.GOV, https://www.mass.gov/service-details/clean-energy-and-climate-plan-for-2020 (last visited Dec. 29, 2021).

for an add-on tariff[163] in addition to a base rate paid to all participating solar projects.[164] Notably, the program's technical design requirements and land eligibility restrictions protect agricultural use even at the cost of solar generation.[165] These requirements have been controversial, and efforts to update the agrivoltaics program have cycled through public notice and comment since its conception.[166] Each set of proposed guidelines has been substantively different than the last, begetting regulatory uncertainty and deterring new projects.[167]

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[163] § 20.02. The $0.06 add-on tariff is paid out for each kilowatt-hour ("kWh") of electricity generated by an agrivoltaics system. *Id; see generally* Heymi Bahar et al., *Domestic Incentive Measures for Renewable Energy with Possible Trade Implications* 28–37 (OECD Trade & Env't, Working Paper No. 01, 2013) (discussing renewable energy tariffs).

[164] § 20.02.

[165] *Id.* § 20.06(d)(2); Dep't of Energy Res. & Dep't of Agric. Res., *Guideline Regarding the Definition of Agricultural Solar Tariff Generation Units,* MASS.GOV (effective Apr. 26, 2018) [hereinafter Current SMART Guideline], https://www.mass.gov/doc/agricultural-solar-tariff-generation-units-guideline-final/download.

[166] Mass. Dep't of Energy Res., *ASTGU Draft Guideline & Public Comments*, MASS.GOV https://www.mass.gov/info-details/smart-400-mw-review-emergency-rulemaking#astgu-draft-guideline-&-public-comments- (last visited Dec. 29, 2021) (providing download link for twenty-one comments); Mass. Dep't of Energy Res., *Agricultural Solar Tariff Generation Units Guideline Straw Proposal Public Comments*, MASS.GOV (Nov. 17, 2020), https://www.mass.gov/doc/agricultural-solar-tariff-generation-units-guideline-straw-proposal-public-comments (linking to fifty comments).

[167] A 2019 proposal would have imposed more stringent technical requirements, Dep't of Energy Res. & Dep't of Agric. Res., *Guideline Regarding the Definition of Agricultural Solar Tariff Generation Units,* MASS.GOV (proposed Oct. 15, 2019), https://www.mass.gov/doc/draft-agricultural-solar-tariff-unit-guideline/download (limiting capacity to 2.5 MW and imposing yield requirements), but the next proposal abandoned those requirements while modifying the size limit, *see* MASS. DEP'T OF ENERGY RES., QUALIFYING DUAL USE AGRICULTURAL SOLAR TARIFF GENERATION UNITS: STRAW PROPOSAL 2, 4 (2020) (limiting project footprints to 50% of a farm's land). The most recent proposal, released in October 2021, would increase the generation capacity limit and broaden land eligibility to encourage the development of more agrivoltaics projects. *See* Dep't of Energy Res. & Dep't of Agric. Res., *Guideline Regarding the Definition of Agricultural Solar Tariff Generation Units,* MASS.GOV (proposed Oct. 12, 2021), https://www.mass.gov/doc/agricultural-solar-tariff-generation-unit-guideline-redline-update/download (increasing capacity limit from two megawatts to five megawatts and abandoning Straw Proposal's footprint limitation). *Compare id.* (expanding to land currently or recently enrolled in Chapter 61A, as well as land classified as "Important Agricultural Farmland"), *with* Current SMART Guideline, *supra* note 165 (limiting to land currently enrolled in Chapter 61A).

As of March 2022, ten projects have applied for the agrivoltaics adder.[168] In late 2020, the first approved project went online with roughly a 250 kW capacity and installation cost of $933,014.[169] This project is owned by Nate Tassinari, a banker and "wannabe-farmer" living on his family's third-generation farm.[170] Tassinari installed the panels over an acre of hayfields; the hay is used to feed dairy cows on his cousin's farm next door.[171] To Tassinari, "it was really about land preservation," as "the economics of that solar farm allow me to preserve all the rest of the land and not have to break it up for house lots and other things."[172] As more projects come online, they will serve as real-time experiments, and the University of Massachusetts Amherst's Clean Energy Extension ("UMass Extension") expects to collaborate with the owners to gather data.[173]

The fact that only ten projects, totaling just 14 MW in generating capacity, have applied for SMART's agrivoltaics adder[174] suggests the program still falls somewhat short in driving agrivoltaics development. One project's successful operation is far from large-scale proof-of-concept,[175] and the program's complicated requirements may easily dissuade some hesitant farmers from applying. Moreover, SMART's incentives may not sufficiently offset the financial cost of agrivoltaics or adequately reward farmers for the positive social benefits of these projects. Farmers and developers considering agrivoltaics projects must carefully weigh upfront capital and maintenance costs against longer-term solar energy and agricultural sales and typically only pursue a project if its net earnings are likely to exceed the sales of a traditional farm.[176] As one developer put it: "If the economic benefit is not enough, why should [farmers] 'tie up' their land asset in a small two [MW] solar land lease

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[168] *SMART Solar Tariff Generation Units*, MASS.GOV (Mar. 8, 2022), https://www.mass.gov/doc/smart-solar-tariff-generation-units (providing download link to spreadsheet).

[169] *Id.*

[170] Held, *supra* note 46.

[171] *Id.*

[172] *Id.*

[173] *Id.*

[174] *See SMART Solar Tariff Generation Units*, *supra* note 169 (listing tens of thousands of applicants for SMART as a whole totaling nearly 715 MW of generation capacity).

[175] *See* Dreves, *supra* note 120.

[176] Malloy, *supra* note 155.

when that same acreage could be converted to four or more house lots or condominiums?"[177]

In sum, Massachusetts' agrivoltaics tariff[178] is a commendable first step toward an effective agrivoltaics incentive program but does not go far enough in pursuit of that goal. The program's limited success underscores the difficulty in incentivizing, and thus regulating, a novel technology. On the other hand, the fact that Massachusetts—a state with relatively minimal solar resources[179]—has *any* privately owned agrivoltaics projects suggests that targeted policy action is worthwhile.

From a broader nationwide perspective, the relative dearth of agrivoltaics-focused laws and policies is presently holding back growth in this promising new industry. Existing solar energy policies and programs, while well-suited to incentivize conventional solar projects, are insufficient to spur rapid growth in agrivoltaics development.[180] Meanwhile, existing agricultural policies often obstruct agrivoltaics projects.[181] Inadequate

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[177] Doug Pope, President, Pope Energy, Comment Letter on Agricultural Solar Tariff Generation Units Guideline Straw Proposal (Oct. 30, 2020), https://www.mass.gov/doc/agricultural-solar-tariff-generation-units-guideline-straw-proposal-public-comments; *see also* Solar Energy Bus. Ass'n of New England, Comment Letter on Agricultural Solar Tariff Generation Units Guideline Straw Proposal, https://www.mass.gov/doc/agricultural-solar-tariff-generation-units-guideline-straw-proposal-public-comments ("[A] recently approved ASTGU in Dighton—were it subject to the proposed guidelines—would have been unable to move forward because the property would have lacked the acreage and DC sizing to . . . make a compelling economic case to the landowner over an alternative development proposal (i.e. housing subdivision).").

[178] *See* Center for Agric., Food, & Env't Clean Energy Extension, *Solar PV and Agriculture Information*, UNIV. OF MASS. AMHERST, https://ag.umass.edu/clean-energy/current-initiatives/solar-pv-agriculture (last visited Dec. 29, 2021).

[179] *See* Billy J. Roberts, Global Horizontal Solar Irradiance (figure), in *Solar Resource Maps and Data*, NAT'L RENEWABLE ENERGY LAB'Y (Feb. 22, 2018), https://www.nrel.gov/gis/assets/images/solar-annual-ghi-2018-usa-scale-01.jpg.

[180] *See, e.g.*, *infra* notes 294–304 and accompanying text.

[181] Crop-specific subsidies push farmers to overproduce corn, wheat, and soy—crops that are currently suboptimal for agrivoltaics. *See* Brian Barth, *Congress Finally Passed a New Farm Bill and It Continues to Pay Homage to the Cult of Corn and Soy*, MODERN FARMER (Jan. 7, 2019), https://www.modernfarmer.com/2019/01/congress-finally-passed-a-new-farm-bill-and-it-continues-to-pay-homage-to-the-cult-of-corn-and-soy. Further, farmers who produce cash crops are often less likely to adopt a new conservation practice because perceived opportunity costs likely outweigh the required initial and

information and community hesitancy only exacerbate the reality that agrivoltaics is currently cost-prohibitive for many farmers. Fortunately, these barriers are not unfamiliar or insurmountable.

II. ROCKY SOIL: CONSTRAINTS ON AGRIVOLTAICS' GROWTH

Although agrivoltaics have great potential as a means for providing food and energy security in the United States, they also remain unfamiliar and unaffordable for most farmers. In the nation's free-market system, spurring optimal levels of investment in such technologies with long-term benefits often requires government intervention.[182] Indeed, many major innovations, including renewable energy technologies, have historically required heavy initial public funding to bridge "the gap in support and financing between basic research and later-stage development, or . . . between proof of concept and a commercial product,"[183] sometimes referred to as the "valley of death."[184] Many renewable energy technologies are susceptible to these challenges because of their inherent technical, economic, and regulatory risks,[185] and agrivoltaics is no exception. Specifically, information gaps, externality problems, and localized resistance in many rural communities plague the nation's fledgling agrivoltaics industry.

