***Rural Policy: The Research Bulletin of the Center for Rural Pennsylvania*, Fall 2024, Volume 3, Issue 1**

Understanding and Addressing the Impact of Solar Development on Pennsylvania Farmland

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Citation: Wiseman, H. et al. (2024). Understanding and Addressing the Impact of Solar Development on Pennsylvania Farmland. *The Research Bulletin of the Center for Rural Pennsylvania, Volume 3* (*Issue 1*). Retrieved from https://doi.org/10.262209/rpvol3iss1pp162.

Abstract: Background: Proposed large (utility-scale) solar energy development in Pennsylvania is growing. Most existing and proposed development is on rural farmland. This study analyzes the demonstrated and potential economic, social, physical, and land-based impacts of utility-scale solar development on farmland, farming practices, and farming communities in Pennsylvania. It then explores a menu of policy options to address these impacts. Method: Study authors conducted a literature review of impacts and solar policies in Pennsylvania and other states; explored and analyzed case studies in four locations; and interviewed 40 individuals. Results: *Physical land-based impacts:* Farmland is temporarily displaced (15 to 30 years) if dual-use agrivoltaic practices (farming beneath and between solar panels) are not pursued. Solar facilities may remain as energy facilities at the end of each facility's useful life due to valuable grid transmission interconnection and a new generation of residents potentially uninterested in farming. *Economics*: Landowner-farmers gain income from solar leases and use the income to continue farming on non-solar land, change farming operations on non-solar land, or retire or change careers. If the site was previously leased, the amount of land available for farmers who rent farmland decreases, which might indirectly impact land rents in the immediate area. There is also no direct evidence of disruption of agricultural supply chains due to utility-scale solar development. Regarding potential secondary positive impacts, there is no solar panel manufacturing in Pennsylvania; solar development can drive temporary construction jobs and some routine maintenance jobs. Local governments can gain tax revenue from roll-back taxes paid when solar facilities occupy agricultural land. Local governments also gain tax revenue from the higher property taxes paid on commercial solar projects. *Social*: Residents express concerns about the aesthetic impacts of solar panels within their communities. Proposed solar facilities cause community conflicts and suppress participation in public discussion of solar facilities, at least in the short term. Some farmer-landowners believe that communities should pay for the preservation of landscapes and views rather than expecting farmers to forgo solar lease benefits.

Keywords: Utility-scale solar energy, agriculture, farming, farmland, sense of place

Executive Summary

Background and Purpose

Many solar energy developers are seeking to build large (utility-scale) solar facilities in Pennsylvania. Nineteen such facilities are operating or partially operating in the Commonwealth, and as of late 2023, at least nine additional projects were under construction (Pennsylvania Department of Environmental Protection (DEP), 2024). Many additional lands have been leased or purchased for the purposes of utility-scale solar development, pending local government approval and permission to interconnect with transmission lines.

The purpose of this study is to identify and analyze the demonstrated and potential economic, social, and physical land-based impacts of utility-scale solar development on farmland, farming practices, and farming communities in Pennsylvania. Based on these findings, the study explores a menu of policy options to mitigate negative impacts and harness the positive outcomes of this development.

Research Methods

We used two research methods to identify the demonstrated and likely economic, social, and physical land-based impacts of utility-scale solar development. These methods included literature reviews and case studies with interviews.

- Review of the academic (peer-reviewed) and gray literature (governmental, nonprofit, and academic/agricultural extension reports) on the impacts of utility-scale solar development on farmland in Pennsylvania and other states, augmented by interviews of experts.
- Pennsylvania case studies: 17 in-person and virtual interviews with local officials, farmer landowners, tenant farmers, neighboring landowners, and business owners in our four case study locations, selected for the following features: [1]
    - Completed utility-scale solar development; site without agrivoltaics;
    - Completed utility-scale solar development; site with agrivoltaics;
    - Rural community in which utility-scale solar development is contested; and
    - Rural community interested in utility-scale solar development, but no project has commenced.
- To augment data from the case studies and analyze issues in other geographic parts of Pennsylvania, we completed an additional 23 interviews with land use planners, solar energy developers, and farmers in Pennsylvania.
- We completed an additional three interviews with experts in states with more utility-scale solar development than Pennsylvania.

We categorized impacts as follows:

- Physical land-based impacts
    - Farmland: changes to agricultural land use; agrivoltaics (dual-use): solar plus crops or livestock.

[1] The majority of these interviews were conducted in person.