Government support can help to address externality problems associated with agrivoltaics research and development, mitigate early investment risks, and facilitate the accelerated advancement of new technologies capable of producing valuable long-term social gains.[186] Federal government interventions in energy markets in recent decades have been proven to be quite successful, as wind and solar energy technologies rapidly progressed toward

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ongoing expenditures. Liz Carlisle, *Factors Influencing Farmer Adoption of Soil Health Practices in the United States: A Narrative Review*, 40 AGROECOLOGY & SUSTAINABILITY FOOD SYS. 583, 595–97 (2016) (weighing how likely a farmer is to implement cover-cropping to improve soil health).

[182] Wilson, *supra* note 48, at 361.

[183] CHARLES WEISS & WILLIAM B. BONVILLIAN, STRUCTURING AN ENERGY TECHNOLOGY REVOLUTION 20 (2009).

[184] *Id.* at 20.

[185] Albert C. Lin, *Lessons from the Past for Assessing Energy Technologies for the Future*, 61 UCLA L. REV. 1814, 1819 (2014).

[186] WEISS & BONVILLIAN, *supra* note 183, at 40–41.

commercialization,[187] and the time has arguably come to more aggressively promote similar advancements for agrivoltaics as well. This Part discusses several factors slowing the growth of agrivoltaics in the United States and potential ways for governments to address them.

A. Underdeveloped Knowledge About Agrivoltaics

One obstacle to the growth of agrivoltaics is the relatively limited body of knowledge available about these technologies and how and where to deploy them most effectively. Unlike conventional ground-mounted solar energy projects, which typically optimize electricity production per acre by maximizing panel density across most of the project site, agrivoltaic systems must also optimize shading through panel spacing and height. Substantially more research is still needed to understand how project design schemes and crop species impact each another, especially across various regional climates.

The controversial technical specifications in Massachusetts' SMART program demonstrate the challenges of designing agrivoltaics incentive policies with such limited scientific knowledge. The SMART program requires developers to configure projects in ways that balance electricity generation and agricultural production.[188] To that end, applicants for benefits under the program must furnish details about the crops or grazing animals involved and the spacing, tilt, and other specifications of their ground-mounted solar arrays.[189] Some technical requirements for eligibility under the program seem arbitrary at best. For example, qualifying projects must not reduce sunlight by more than 50% during the growing season.[190] Farmers, conservation groups, renewable energy developers,

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[187] *See* Felix Mormann, *Requirements for a Renewables Revolution*, 38 ECOLOGY L.Q. 903, 947 (2011). Domestic projects like the Solar Photovoltaic Research, Development, and Demonstration Act of 1978, as well as international laws like Germany's Wind Program of 1989 and Denmark's SOL-300 Project were vital to "raising public awareness and interest in in the new technology." *Id.*

[188] 225 MASS. CODE REGS. 20.06(d)(2).

[189] *Id.* 20.06(d)(6).

[190] *Id.* The growing season is March to October, and the direct sunlight requirements apply between 10:00 am and 5:00 pm for March and October, and 9:00 am to 6:00 pm for April through September. *Id.* Fixed-tilt panels must be at least 8 feet at their lowest point and tracking panels must be at least 10 feet tall when horizontal. *Id.*

and NIMBYs have criticized such requirements as inflexible, complicated, and unsupported by science.[191] Conversely, some opponents of local agrivoltaics development have argued that the technical requirements are too lax and crafted to benefit out-of-state solar developers.[192] One opponent went so far as to allege that, given the absence of any "long-term studies" supporting the program, it was effectively a "sham."[193] Much more research of the science of agrivoltaics design is needed to make it possible to tailor such incentive programs to serve their intended purposes and to garner broad community support and farmer participation.

Farmers' limited knowledge about agrivoltaics and their practical and economic benefits further constrains agrivoltaics growth. Many U.S. farmers and rural communities know little

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[191] A NIMBY—or Not in My Back Yard—is someone that raises strong opposition to projects in their community, while not objecting to these same ideas in other places. See NIMBY, Oxford Learner's Dictionaries, https://www.oxfordlearnersdictionaries.com/us/definition/english/nimby (last visited Feb. 3, 2023). *See, e.g.*, Mass. Sierra Club, Comment Letter on Agricultural Solar Tariff Generation Units Guideline Straw Proposal (Oct. 30, 2020), https://www.mass.gov/doc/agricultural-solar-tariff-generation-units-guideline-straw-proposal-public-comments ("The proposed guidelines are less prescriptive and more truly guidelines, with the advantageous result of allowing for more flexibility in farmers' and developers' response."); Hank Ouimet, Managing Partner, Renewable Energy Dev. Partners, LLC, Comment Letter on Proposed Changes to Guideline Regarding the Definition of Agricultural Solar Generation Tariff Units (Nov. 6, 2019); Brad Mitchell, Deputy Exec. Dir., Mass. Farm Bureau Fed'n, Comment Letter on Proposed Changes to Guideline Regarding the Definition of Agricultural Solar Generation Tariff Units (Nov. 5, 2019), https://www.mass.gov/info-details/smart-400-mw-review-emergency-rulemaking#astgu-draft-guideline-&-public-comments-.

[192] *See, e.g.*, Joel Johnson, Comment Letter on Proposed Changes to Guideline Regarding the Definition of Agricultural Solar Generation Tariff Units (Oct. 17, 2019), https://www.mass.gov/info-details/smart-400-mw-review-emergency-rulemaking#astgu-draft-guideline-&-public-comments- ("[Our neighbor with sixty acres] has no intention to care about the farming operation if he were to gain approval.").

[193] *See* Kelly Gallagher, Residents for Responsible Solar Energy, Comment Letter on Agricultural Solar Tariff Generation Units Guideline Straw Proposal (Oct. 30, 2020), https://www.mass.gov/doc/agricultural-solar-tariff-generation-units-guideline-straw-proposal-public-comments ("Because no long-term studies have been done, Umass Agricultural Extension has no idea if any of this will work"); *see also* Mass. Land Tr. Coal., Comment Letter on Agricultural Solar Tariff Generation Units Guideline Straw Proposal (Oct. 30, 2020), https://www.mass.gov/doc/agricultural-solar-tariff-generation-units-guideline-straw-proposal-public-comments (calling for a "vigorous pilot program to determine if dual use is agriculturally viable for the farm as well as financially viable for the PV owner").

about agrivoltaics or their potential advantages over conventional solar. Farmers already tend to be relatively risk averse because of the volatility of food commodity markets and the uncertainties of their industry,[194] and the prospect of introducing a new technology onto their farm may further erode their sense of control.[195] They are less likely to adopt a new technology such as agrivoltaics given that they have never adopted comparable technologies in the past.[196] Some farmers may also be reluctant to embrace agrivoltaics due to fears that doing so could threaten existing productive farming methods, especially given the limited amount of existing research on such potential effects.[197]

The relative lack of technical information about agrivoltaics project designs and their impacts also tends to increase the soft costs associated with such development. The efficient adoption of new technologies in free markets typically requires that all parties have access to all relevant information.[198] Presently, the body of available information about agrivoltaics projects and their impacts is quite limited, creating additional costs and difficulties for policymakers, investors, and farmers.[199] For example, zoning officials' unfamiliarity with how new and existing zoning policies might apply to agrivoltaics is likely to increase the time and cost associated with permitting such projects in many jurisdictions.

Building a more complete body of knowledge about agrivoltaics will be expensive,[200] and market forces alone are unable to adequately incentivize private investment in that buildout because the information gained through such endeavors is largely a public good.[201] Markets tend to under-

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[194] *See generally supra* notes 67–95 and accompanying text.

[195] *Id.*

[196] *Id.* at 530.

[197] Carlisle, *supra* note 81, at 595.

[198] *See* Daniel C. Esty, *Environmental Protection in the Information Age*, 79 N.Y.U. L. REV. 115, 121–22, 210 (2004).

[199] *Id.* at 198.

[200] Joseph E. Stiglitz, *The Contributions of the Economics of Information to Twentieth Century Economics*, 115 Q.J. ECON. 1441, 1441 (2000) (noting that obtaining information can be costly).

[201] *Id.* at 1448 (discussing information as "nonrivalrous," and socially inefficient to exclude others from); *see* Esty, *supra* note 198, at 197 ("It is an oversimplification to see environmental knowledge as purely a public good."). *But see* Daniele Archibugi & Andre Filippetti, *Knowledge as Global Public*

invest in the development of public goods because they are non-excludable and non-rivalrous in consumption,[202] making it difficult for those creating them to capture most of the benefits of such efforts.[203] Government investment has long been justified as an effective means of overcoming these challenges and thereby producing greater scientific knowledge and policy innovation.[204]

B. Externality Problems Leading to Underinvestment

Positive externality problems also plague agrivoltaics, further contributing to sub-optimally low levels of private investment. Externalities, which arise when market prices do not reflect the full costs or benefits of an activity, lead to inefficient levels of production and consumption—market failures that may justify government intervention.[205] Positive externality problems arise when producers of particular products or services are unable to capture the full societal benefits of their action, leading to underproduction.[206] For instance, in 1952, economist James Meade cited beekeeping as an activity prone to positive externality problems.[207] In Meade's example, a beekeeper benefits only from the honey made by her bees, but her neighbors also benefit from the pollination of their food crops.[208] Because the beekeeper receives no proceeds of the latter and will thus underinvest in beekeeping activities,[209] government intervention is justified to incentivize the beekeeper

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Good, *in* THE HANDBOOK OF GLOBAL SCIENCE, TECHNOLOGY, AND INNOVATION 479, 487 (2015) (arguing that knowledge is not a pure public good because once the information is produced, there is still a dissemination process).

[202] *See* Archibugi & Filippetti, *supra* note 201, at 481. Conversely, private goods are rivalrous and exclusive; in between public and private goods lie common and congestible goods (e.g., pastures), and club goods (e.g., canals). *Id.* at 481.

[203] *See* Amy L. Stein, *Regulating Reliability*, 54 HOUS. L. REV. 1191, 1241 (2017) (discussing whether *reliability* of electricity is a public good)

[204] *See* Archibugi & Filippetti, *supra* note 201, at 487.

[205] Amy L. Stein, *Renewable Energy Through Agency Action*, U. COLO. L. REV. 651, 656–58 (2013) (explaining externalities of renewable energy).

[206] *Id.* at 656–58.

[207] *See generally* J.E. Meade, *External Economies and Diseconomies in a Competitive Situation*, 62 ECON. J. 54, 56–61 (1952) (introducing the apple orchard–beekeeping positive externality paradigm).

[208] *Id.* at 56–58.

[209] Stein, *supra* note 205, at 656–58.

to increase such activities to a more socially optimal level.[210] Similarly, free market actors cannot capture many broader societal benefits of renewable energy development—such as reduced greenhouse gas emissions, cleaner air and water, and climate benefits—and federal and state governments have thus long subsidized these activities.[211]

Presently, the economic rewards available in the market for those with agrivoltaic systems largely ignore agrivoltaics' broader societal benefits, such as helping to preserve agricultural land and promote greater water and food security.[212] Existing market prices may also not fully reflect agrivoltaics' potential to creating and sustaining new jobs in rural America.[213]

C. NIMBYism and Community Resistance

Local community opposition to agrivoltaics is another major constraint on the deployment of these techniques and technologies. Some rural areas have long been wary of renewable energy development and its potential impacts on their communities,[214] which can give rise to the Not In My Backyard (NIMBY) problem—localized opposition to the siting of such projects. One familiar example of NIMBYism against renewable energy development was the proposed Cape Wind offshore wind farm project that ultimately failed after years of litigation driven by locals who were mostly worried about the

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[210] *But see* Steven N.S. Cheun, *The Fable of the Bees: An Economic Investigation*, 16 J.L. & ECON. 11, 11 (1973) (observing that, in practice, private contracts between orchards and beekeepers eliminate need for government intervention).

[211] Benjamin J. Richardson, *Reforming Climate Finance Through Investment Codes of Conduct*, 27 WIS. INT'L L.J. 483, 510–11 (2009) (discussing the pressures from the socially responsible investment movement (SRI)); Stein, *supra* note 205, at 658 ("Reliance on more renewable energy can strengthen the economy, eliminate the need for disruptive extraction techniques, further diversify the nation's electricity portfolio to better insulate the nation from service disruptions, reduce air pollutants that adversely affect human health, and reduce greenhouse gas ("GHG") emissions that intensify events related to climate change.").

[212] *Benefits of Renewable Energy Use*, UNION OF CONCERNED SCIENTISTS, https://www.ucsusa.org/resources/benefits-renewable-energy-use (Dec. 20, 2017). Using agrivoltaics to supply just 20% of the United States' electricity would be the equivalent of taking over 71,000 cars off the road, in terms of reduced CO_2 emissions. Proctor et al., *supra* note 33, at 6.

[213] *See* Stein, *supra* note 205, at 668–69.

[214] Wiseman, *supra* note 150, at 80.

project's potential impacts on their ocean views.[215] NIMBYism is not unique to renewables; it is pervasive across the United States for development of a wide range of potential valuable projects.[216] Although NIMBYism was originally thought to stem from self-interest and ignorance, researchers have since recognized that the drivers of NIMBYism are more complex and can include a range of "social, political, emotional, and economic factors."[217]

Incumbent market stakeholders can be sources of local opposition to agrivoltaics projects as well. To the extent that utilities or certain other parties view agrivoltaics as against their economic interests,[218] such parties may wield their strong political influence to create additional headwinds to such types of development.[219] Other groups may lodge aesthetics-based arguments against agrivoltaics projects, asserting that these projects could create visual eyesores or disrupt the rural look and feel of their communities.[220]

Agrivoltaics developers have already encountered problems stemming from community opposition.[221] For example, in

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[215] Ben Dininger, *The Twenty-First Century Offshore Wind Boom: Why Texas is Leading the Way*, 44 TEX. ENV'T L.J. 81, 85–86 (2014); Katharine Q. Seelye, *After 16 Years, Hopes for Cape Cod Wind Farm Float Away*, N.Y. Times (Dec. 19, 2017), https://www.nytimes.com/2017/12/19/us/offshore-cape-wind-farm.html#:~:text=Cape%20Wind%20was%20dealt%20a,the%20wind%20power%20to%20land.

[216] Ori Sharon, *Field of Dreams: An Economic Democracy Framework for Addressing Nimbyism*, 49 ENV'T L. REP. NEWS & ANALYSIS 10264, 10265 (2019).

[217] *Id.* at 10267 (explaining the traditional view of a "social gap" which "stem[s] from self-interest 'implying selfishness, ignorance, and irrationality on behalf of residents interested in "protecting their own turf" and putting personal interests ahead of societal benefits'") (citing Maria A. Petrova, *From NIMBY to Acceptance: Toward a Novel Framework—VESPA—For Organizing and Interpreting Community Concerns*, 86 Renewable Energy 1280, at 1280 (2016)). Now, researchers think opposition is "driven by a complex set of social, political, emotional, and economic factors, including, inter alia, concerns about equity, response to what is viewed as intrusion by external interests, distrust of technology, developers, or government regulators, conflicting information about the risks of a project, environmental values, and place attachment sentiments." *Id.*

[218] *Id.* at 930.

[219] *Id.*

[220] *Id.*

[221] *See, e.g.*, Alexis S. Pascaris et al., *Do Agrivoltaics Improve Public Support for Solar Photovoltaic Development? Survey Says: Yes!*, MICH. TECH, UNIV. (May 5, 2021) https://doi.org/10.31235/osf.io/efasx (finding that respondents in two "relative rural" counties in Texas and Michigan were less

opposition to a proposed 100 MW agrivoltaics project, a California rancher was careful to note that he and other neighbors supported "green energy" before emphasizing that *this project* "would be a sea of glass" and "disturb[] the environment."[222] He argues local zoning ordinances intended to protect existing open space and habitat foreclose the project, which would install around 229,000 panels eight feet off the ground to allow for grazing and beekeeping.[223] Given the hesitations many rural communities have surrounding agrivoltaics, taking steps to educate and involve local communities will be essential to ensuring that such opposition does not continue to hinder the deployment of these technologies.

III. CULTIVATING AGRIVOLTAICS THROUGH TARGETED POLICIES

Agrivoltaics have the potential to thrive in a fertile, well-structured policy environment. The types of challenges facing agrivoltaics are not entirely new, so existing solar and agricultural policies can serve as useful guides for designing agrivoltaics policies. Greater federal support for scientific and policy research and development (R&D) is needed to help fill information gaps associated with agrivoltaics and to make it possible to better educate and engage communities in project development. State governments could further bolster agrivoltaics by modifying their existing renewable energy policies to better reflect the unique additional benefits these projects offer.[224] Local governments also have the power to incentivize agrivoltaics development by modifying their zoning codes to unambiguously allow for agrivoltaics, thereby reducing the soft costs of installation. The following materials will discuss how federal government investment can initiate agrivoltaics'

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opposed to an agrivoltaics project visible from their property than a conventional project); Mark Chediak, *California Nimbys Threaten Biden's Clean Energy Goals*, BLOOMBERG GREEN (July 30, 2021, 1:58 PM), https://www.bloomberg.com/news/features/2021-07-29/san-francisco-bay-area-solar-farm-opposed-by-nimbys (citing opposition to a 350 acre dual-use project designed to allow grazing and bee-keeping).

[222] Notably, the rancher powers his own 50-acre ranch using rooftop solar panels. Chediak, *supra* note 221.

[223] *Id.*

[224] *See* Hanak et al., *supra* note 68, at 3, 61. To start, Congress could divert some of the $10 billion invested in crop-specific subsidies to USDA-coordinated agrivoltaics projects, to the advantage of many farmers currently unable to access traditional subsidies. *See supra* notes 83–95 and accompanying text.

growth and provide a basis for state and local policymaking and private investment.