    - Community and state: landscape changes, quantity of land occupied by solar development, decommissioning at the end of a solar project's useful life.
- Economic:
    - Farmland and farming practices: impacts on landowner farmer income, land rental rates, and operations.
    - Community and state: impacts on local tax revenues, non-farm property values, supply chains, and "multiplier" effects (spending of income from solar in other sectors).
- Social:
    - Farmland and farming practices: impacts on farmers' goals for their operations and use of their land.
    - Community and state: aesthetics and sense of place, public participation in project review.

Key Findings and Project Results

Physical Land-Based Impacts

Impacts on farmland:

- A substantial percentage of utility-scale solar development is on farmland across the United States and in Pennsylvania, including some prime agricultural soils.
- Farming operations are temporarily displaced for the life of utility-scale solar projects unless agrivoltaics are included.
- Agrivoltaics are uncommon in Pennsylvania but are growing.
- Utility-scale solar farms, unlike warehouses and housing developments, have a relatively impermanent impact on farmland. Installed solar facilities have a useful life of approximately 30 years. Note, however, that solar leases often total 50 years (20 to 25 years for the initial lease term, with an approximate 20- or 25-year extension option). For a solar farm to last more than approximately 30 years, "repowering" (placing new panels on the existing racks) is required (Sorenson et al., 2022, p. 3).
- Solar sites may remain as energy facilities at the end of their useful lives because they have obtained valuable regulatory approval for electric grid interconnection at the sites. With updated interconnection approval, they may be repowered (replaced with new solar panels) or converted to another type of electric facility.
- At the end of a solar facility's life, the equipment at solar sites may not be fully removed, and sites may not be returned to farmland conditions or conditions amenable to transforming the sites back to farmland. This is particularly a risk where local governments have not taken measures at the beginning of solar projects to ensure that solar developers post some sort of financial security—funds that are available in the event the facility is not properly "decommissioned" (removal of equipment and restoration of land).

Economic Impacts

Impacts on farmland:

- Crop and livestock production declines unless agrivoltaics are included in solar projects. Impacts on state and national agricultural production are minimal, but local impacts can be more substantial.
- Solar development displaces land that could otherwise be available for farmers who rent land; many development pressures (including housing in addition to solar) are likely to contribute to higher leasing costs.

Impacts on farming practices:

- Solar development generates lease revenue for farmers. Current lease rates paid in some regions of PA for utility-scale solar range from approximately $800 to $2,200/acre annually, with a typical 2 percent annual inflation escalator built into the lease. This escalator value has been increasing annually.

Impacts on communities and the state:

- Host counties receive increased revenue from the payment of roll-back taxes under the Clean and Green preferential tax assessment program.
- Host townships/boroughs, counties, and school districts may receive increased revenue from the higher property taxes paid by commercial solar projects compared to the property taxes paid by agricultural uses.
- In states with more developed utility-scale solar, there is no direct evidence of farming supply chain impacts from solar development, such as the closure of feed or equipment stores.
- Local governments in areas with concentrated solar activity may experience the temporary growth of local industry, such as minor construction, land excavation, hospitality, and some routine maintenance jobs.
- There is currently no solar manufacturing in Pennsylvania; other states, such as North Carolina, have experienced positive solar supply chain impacts associated with expansive utility-scale solar development. Pennsylvania is unlikely to host solar manufacturing or battery manufacturing; other countries dominate this area, and the smaller amount of US manufacturing is concentrated in a limited number of states.

Social Impacts

Impacts on farming practices:

- Farmers may use the income from solar leasing to retire, in which case farming is unlikely to recommence following the end of the solar facility’s useful life. In other cases, farmers use the income to support farming on the non-solar portions of their land, including expanding operations through renting or purchasing additional land, or adding new types of farming operations.
- Due to the older median age of Pennsylvania farmers, some farmers losing land to solar leasing are choosing to downsize instead of finding replacement acres for those lost to solar development.

Impacts on communities and the state:

- Sense of place: The predominant concern of residents near proposed utility-scale solar development on farmland is aesthetic impact. Many residents believe that solar energy development will affect the rural character of the area in which they live.

- Some landowner-farmers believe that residents concerned about preserving viewsheds should pay for that preservation. These farmers focus on property rights and the burden of forgone solar leasing (and income).
- Controversy surrounding proposed solar developments causes social rifts within communities and makes residents, farmers, and business owners fearful to engage in public discussion regarding proposed solar facilities, at least in the short term.