A. Expanding Federal Agrivoltaics Research Support

More substantial government investment in agrivoltaics R&D through expanded federal grant offerings could help address agrivoltaics' information gaps and lay a foundation for structuring agrivoltaics incentive programs and policies. Such expanded grant programs would help to address the public goods problems that have heretofore constrained investment in the agrivoltaics-related research needed to provide vital information to farmers, developers, and investors.

1. A History of Successful Federal R&D Programs

For decades, federally-funded R&D programs have successfully promoted technological innovation in the renewable energy and agricultural industries. Federal R&D funding for renewable technologies has helped to promote the development of more efficient solar panels, more optimal wind turbine designs, and permitting systems that reduce the soft costs associated with renewable energy project siting.[225] Recognizing solar generation technologies as a public good, policymakers have leveraged policies to prompt the federal government and private sector to collectively expend over $3 billion on solar R&D since 1950.[226]

One particularly successful example of the use of federal grants to spur advancements in the renewable energy sector is the U.S. Department of Energy's SunShot Initiative. Launched in 2011, the SunShot Initiative aimed to make solar energy cost-competitive with other forms of energy at a large scale, in part by setting benchmarks for residential, commercial, and utility-scale solar through 2020.[227] In part due to the SunShot Initiative, solar energy costs fell two-thirds of the way to the program's goal in the first three years, and prices of rooftop systems dropped to just 1% of what they had cost thirty-five

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[225] Garrick B. Pursley & Hannah J. Wiseman, *Local Energy*, 60 EMORY L.J. 877, 902–03 (2011).

[226] Wilson, *supra* note 48, at 346.

[227] Solar Energy Techs. Off., *The SunShot Initiative*, U.S. DEP'T OF ENERGY, https://www.energy.gov/eere/solar/sunshot-initiative (last visited Jan. 2, 2022).

years earlier.[228] Grant-funded research and programs within the SunShot Initiative similarly helped drive down the costs of utility-scale solar energy development.[229]

Federal research funding has also long played a vital role in the agricultural industry. While farming itself is highly localized, the sheer scale of resources involved in agricultural policy necessitates federal involvement.[230] Bringing federal programming to rural farming communities is challenging,[231] so the USDA has relied heavily on university extension programs.[232] While originating within the university system, extension programs ultimately provide practical resources to rural communities with the goals of "improv[ing] agricultural, economic, and social conditions," and "break[ing] the cycle of poverty."[233] Studies have shown that extension programs, which

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[228] SUNSHOT INITIATIVE, U.S. DEP'T OF ENERGY, TACKLING CHALLENGES IN SOLAR: 2014 PORTFOLIO 6, 10 (2014), http://energy.gov/sites/prod/files/2014/08/f18/2014_SunShot_Initiative_Portfolio8.13.14.pdf.

[229] Solar Energy Techs. Off., *Solar Energy Technologies Office Updated 2030 Goals for Utility-Scale Photovoltaics*, OFF. ENERGY EFFICIENCY & RENEWABLE ENERGY, https://www.energy.gov/eere/solar/solar-energy-technologies-office-updated-2030-goals-utility-scale-photovoltaics (last visited Jan. 2, 2022) (noting that utility-scale solar reached the benchmark of $0.06 per kilowatt-hour ("kWh") in 2017 (down from $0.28 per kWh in 2010)—three years early—so, new goals were set: $0.03 per kWh by 2025 and $0.02 per kWh by 2030).

[230] *See supra* text accompanying notes 79–91 (discussing agricultural subsidies); *see also* Jess R. Phelps, *Conservation, Regionality, and the Farm Bill*, 71 MAINE L. REV. 293, 296–97 (2019) (discussing interplay between federal, state, and local government in administering Farm Bill policy while emphasizing "the localized issues that matter most within [a particular] geographic context").

[231] *Cf.* Anne C. Hazlett, *Rural America and the Opioid Crisis: Dimension, Impact, and Response*, 23 DRAKE J. AGRIC. L. 45, 45 (2018) (discussing USDA's role in rural communities as extending even to opioid epidemic). The USDA also has local field offices in its arsenal. *See* FARM SERVICE AGENCY, U.S. DEP'T OF AGRIC., https://www.fsa.usda.gov/ (last visited Jan. 3, 2022); Phelps, *supra* note 230, at 310–12.

[232] GENEVIEVE K. CROFT, CONG. RSCH. SERV., R45897, THE U.S. LAND-GRANT UNIVERSITY SYSTEM: AN OVERVIEW (Aug. 29, 2019).

[233] Scott Angle, *NIFA Highlights Research, Education, and Extension Successes of 2019*, U.S. DEP'T AGRIC. (Jul. 29, 2021), https://www.usda.gov/media/blog/2019/12/03/nifa-highlights-research-education-and-extension-successes-2019 ("NIFA applies an integrated approach of research, education, and Extension to ensure that groundbreaking discoveries in agriculture-related sciences and technologies reach those who can put them into practice, ultimately benefiting America's farmers, ranchers, producers, and consumers.").

provide farmers with an array of resources, are one of the most effective ways to invest in farmers.[234] A 2016 study on their effectiveness showed that agricultural extensions reduced the number of farmers that exited the farming industry by roughly 22% from 1986 to 2010.[235] The same study also suggested they create jobs and allow farmers to exchange new information.[236] Therefore, public investments in farm related research and education are more effective through the land-grant university system than via direct subsidies.[237]

2. Funding Agrivoltaics Research Through University Extension Programs

Like solar energy technologies, agrivoltaics exhibit dynamic economies of scale that justify significant government investment at the R&D stage.[238] Greater federal funding for university extension-managed agrivoltaics pilot projects could be one effective way to accelerate agrivoltaics R&D and attract more private investment in this emerging industry. Such university extension pilot programs have already shown positive results. For instance, collaborations between universities are allowing researchers to study various agrivoltaic design schemes in different climates and crop types, such as for cash crops.[239]

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[234] Stephan J. Goetz & Meri Davlasheridze, *State-Level Cooperative Extension Spending and Farmer Exits*, 39 APPLIED ECON. PERSPS. & POL'Y 65, 66 (2016).

[235] *See id.* (showing that with extension programs, 490,000 farmers exited the industry, but without extension programs, another 137,000 would have exited).

[236] Nat'l Inst. of Food & Agric., *Cooperative Extension Programs Help Farmers Stay in Business*, U.S. DEP'T AGRIC. (May 4, 2016), https://nifa.usda.gov/announcement/cooperative-extension-programs-help-farmers-stay-business.

[237] *See* NE. REG'L CTR. FOR RURAL DEV., COOPERATIVE EXTENSION'S EFFECTS ON FARMER RETENTION 1–2 (2016).

[238] *See* MICHAEL TAYLOR, INT'L RENEWABLE ENERGY AGENCY, ENERGY SUBSIDIES: EVOLUTION IN THE GLOBAL ENERGY TRANSFORMATION TO 2050 15 (2020). Dynamic economies of scale justify subsidies when "an industry benefits from strong learning-by doing." *Id.* Based on agrivoltaics ability to increase net annual revenues and reduce volatility, money can be shifted from crop insurance programs to agrivoltaics investment. *See* Cuppari et al., *supra* note 113.

[239] The University of Illinois received a $10 million, four-year grant through USDA's National Institute of Food and Agriculture's Sustainable Agriculture Systems Program and will be partnering with other universities in Arizona and Colorado to complete an effective study. Press Release, Inst. for

University extensions also facilitate valuable partnerships between universities and private developers to explore new means of deploying agrivoltaics. For example, the University of Arizona recently partnered with private companies to combine agrivoltaics with rooftop solar.[240] This project is open to the public, thus doubling as an educational and research tool. Another example is a partnership among BlueWave Solar, University of Massachusetts, and American Farmland Trust that aims to combine agrivoltaics with community solar to create a roadmap for scalability across the United States.[241] Because New England must import 90% of its food, the partnership's hope is to find ways to source food and energy more locally with sustainability and resiliency in mind.[242]

Federally funded extension programs can also be useful tools for educating farmers about agrivoltaics. Educating solar developers, farmers, and surrounding communities is key to maximizing agrivoltaics' potential synergies.[243] Public access to an expanded body of research data gained through university extensions could help private developers as they site and design these projects.

States seeking to incentivize agrivoltaics research in their region can also allocate funding to university pilot projects. For example, New Jersey's Dual-Use Solar Energy Pilot Program allocates $2 million of its 2022 budget for research farms.[244] The UMass Extension has similarly played a key role in disseminating resources to farmers who are interested in SMART's agrivoltaics tariff.[245] Particularly in states with priorities such as reaching aggressive renewable energy goals or revitalizing agricultural communities, state-level investments

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Sustainability, Energy, & Env't, Univ. of Ill. Urbana-Champaign, *supra* note 108.

[240] *ENR2 Rooftop Photovoltaic (PV)+ Project*, UNIV. OF ARIZ. OFF. SUSTAINABILITY, https://sustainability.arizona.edu/projects/enr2-rooftop-photovoltaic-pv-project.

[241] Kate Zerrenner, *New England is Emerging as a Testing Ground for Agrivoltaics*, TRIPLE PUNDIT: ENERGY & ENV'T, (Jul. 20, 2020), https://www.triplepundit.com/story/2020/new-england-agrivoltaics/120946.

[242] *Id.*

[243] Pascaris, *supra* note 63, at 11.

[244] *Rutgers Agrivoltaics Program*, RUTGERS, https://ecocomplex.rutgers.edu/agrivoltaics-research.html (last visited Sept. 2, 2021).

[245] *See* Clean Energy Extension, *supra* note 131.

in extension programs could catalyze local agrivoltaics development.

3. Developing Federal Definitions and Standards for Agrivoltaics

One other potentially valuable product of expanded agrivoltaics research is a set of clearer and more scientifically-supported definitions and standards for policymakers to integrate into agrivoltaics-focused government incentive programs. Among other things, a general federal definition for "agrivoltaics" that focuses on the conversion of existing farmland into a dual-use project would be a useful starting point.[246] An effective federal definition of "agrivoltaics" could help to deter misuse of incentive programs—for example through haphazard placement of a few solar panels or scattered seedlings on a property to secure a government benefit[247]—thereby promoting greater social acceptance and high-quality implementation.[248] A clear federal definition of agrivoltaics could provide greater guidance and certainty for those looking to install agrivoltaic systems. Ideally, any such definition would also preserve some flexibility for states and localities to make adjustments based on localized variations.[249]

Beyond a basic general definition, federal policymakers armed with greater scientific knowledge about agrivoltaics could ultimately also craft more specific standards and definitions encompassing the many relevant factors impacting the effectiveness of agrivoltaics projects. Agrivoltaics designs often vary by region depending on such factors as sunlight intensity and water availability, which will require policymakers to exercise care in categorizing various agrivoltaic systems and structuring incentives for their development in particular areas of the country. The scientific community already recognizes that an agrivoltaics system can be designed to prioritize solar output (i.e., "solar-centric design"), crop production (i.e., "vegetation-centric"), or equally maximize both solar and crop yield (i.e.,

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[246] AM. FARMLAND TR., WHAT IS DUAL-USE SOLAR? (2020), https://s30428.pcdn.co/wp-content/uploads/sites/2/2020/08/Dual-use-one-pager-web.pdf.

[247] *See* Bellini, *supra* note 95.

[248] Schindele, *supra* note 99.

[249] *See* Mitchell, *supra* note 191(proposing a "more qualitative than quantitative approach").

"colocation design").[250] Federal definitions could eventually codify these categories based on the research discussed above,[251] including creating general specifications for horticulture, rangeland, and pollinator habitat. For each category, policymakers designing incentive programs will need to consider the design scheme's primary focus, the types of crops involved, and other relevant factors. Government-funded research conducted with these specifications in mind could eventually provide policymakers with the knowledge and tools needed to develop agrivoltaics policies that effectively promote "low-impact solar development" and alleviate the need for land conversion.[252]

Federal laws and programs that more clearly define basic agrivoltaics systems and standards might also aid state governments in formulating their own agrivoltaics policies.[253] Because regions differ in available sunlight, soil condition, primary exports, and space, technical requirements and eligible land may look different in different states.[254] States' varied expectations concerning baseline crop, solar panel productivity, and agrivoltaic efficiency only amplify these differences, all of which states could address within their own agrivoltaics-focused initiatives and programs.

Agrivoltaics' technical definition will inevitably shape behavior, and policymakers must anticipate the implications of any binding definition. For example, Japan's technical definition requires that an agrivoltaic system cannot cause more than a 20% reduction in crop yield, but the shading rate can vary.[255] Interestingly, this appears to have led developers to design a PV project, identify its shading rate, and then pick an appropriate crop, rather than designing a project around existing

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[250] *Id.*

[251] *See supra* notes 239–246 and accompanying text.

[252] Pascaris, *supra* note 63, at 2.

[253] *See, e.g.*, Current SMART Guideline, *supra* note 165.

[254] AM. FARMLAND TR., *supra* note 246; Current SMART Guideline, *supra* note 165 (requiring land to be Chapter 61A-enrolled); *see, e.g.*, MASS. GEN. LAWS ch. 61A, § 1 (2021) (defining agricultural land as "primarily and directly used in raising animals"); *id.* § 2 (defining horticultural land as "primarily and directly used in raising fruits, vegetables, berries, nuts, and other foods").

[255] Rona Rita David, *Agrivoltaic Systems, A Promising Experience*, ENERGY INDUS. REV. (Apr. 30, 2021), https://energyindustryreview.com/analysis/165ovember165ics-systems-a-promising-experience/; Makoto Tajima & Tetsunari Iida, *Evolution of Agrivoltaic Farms in Japan*, 2361 AIP CONF. PROCEEDINGS, June 28, 2021, at 1, 5, https://aip.scitation.org/doi/pdf/10.1063/5.0054674.

agriculture.[256] And as seen in Massachusetts, technical definitions heavily influenced community buy-in and farmer participation.[257] Therefore, information gained through expanded federally-funded R&D will be invaluable in providing the knowledge base and proof-of-concept necessary to support effective agrivoltaics policies.[258]

B. Increasing Federal Incentives for Agrivoltaics Projects

Another important means of accelerating agrivoltaics development in the United States would be to subsidize it at levels that more accurately account for its unique social benefits. Because it resides at the nexus of energy and food, agrivoltaics development must overcome both energy and agricultural market distortions. Although existing solar energy incentives provide a foundation for incentivizing agrivoltaics, they fail to reflect the distinct benefits agrivoltaics provide and the unique attributes of these projects. Making it possible for farmers throughout the country to truly "profit from selling the sunlight they farm" will likely require multiple types of incentive programs that more accurately reflect agrivoltaics' tremendous social value.[259] At the federal level, Congress could use targeted Investment Tax Credits to lower the costs associated with the development and scale-up of new technologies. Meanwhile, states could modify their renewable portfolio standards to specifically promote agrivoltaics and to increase market demand for agrivoltaics-generated electricity. States could also further subsidize agrivoltaics by offering special property tax benefits to project landowners. Collectively, such policies would better reward developers and hosts of agrivoltaics projects and thereby lead to more optimal levels of development.

1. Creating a Targeted Federal Investment Tax Credit for Agrivoltaics

Federal tax credits designed to specifically target agrivoltaics project development could lower the capital costs associated with such projects, accelerating growth and the

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[256] Tajima & Iida, *supra* note 255, at 6.

[257] *See supra* notes 189–194 and accompanying text.

[258] *See supra* notes 227–246 and accompanying text.

[259] *See* Malloy, *supra* note 155 (noting the need for a "combination of policy, tax incentives, favorable loans, and/or integration into electric grids").

maturation of agrivoltaics technologies. Federal tax credits have similarly helped to address the positive externality problems associated with conventional solar energy development, promoting growth in that industry. Commercial- and utility-scale solar energy developers have long benefited from the Investment Tax Credit ("ITC").[260] Introduced in the Energy Policy Act of 2005, the ITC provides developers with income tax credits that help to offset the construction and equipment costs associated with solar energy projects.[261] The ITC is a phase-out tax credit; projects installed in 2019 received a 30% credit, and then the tax credit gradually decreased for subsequent projects, until plateauing at 10% for commercial projects and 0% for residential projects in 2024.[262] Reducing incentives over time helped solar reach economies of scale by rewarding early adopters of large-scale projects.[263]

Unfortunately, the existing ITC has proven ineffective at promoting agrivoltaics development. Under the current scheme, agrivoltaics projects receive the same government-provided monetary incentives as conventional solar even though they produce additional social benefits such as water conservation and land preservation and tend to cost significantly more to install.[264]

In light of the deficiencies of the existing ITC, a new agrivoltaics-specific ITC is warranted and could do much to increase private investment in agrivoltaics projects. Specifically, Congress could pass legislation with a stepped-up targeted income tax credit that better accounts for the unique benefits of agrivoltaic structures, potentially even offering varying incentive levels for different agrivoltaics project categories. Moreover, Congress could incorporate the "direct pay" provision

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[260] Wilson, *supra* note 48; F. John Hay, *Considerations for Leasing Land for Solar Development*, INST. OF AGRIC. & NAT. RES. (May 28, 2021), https://cropwatch.unl.edu/2020/considerations-leasing-land-solar-development.

[261] 26 U.S.C. § 48 ("[T]he energy credit for any taxable year is the energy percentage of the basis of each energy property placed in service during such taxable year."); *see also* HALL ET AL., *supra* note 52, at 5 (describing the incentives for solar development in the U.S.).

[262] Hay, *supra* note 260; HALL ET AL., *supra* note 52; Solar Energy Indus. Ass'n., *Solar Investment Tax Credit (ITC) Fact Sheet*, (Jan. 2021), https://seia.org/sites/default/files/2021-01/SEIA-ITC-Factsheet-2021-Jan.pdf.

[263] Hay, *supra* note 260; HALL ET AL., *supra* note 52.