Conclusions

Utility-scale solar development in Pennsylvania is still at an emerging stage. The Commonwealth ranks last in the nation in the percentage growth of solar, wind, and geothermal energy between 2013 and 2022 (Kerns & Cardoni, 2023). Due to the early phase of utility-scale solar development in Pennsylvania, there is insufficient quantitative evidence amassed to comprehensively analyze impacts. However, based on initial data from Pennsylvania and information from states with more mature development, the impacts of utility-scale solar development on farmland are primarily local. Overall, statewide or national food production will not be substantially reduced by utility-scale solar development.

Experts at the National Renewable Energy Laboratory estimate that if the US were to rely on 100 percent zero-carbon energy generation by 2035, the scenario involving the most renewable energy would require approximately 8.5 million direct acres of land (e.g., acres occupied by solar panels and wind towers), or 0.44 percent of all U.S. contiguous land area for all forms of renewable energy development, not just solar energy (Denholm et al. 2023, pp. 51-53). [2] A study in the Netherlands estimated that a much larger percentage of land occupied by solar energy than the land projected to be occupied in the United States–1 percent of all agricultural land–would change land and food prices by 0.5 percent (van der Horst, 2019).

Although national food production is unlikely to be substantially affected by utility-scale solar development, local impacts can be more prominent. When numerous landowners within one community lease their land for solar development, this has localized impacts on food and livestock production and the land available for farming.

Residents also express concerns about the impacts of solar on aesthetics and the rural character of communities, while some farmer-landowners focus on property rights. For long-term aesthetic and safety concerns, decommissioning of solar panels will be an important consideration at the end of a facility's useful life, but many stakeholders discuss the possibility that non-uniform or overly stringent decommissioning requirements imposed by local governments could stifle project development.

[2] If one includes the space between wind towers in the estimate of land required for 100 percent zero-carbon energy by 2035 (under the maximum renewable energy scenario), the land required expands to 112.7 million acres, which is 5.96% of US contiguous land area (Denholm et al., 2023, p. 53). It is relatively common for farmers to use the land between wind towers for grazing and other purposes.

Benefits of utility-scale solar include roll-back tax revenue to local governments, increased local tax revenue from commercial land, lease income to farmer landowners, and likely but not yet measured multiplier effects from this income. Other states, such as North Carolina and Ohio, with more utility-scale solar development have also experienced positive job-based, solar panel manufacturing, and supply chain results.

Policy Considerations

Physical Land-Based Impacts

- Consider providing state incentives for the siting of solar in locations without prime agricultural soils (USDA Class I and II).
- Provide additional incentives–beyond those currently being pursued by the DEP–for the development of solar on disturbed lands such as former mine lands.
- Implement incentives and other policies to harness the benefits of agrivoltaics to be identified by the Joint State Government Commission—a Commission tasked by House Resolution 224 (2023) to study the benefits and opportunities of agrivoltaics.

Economic and Social Impacts

- Provide additional funding for data collection and studies that address the social and economic impacts of utility-scale solar facilities in Pennsylvania as developers construct and continue to operate more facilities, including, for example, local government tax revenues and job creation.
- Track and record the acreage and type of land (farmland, former industrial) and specific type of soil on which each utility-scale solar facility is located.
- Consider implementing a Payment in Lieu of Taxes (PILOT) local government option for solar energy and revising the Clean and Green preferential tax assessment program to align with wind energy and oil and gas development.
- Continue considering uniform, statewide regulation of bonding and decommissioning of utility-scale solar energy.
- Continue and expand the Pennsylvania Department of Environmental Protection's work providing information for local governments to help them effectively regulate utility-scale solar development.
- Convene a statewide session of local government officials and DEP experts at annual meetings of county and township associations to share effective strategies for utility-scale solar regulation. Publish a white paper summarizing the workshop conclusions.
- Continue considering the allowance of mid-scale "community solar" projects in Pennsylvania that avoid interconnection delays and can be more strategically sited to address concerns about aesthetics and solar on prime agricultural soils.

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Background

Pennsylvania is a major producer and exporter of fossil fuel-based energy, and the state's consumption of electricity is growing. The Commonwealth is also a leading agricultural state. As of 2022, Pennsylvania had 49,053 farms covering 7.05 million acres, ranking 33rd among the states for the amount of land in farms and 14th for the number of farms (USDA, 2024). Pennsylvania farmers produced more than $10 billion in crops and livestock in 2022, which contributes to thousands of food-related jobs and billions of dollars more in economic activity (Pennsylvania Department of Agriculture, n.d.a.). The state ranked 23rd among states for agricultural exports in 2022 (USDA, 2024).