[264] *See* 26 U.S.C. § 25D, 48 (defining expenditures within the statute). For a discussion of these costs, see *supra* notes 156–158 and accompanying text.

proposed in the Build Back Better Act,[265] which enables qualifying project owners to elect for direct payment instead of a non-refundable deduction.[266] A direct pay provision for agrivoltaics projects would allow investors without sufficient taxable income to reap the full benefits of the ITC, including small-scale developers, state, local, and tribal governments,[267] and small farmers seeking to install agrivoltaics systems out-of-pocket. An agrivoltaics-specific ITC would reduce capital costs to investors and internalize some of the positive externalities associated with agrivoltaics, resulting in more optimal levels of private investment in these important projects.

2. Leveraging State Renewable Portfolio Standards

At the state government level, policymakers could add carve-out or multiplier provisions to renewable energy portfolio standards ("RPSs") or use net-metering benefits to further accelerate agrivoltaics development. RPS carve-out or multiplier provisions could generate new artificial demand for agrivoltaics-produced power by requiring or encouraging utilities to specifically source more electricity from agrivoltaics projects. Meanwhile strong net- metering benefits or feed-in tariffs for agrivoltaics projects would make these ventures more economically viable for farms by more generously crediting and compensating them for excess solar power fed onto the electric grid.

a. Renewable Portfolio Standards

Most state governments have enacted RPSs, which require—or encourage—public utilities to source a specific amount of power from renewable sources and help make energy from those sources profitable using carve-outs or multipliers.[268]

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[265] Thought Leadership, *House-Passed Build Back Better Act – Green Energy Tax Perspective*, BAKER BOTTS (Nov. 24, 2021), https://www.bakerbotts.com/thought-leadership/publications/2021/november/house-passed-build-back-better-act—-green-energy-tax-perspective.

[266] *Id.*

[267] *Id.*; *see, e.g.*, Debaleena Majumdar & Martin J. Pasqualetti, *Dual Use of Agricultural Land: Introducing 'Agrivoltaics' in Phoenix Metropolitan Statistical Area, USA*, 170 LANDSCAPE & URB. PLAN. 150 (2018) (discussing agrivoltaics' potential on tribal land).

[268] *State Renewable Portfolio Standards and Goals*, NAT'L CONF. OF STATE LEGISLATORS (Aug. 13, 2021), https://www.ncsl.org/research/energy/renewable-

RPSs vary among states but generally encourage utilities to invest more heavily in renewable energy sources and localized energy production.[269] To comply, utilities must either generate qualifying electricity or purchase credits from generation facilities with excess qualifying energy, thus stimulating the growth of that technology.[270]

Many RPS policies feature carve-out or multiplier provisions that encourage greater investment in specific types of energy sources such as rooftop solar. Carve-outs require that utilities satisfy an express percentage of their RPS requirement with energy from the targeted energy source.[271] By contrast, multiplier provisions award additional or enhanced credits to utilities for sourcing certain targeted types of energy.[272]

State policymakers could promote agrivoltaics development within their jurisdictions by introducing special RPS carve-outs or multipliers for agrivoltaics-generated power. While agrivoltaics projects are technically eligible for some existing solar carve-outs, such as those for distributed solar projects,[273] agrivoltaics create benefits that are unattainable through conventional solar projects.[274] Given that utilities tend to use the least-cost means to meet their RPS requirements, they are unlikely to seek out agrivoltaics projects unless an RPS policy includes such special incentive provisions. Integrating such provisions into state RPS policies could help to create more reliable markets for agrivoltaic-generated power, benefitting a state's farmers and rural communities while also promoting solar energy development within the state.

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portfolio-standards.aspx. In some states, RPSs are voluntary goals; in others, they are mandates. *Id.*

[269] *Id.*

[270] *See, e.g.*, HALL ET AL., *supra* note 52, at 6 (discussing compliance with renewable portfolio standards).

[271] *State Renewable Portfolio Standards and Goals*, *supra* note 268.

[272] *See, e.g.*, *id.*

[273] *See, e.g.*, ARIZ. ADMIN. CODE § 14-2-1802(A)(10) (defining eligible "Solar Electricity Resources" as those that "use sunlight to produce electricity by either [PV] devices or solar thermal electric resources"). Agrivoltaics projects may also qualify for carve-outs that target distributed solar development. *See, e.g.*, ARIZ. ADMIN. CODE § 14-2-1805 (2022) (requiring that 30% of electricity be generated through distributed renewable energy systems, such as residential solar).

[274] *See supra* notes 97–155 and accompanying text (discussing agrivoltaics and how they are different from conventional solar projects).

b. Generous Net Metering Policies or Feed-In Tariffs for Agrivoltaics

Policies requiring utilities to compensate smaller farms more generously for the excess solar energy they generate and feed onto the electric grid are another potential means of accelerating agrivoltaics development.[275] State-mandated net metering or feed-in tariffs allow individuals to benefit from RPSs. Net metering occurs when a customer generates electricity on-site using a targeted source and receives an offset for that amount on their electric bill.[276] Feed-in tariffs similarly require utilities to compensate customers who generate more electricity than they use and feed that excess electricity into the grid at a set rate or "adder."[277] Both types of policies financially reward solar energy system owners for the excess power they generate.[278] States seeking to specifically incentivize agrivoltaics development can tailor either of these policies to advance that goal.

At least one state already uses adders to promote agrivoltaics, but states could do much more in this area. Massachusetts' SMART program seeks to encourage agrivoltaics development in conjunction with the state's aggressive RPS through special feed-in tariffs. Under SMART, participants who feed excess power onto the grid receive a base compensation rate according to a system's solar generation capacity, subject to certain adders,[279] including one for qualifying agrivoltaic systems.[280] In turn, utilities can count agrivoltaics-generated energy towards solar carve-outs or multipliers.[281]

Such adders could potentially give states flexibility to craft varying monetary incentives to subsidize diverse categories of agrivoltaics at different rates. Just as Massachusetts assigns a

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[275] *Feed-in Tariff: A Policy Tool Encouraging Deployment of Renewable Electricity Technologies*, U.S. ENERGY INFO. ADMIN. (May 30, 2013), https://www.eia.gov/todayinenergy/detail.php?id=11471.

[276] *Id.*

[277] *Id.*

[278] *Id.*; *see also* Mormann, *supra* note 187, at 964 (noting feed-in tariffs also offer a more direct support scheme to smaller investors than tax credits).

[279] *See* 225 MASS. CODE REGS. 20.07 (2021) (noting that adders are available for PV sited on brownfields and landfills, as well as pollinator habitat).

[280] 225 MASS. CODE REGS. 20.02.

[281] *See List of Qualified Generation Units*, MASS.GOV, https://www.mass.gov/service-details/lists-of-qualified-generation-units (last visited Mar. 31, 2022).

larger adder to agrivoltaics than to PV+ systems, a state could opt to incentivize agrivoltaics involving particular crops or grazing animals at different rates depending on the state's priorities. For instance, California might decide to give specific drought-resilient crops a large adder while giving water-needy crops a near-zero adder, whereas states like Wyoming might exclusively seek to incentivize grazing. Together with RPS carve outs and multipliers, such feed-in tariffs could allow states to offer a diverse set of tailored agrivoltaics incentives that account for the distinct benefits of particular project types in a jurisdiction's varied regions.

3. Creating State Property Tax Benefits

States and municipalities seeking to incentivize agrivoltaics development could also enact or adopt property tax codes provisions that reward landowners for hosting these projects. Property tax exemptions and discounts lower the annual property tax liability associated with specific types of real property improvements. Property tax policies affecting solar energy projects and farms come in a variety of forms. Some states tax solar farms using a nameplate capacity tax that is calculated based on the solar generating capacity of a system.[282] The land beneath the solar panels typically retains its original classification under this approach.[283] Some states also tax land that is used for agriculture or horticulture at a commercial or open space rate, instead of at its fair market value, reducing costs associated with property improvements.[284]

To account for the unique benefits of siting renewable energy systems above crops, a few states such as Massachusetts

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[282] Hay, *supra* note 260; *see, e.g.*, NEB. REV. STAT. § 77-6203 (2022) (noting Nebraska state taxes).

[283] § 77-6203; *see, e.g.*, Dep't of Revenue, *Nameplate Capacity Tax FAQs*, NEB., https://revenue.nebraska.gov/about/frequently-asked-questions/nameplate-capacity-tax-faqs ("[L]and that is currently classified as agricultural and horticultural land will continue to be classified as agricultural and horticultural land.").

[284] MASS. GEN. LAWS ch. 61A, § 4 (applying commercial property rate as default); *id.* § 4A (applying open space rate where adopted by encompassing municipality); Victoria Corless, *No Longer Just Solar Sharing: Bringing Agrivoltaics to the Next Level*, ADVANCED SCI. NEWS (Aug. 3, 2020); *see also* Ariz. Rev. Stat. § 42-13101(A) (2022) ("Land that is used for agricultural purposes shall be valued using only the income approach to value without any allowance for urban or market influences.").

are beginning to integrate existing agricultural tax policies and solar tax incentives, with varying degrees of success.[285] Under Massachusetts's tax code, a farmer who generates electricity on farmland can only use that electricity on land he owns or leases.[286] To qualify for subsidization, the renewable energy system cannot generate over 125% of the farmer's own "annual energy needs."[287] As a consequence, a farmer will lose the SMART adder, any other state-level subsidies, and the more favorable tax rate if their system generates too much electricity.[288] Agrivoltaics development also risks re-classification of the land's use. Currently, the Massachusetts tax code preserves land for agricultural use by giving the local municipality the right to purchase any land that an agricultural landowner intends to sell or change the use of.[289] Therefore, generating excess power not only exposes a farmer to greater tax liability and the risk of losing SMART eligibility—it could cost him his land.

To avoid unintended property tax impacts in the context of agrivoltaics, states could develop an agrivoltaics-specific tax policy that resolves the conflicts between agricultural and solar interests. Because of the value that agrivoltaic infrastructure brings to a property, states should incorporate an agrivoltaic-specific provision that addresses valuation of agrivoltaic-developed land. For example, states could write off the value of agrivoltaic infrastructure[290] or impose a nameplate capacity tax based on generating capacity while continuing to tax the land underneath as agricultural land. The additional tax revenue

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[285] *See, e.g.*, MASS. GEN. LAWS ch. 61A, § 2A; NEB. REV. STAT. § 77-6203 (2022) (noting regulations for tax policies and solar tax incentives for Massachusetts and Nebraska).

[286] MASS. GEN. LAWS ch. 61A, § 2A.

[287] *Id.*

[288] *See id.*; Corless, *supra* note 284 (discussing the tax system in regards to state-level subsidies for agrivoltaics).

[289] *See id.* §§ 14–15 (the provision also gives towns a right-of-first-refusal if the farmer intends to sell the land); *see e.g.*, Brad Mitchell, Deputy Exec. Dir., Mass. Farm Bureau Fed'n, Comment Letter on Agricultural Solar Tariff Generation Units Guideline Straw Proposal (Oct. 29, 2020), https://www.mass.gov/doc/agricultural-solar-tariff-generation-units-guideline-straw-proposal-public-comments (the change-of-use trigger is concerning to various agrivoltaics advocates); Mass. Sierra Club, *supra* note 191.

[290] *See, e.g.*, ARIZ. REV. STAT. ANN § 42-11054(C)(2) (2019) ("Solar energy devices . . . are considered to add no value to the property on which such a device or system is installed.").

generated by this scheme lowers public resistance from some communities.[291] Most importantly, states should ensure that their tax code does not impose burdens that disincentivize agrivoltaics development. To that end, state legislatures can revise agriculture-specific tax code provisions, or add agrivoltaic-specific guidance, to guarantee installing agrivoltaics does not destroy land's agricultural status or trigger a purchase right.[292]

C. Overcoming Community and Market Hesitancy

Policies that mitigate the business risks of agrivoltaics development and encourage communities that host these projects to more willingly embrace them could likewise do much to drive greater private investments in agrivoltaics projects. In particular, Congress could expand federal loan guarantee programs to better assist with agrivoltaics project financing, and local governments could adopt overly zoning ordinances that help to pre-identify agrivoltaics-ready areas within a city or county and drive development in those areas which could help to reduce some of the uncertainty risks.

1. Expanding Federal Loan Guarantee Programs

Because of the relative novelty of agrivoltaics projects and the large initial capital investments required to build them, it can be challenging for developers to secure low-cost financing for these projects. Private lenders are often hesitant to finance new technologies, including new types of renewable energy development. Recognizing this problem more than a decade ago, Congress authorized the creation of a federal loan guarantee program for large-scale solar energy projects as part of the Title 17 Innovative Energy Loan Guarantee Program ("IELGP").[293] The program provided billions of dollars in loans to solar developers while generating millions in federal revenues

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[291] *See, e.g.*, *Grafton, MA*, *supra* note 7 (noting roughly $500,000 in local tax revenue over lifetime of project).

[292] *Compare* NEB. REV. STAT. § 77-6203(4) (2022) (classifying underlying land as if generation facility did not exist), *with supra* note 286.

[293] 42 U.S.C. § 16513; Loan Programs Off., *Renewable Energy & Efficiency Energy Projects Loan Guarantees*, U.S. DEP'T OF ENERGY, https://www.energy.gov/lpo/renewable-energy-efficient-energy-projects-loan-guarantees (last visited Jan. 2, 2022).

through interest payments.[294] By financing early utility-scale solar projects, the IELGP also helped to catalyze the growth of the solar industry.[295] Federal loan guarantees reduced lenders' risks, promoting greater private investment in a relatively unproven industry.[296] As initial solar projects proved to be successful, private lenders have increasingly grown comfortable in financing them even without federal guarantees.[297]

Unfortunately, the current IELGP structure is not compatible with agrivoltaics development. In fact, many agrivoltaics projects may not even qualify for loan guarantees because they must use "new or significantly improved technology."[298] This requirement is particularly troublesome for agrivoltaics, which typically involve novel *placement* or design schemes but use tracking or fixed solar panels—an already proven technology. Moreover, the IELGP prioritizes projects with a "clear strategy" for monetizing tax incentives, and existing incentives' applicability to agrivoltaics is unclear.[299] Applicants must likewise provide data showing proof-of-concept—a requirement that many agrivoltaics-minded applicants likely could not currently meet because data on agrivoltaics is relatively limited and highly region-specific.[300] Developing an adequate knowledge base that enables

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[294] *See* Loan Programs Off., *Stability in a Year of Uncertainty: Annual Portfolio Status Report Fiscal Year 2020,* U.S. DEP'T OF ENERGY, at 2 (2021), https://www.energy.gov/sites/default/files/2021-03/DOELPO_APSR_FY2020.pdf; *id.* at 3, 6, 11 (the IELGP has provided $35 billion in funding, netting over $3 billion in interest payments, and it continues to grow); Loan Programs Off., *Monthly Application Activity Report*, U.S. DEP'T OF ENERGY, https://www.energy.gov/lpo/monthly-application-activity-report (Nov. 30, 2021) (noting $53.6 billion in loan applications); *id.* at 11 (PV solar is responsible for $3 billion in loans and roughly 17% of IELGP's total portfolio, repaying $650 million in fiscal year 2020 alone).

[295] *See id.*

[296] *See* Daniel K. Tracey, *The Missing Lending Link: Why a Federal Loan Guarantee Program Is Critical to the Continued Growth of the Solar Power Industry*, 16 N.C. BANKR. INST. 349, 361–62 (2012).

[297] *See id.* at 362 (discussing the program's near-instantaneous success).

[298] Loan Programs Off., *supra* note 294.

[299] *See* U.S. DEP'T OF ENERGY, SUGGESTIONS FOR A STRONG TITLE XVII INNOVATIVE CLEAN ENERGY LOAN GUARANTEE APPLICATION 2–3 (2016), https://www.energy.gov/sites/default/files/2016/06/f33/Suggestions_for_Strong_Loan_Guarantee_Application_June2016.pdf.

[300] *See id.* at 4 (requiring at least 1,000 of operating data from a "demonstration facility").

agrivoltaics projects to widely qualify for the IELGP will require extensive government investment in pilot projects.

Another federal program that could potentially be modified to assist with agrivoltaics financings is the Rural Energy for America Program ("REAP"), which provides loan guarantees and grant funding to farmers and small businesses investing in renewable energy infrastructure.[301] Unfortunately, REAP is also ill-suited to spur private investment in agrivoltaics development. Among other things, farmers cannot qualify under REAP if their income from surplus power exceeds income from on-farm agricultural operations. This requirement may dissuade some farmers from investing in large-scale agrivoltaics installations that could qualify as a "non-agricultural use" under REAP.[302] A requirement that small business recipients be located in rural areas with 50,000 residents or fewer[303] could further disqualify many solar developers from REAP eligibility.[304]

Congress could relatively easily modify IELGP and REAP to facilitate agrivoltaics projects. For example, Congress could expand REAP's small business restriction to include solar developers for purposes of agrivoltaics development. The Department of Energy could likewise issue guidance clarifying that agrivoltaics projects are eligible for the IELGP even if they use conventional solar panels. And the USDA could clarify that income from the sale of renewable electricity generated onsite does not affect a farmer's eligibility for REAP. These and other modifications could make two potentially valuable existing financing programs better available to farmers and developers seeking to build early large-scale agrivoltaics projects.

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[301] Rural Dev., *Rural Energy for America Program (REAP) Renewable Energy & Energy Efficiency*, U.S. DEP'T OF AGRIC., at 1 (2020), https://www.rd.usda.gov/sites/default/files/factsheet/508_RD_FS_RBS_REAP_RE.pdf (funding "renewable energy systems" and "energy efficiency improvements"); *id.* (REAP guarantees loans up to 75% of total eligible project costs and offers grants up to 25%).

[302] *See id.* To qualify for REAP, at least half of a farmer's gross income must come from "agricultural operations."