Rural farmland rests at the nexus of Pennsylvania's energy and agricultural economies because it is attractive for utility-scale solar development—the fastest-growing form of electric generation capacity in the US (US Energy Information Administration, 2024). The majority of Pennsylvania's total current solar energy development (representing only 0.57% of electricity output in 2022) is small, consisting of solar panels on residential rooftops and commercial sites for onsite electricity consumption (SEIA, 2023b). Nationwide, however, from now through 2050, *utility-scale* solar is expected to account for 80 to 90 percent of new solar capacity (US Department of Energy, 2021, p. 6). [3] As it is nationwide, utility-scale solar development is growing in Pennsylvania. This raises questions about how utility-scale solar development will present challenges and opportunities with respect to land use, economics, and social impacts in rural agricultural regions of Pennsylvania.

Introduction

Pennsylvania farms have experienced a range of impacts associated with the "siting" (location) of infrastructure on farmland in recent decades. These have included, for example, cell phone towers, Marcellus gas wells, warehouses, housing developments, and wind farms. Utility-scale solar development, which is growing in Pennsylvania, re-raises ongoing questions about the use of farmland for non-farming purposes.

In this report, we define utility-scale solar development as solar installations that serve customers beyond the site on which the installations are located and that feed electricity back to the electric grid. As utility-scale solar expands throughout the US, some of this growth will occur in Pennsylvania. This is due to state and federal policies, goals, and incentives; competitive economic forces; growing demands for lower-carbon

[3] Utility-scale solar facilities, which accounted for approximately two-thirds of all US solar generation capacity, had 73 gigawatts (GW) of electrical generating capacity as of January 2023 (US Energy Information Administration, 2023; SEIA and Wood Mackenzie, 2022, p. 15). This amounted to six percent of total US electrical generating capacity. In the first quarter of 2023, the US added 6.1 GW of solar capacity, accounting for 54 percent of new electricity-generating capacity. (SEIA, 2023a). In 2050, solar projects are expected to provide 45 percent of US electricity (US Department of Energy, 2021). A megawatt is a measure of power equal to one million watts and is able to provide electricity to approximately 190 homes. A gigawatt is a unit of electricity equal to one billion watts (1,000 megawatts), able to power approximately 750,000 homes (Dellinger, 2022). In early 2023, the SEIA projected that Pennsylvania would add 2.806 GW over the next five years. This would rank Pennsylvania 18th among states adding solar capacity (SEIA, 2023b).

energy from corporate shareholders and other stakeholders; and Pennsylvania's abundant open, flat land (much of which is farmland) and transmission line infrastructure. The economic forces pushing solar development tend to favor utility-scale solar, specifically because of the economies of scale in electricity generation. Larger solar projects have a lower cost per megawatt to build and operate (Lazard, 2023, p. 2).

In the realm of policies, goals, and incentives, Pennsylvania's Solar Future Plan of 2018 set a goal for in-state solar facilities to provide 10 percent of in-state electricity consumption by 2030 (DEP 2018, p. 9). Additionally, the federal Inflation Reduction Act of 2022 offers incentives that could drive more solar development. Specifically, it expands an investment tax credit for solar projects that provides money to developers at the time of construction and creates a production tax credit that provides money when solar energy is generated.

In addition to responding to policy signals, developers are seeking to build utility-scale solar energy in Pennsylvania and other states because solar is the least expensive form of new electricity generation capacity in the US (US Energy Information Administration, 2023). Furthermore, large corporations are entering into power purchase agreements (PPAs, which are long-term contracts) with solar developers to fulfill low-carbon commitments to shareholders (Schellhammer, 2021). Educational institutions, including, for example, The Pennsylvania State University, the University of Pennsylvania, Dickinson College, and six universities and colleges associated with the Keystone Solar project, are entering into similar PPAs (Lightsource BP, n.d.; Crable, 2024; Community Energy, n.d.; Dickinson, n.d.).

As a result of these trends, utility-scale solar development in Pennsylvania is already expanding, although more slowly than in other states. [4] There are currently 19 utility-scale solar facilities operating or partially operating in Pennsylvania, and at least nine under construction (Pennsylvania Department of Environmental Protection, 2024). The vast majority of utility-scale solar facilities in Pennsylvania have in-service dates of 2023 (Pennsylvania Department of Environmental Protection, 2024).