[303] *Id.*

[304] *See id.*

2. Using Zoning Laws To Promote Agrivoltaics Development

Even local governments could help to encourage agrivoltaics' growth by creating agrivoltaics overlay zones and by removing zoning-related barriers to agrivoltaics development. State governments delegate broad zoning authority to municipalities to allow for more localized policymaking, but they can also enact statewide land use laws that encourage specified types of development.[305] For example, New York and Ohio have state-wide programs that seek to reduce the soft costs of renewable energy development by streamlining the siting approval processes.[306] Texas has taken an even more aggressive approach, designating resource-rich areas for wind development as "Competitive Renewable Energy Zones" and developing new networks of transmission lines to connect those areas with larger population zones.[307]

At the municipal level, many cities and counties already regulate distributed solar and wind development through zoning.[308] Some municipalities use overlay zoning to promote specific types of development in designated areas within their jurisdiction. Overlay zoning creates a zoning district subject to targeted regulations or incentives that guide development.[309] This pre-approval siting process can encourage renewable energy development by clearing the "red tape" for developers, thus lowering soft costs. For example, the city of Gila Bend,

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[305] Current SMART Guideline, *supra* note 165.

[306] Alexander Fields, Note, *Will Section 94-C Enable Renewable Energy Project Siting and Help New York State Achieve Its Energy Targets?*, 46 COLUM. J. ENV'T L. 125 (2020); *see also* HALL ET AL., *supra* note 52.

[307] *Transmission & CREZ Fact Sheet*, POWERING TEXAS (2018), https://poweringtexas.com/wp-content/uploads/2018/12/Transmission-and-CREZ-Fact-Sheet.pdf.

[308] For example, Woodbury, Minnesota includes residential wind as "a permitted accessory use" and Winnebago County, Illinois passed an ordinance designating wind farms in the county as a "permitted use," meaning no special action permit is required to bypass zoning. WOODBURY, MINN., MUN. CODE § 24-405 (2010); WINNEBAGO CNTY., ILL., MUN. CODE ch. 90, art. 17 (2009). Other large cities have taken similar steps to establish permitted uses. *See, e.g.*, TOWNSHIP OF WAYNE, N.J., MUN. CODE § 134-111.9 (2009); AUSTIN, TEX., MUN. CODE § 25-2-893 (2010).

[309] *See, e.g.*, Jim Malewitz, *$7 Billion Wind Power Project Nears Finish*, TEX. TRIB. (Oct. 14, 2013), https://www.texastribune.org/2013/10/14/7-billion-crez-project-nears-finish-aiding-wind-po/ (noting that Texas' "competitive Renewable Energy Zone" initiative led to "18,500 megawatts of wind power across the state").

Arizona, has adopted an expedited site permitting process for solar development that guarantees project review within two weeks.

Unfortunately, many existing zoning ordinances fail to promote agrivoltaics development. Among other things, placing solar on agriculturally zoned land often causes the parcel to be re-classified as industrially or commercially zoned, which can result in a loss of certain favorable benefits associated with an agricultural zoning designation.[310] Moreover, many communities have not addressed renewable energy development zoning at all, and this uncertainty inhibits potential developers and increases costs.[311] Worse still, some municipalities have used zoning codes to prohibit renewable energy development entirely.[312] Fortunately, most state governments with substantial renewable energy development potential have enacted laws that preempt unreasonable zoning restrictions on renewable energy development.

Because localized resistance can further deter agrivoltaics development, zoning laws that streamline the siting approval process and prevent unreasonable local restrictions on agrivoltaics can also help to encourage this relatively new type of development. Zoning ordinances' local nature allows them to be tailored to the precise needs of communities and specific types of development.[313] Agrivoltaics-specific overlay zones could be a particularly powerful signal to would-be developers that a given community is ready and able to host these important projects.

3. Engaging with Local Communities

Given the important role of community acceptance in agrivoltaics development, rural local governments could also use public education initiatives and green marketing to help increase such acceptance within their jurisdictions. Local governments have long been integral in regulating and installing distributed renewable generation.[314] This long history of locally-driven zoning makes local governments better situated

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[310] *See supra* notes 286–290.

[311] Pursley & Wiseman, *supra* note 225, at 915.

[312] Patricia E. Salkin, *New York Climate Change Report Card: Improvement Needed for More Effective Leadership and Overall Coordination with Local Government*, 80 U. COLO. L. REV. 921, 946 (2009).

[313] *See* Wiseman, *supra* note 150, at 91.

[314] *See, e.g.*, Pursley & Wiseman, *supra* note 225, at 939.

to address community wants, needs, and priorities.[315] Community-driven renewable energy initiatives have proven to be successful in other contexts,[316] and increasing engagement with local citizens and earning their support could similarly help to reduce local resistance to agrivoltaics projects.

Initiatives and programs in some other countries centered on community acceptance of renewable energy could offer valuable guidance in designing such programs for agrivoltaics. For example, Denmark and Germany have promoted community-owned "wind co-operatives" that give communities a personal stake in renewable energy facilities.[317] When communities own an energy facility, the costs and benefits of energy generation remain aligned,[318] increasing local acceptance primarily via community empowerment.[319] Increasing community members' control likewise helps to ensure that each project is more tailored to individual and local needs.[320] Communities with high agrivoltaics potential could similarly consider programs that use co-operative owned agrivoltaics systems to transform community members into shareholders and thereby promote greater local buy-in.[321] Rural citizens are ultimately more likely to welcome agrivoltaics in their

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[315] *Id.* at 929; *see also* Sara Bronin, *Solar Rights*, 89 B.U. L. REV. 1217, 1247–49 (2009).

[316] A successful example of community driven zoning action was California's "Seaweed Rebellion"—where citizens unhappy with federal and state regulations proposing installation of offshore drilling wells backed local zoning measures that blocked "the placement of necessary onshore processing facilities." Pursley & Wiseman, *supra* note 225, at 929, 936.

[317] *See* Nicolaj Stenkjaer, *Wind Turbine Co-ops in Denmark*, NORDIC FOLKECENTER FOR RENEWABLE ENERGY (2008), http://www.folkecenter.net/gb/rd/wind-energy/48007/windturbinecoopsdk/; Stefan Gsänger, *Community Power Empowers*, DISCOVERY (May 26, 2009, 3:23 PM), http://news.discovery.com/tech/community-wind-power-opinion.html; Paul Gipe, *North German State to Double Wind Energy on Land*, AM. SOLAR ENERGY SOC'Y (Feb. 22, 2011), http://www.ases.org/index.php?option=com_myblog&show=North-German-State-to-Double-Wind-Energy-on-Land.html&Itemid=27.

[318] Sharon, *supra* note 216, at 10276.

[319] *Id.* at 10277.

[320] *Id.*

[321] *Id.* ("In general, studies of NIMBYism in renewable energy development consistently find that community ownership models are 'associated with more active patterns of local support.'").

communities if they are given more of an individual stake in at least some of these projects.[322]

Municipal governments can also cultivate community interest in new technologies such as agrivoltaics through green marketing programs designed to raise awareness of and demand for agrivoltaics projects. Voluntary labeling and certification programs already increase demand for products generated in certain eco-friendly ways such as green energy or organic produce.[323] These programs enable consumers to make more beneficial choices by leveraging private companies and consumers' ability to influence change through their purchases. In 2010 alone, the EPA's Energy Star Program saved electricity consumers $18 billion through voluntary labeling.[324] Voluntarily labeling programs have also proven successful for some restaurants and cafes that choose to emphasize their use of organic produce or fair-trade coffee.[325]

Voluntary labeling programs for food products and electricity produced within agrivoltaics projects could similarly help to increase demand for these projects. Labeling produce as agrivoltaics-grown or allowing businesses to advertise that they use agrivoltaics-generated electricity would raise public awareness and demand, creating an incentive for grocery stores and utility companies to supply their customers with these products. Voluntary labeling could also provide farmers with opportunities to capitalize on public recognition of their projects in return for their investment in new technologies.[326] Together with the other policy strategies highlighted in this Article, such programs could finally unleash the true potential of agrivoltaics technologies, enabling them to flourish across the United States.

CONCLUSION

Although agricultural and energy land uses were historically mutually exclusive, agrivoltaics projects site both on the same land in synergistic ways that not only increase a farm's profitability but also allow it to conserve water and help fight climate change. Up to now, the nation's fledgling agrivoltaics

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[322] Zerrenner, *supra* note 241; *see also* Pascaris et al., *supra* note 221, at 3.

[323] *See* Mormann, *supra* note 187, at 954–54.

[324] *Id.* at 953.

[325] *Id.* at 954.

[326] *Id.*

industry has been hindered by inadequate research funding, positive externality problems, and resistance in rural host communities. These obstacles continue to slow the growth of agrivoltaics in the United States and the unique benefits these projects can provide.

Fortunately, a wide array of proven policy strategies are available that could at last unleash agrivoltaics technologies across the country. As an initial matter, greatly expanded federal funding for agrivoltaics research through university extension programs and other means is needed to build a body of knowledge about these technologies. Such knowledge can better inform the development of agrivoltaics laws that fit the distinctive characteristics of various regions of the country. Meanwhile, targeted federal income tax credits and adjustments to state-level renewable portfolio standards and property tax policies could help to address the externality problems that have historically led to underinvestment in agrivoltaics projects. At the municipal level, overlay zoning ordinances and community agrivoltaics programs could likewise help to increase local support for these novel projects. Collectively, these policies could finally enable farmers and the entire country to reap the unique benefits of synergistically improving food, energy, and water security through agrivoltaics projects.