Although there are only 19 utility-scale solar projects in service or partially in service in Pennsylvania as of February 13, 2024—as compared to, for example, approximately 670 such projects in North Carolina (Susser, 2021) [5]—there are signs that utility-scale solar will substantially grow in the Commonwealth, depending on a variety of factors. The availability of transmission interconnections, landowners' willingness to lease land, and local governments' regulations for solar developments will determine the pace at which growth occurs. Figure 1 shows the total number of proposed utility-scale solar projects—450—waiting for interconnection with the transmission grid operated by an organization called PJM as of December 2023.

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[4] The Solar Energy Industries Association (SEIA) reported that Pennsylvania had 1.275 GW of solar generating capacity at the end of 2023; the Commonwealth ranked 24th among states for installed solar capacity (SEIA, 2024).

[5] Neighboring states such as Ohio also have far more utility-scale solar capacity than Pennsylvania. Ohio has more than 25 facilities that exceed 1 gigawatt (1,000 MW) (Ohio Power Siting Board, 2024a), whereas the largest utility-scale solar facility in Pennsylvania is 100 MW. See Table 1.

Figure 1: Proposed Utility-Scale Solar Projects Awaiting Interconnection with Pennsylvania's Regional Grid as of December 7, 2023 (DEP, 2024b; PJM, n.d.) 5F

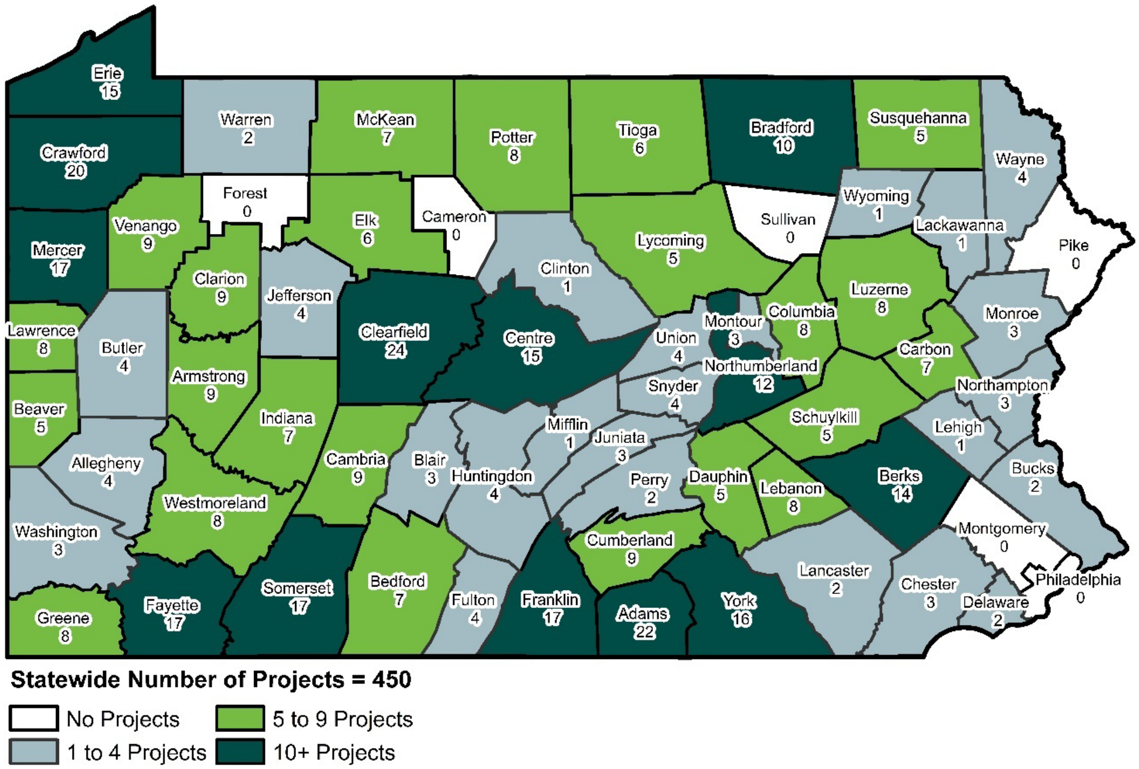


Table 1 summarizes the utility-scale solar developments already built in Pennsylvania. [6]

[6] Table 1 uses this report's definition of utility-scale solar development (production for off-site uses) but also meets other definitions. Utility-scale solar is often defined as a project capable of generating at least five megawatts of electricity (Daniels, 2023b), and as shown in the table, all but one of the projects listed meet this definition.

Table 1: Fully and Partially Operational Utility-Scale Solar Facilities in Pennsylvania as of February 13, 2024 (Pennsylvania Department of Environmental Protection, 2024a; PJM, n.d.) 7F

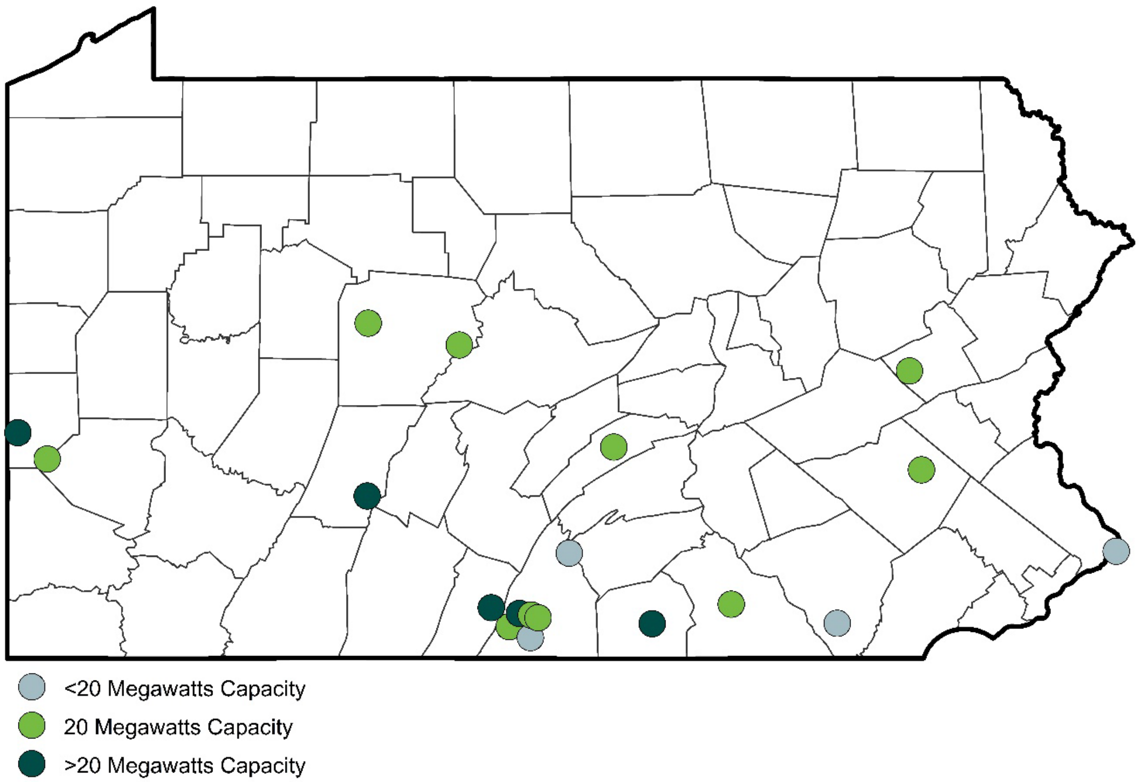
Name of Solar Facility	Developer	Location	Megawatts Capacity	Year First in Service
Adams Solar	Energix Renewables	Straban Township, Adams County	100	2023
Great Cove Solar #2	AES	Peters Township, Franklin County	150	2023
Great Cove Solar #1	AES	Ayr Township, Fulton County	70	2023
Cottontail Solar #5 [7]	Lightsource BP	Walker Townships, Juniata County	20	2023
Cottontail Solar #2	Lightsource BP	West Manchester Township, York County	20	2023
Lyons	Belltown Power	Richmond Township, Berks County	20	2023
CPV Maple Hill	CPV	Portage Township, Cambria County	100	2023
Pine Solar	Four Twelve Renewables	Greene Township, Beaver County	34.2	2023
Gaucho Solar	Vesper Energy	Findlay Township, Allegheny County; Independence Township, Beaver County	20	2023
CL-Viaduct	Pine Gate Renewables	Bloom Township, Clearfield County	20	2023
UN-School House	Pine Gate Renewables	Morris Township, Clearfield County	20	2023

[7] Cottontail Solar #5 and Great Cove Solar #1 have the same in-service date (December 8, 2023) (Pennsylvania Department of Environmental Protection, 2024).

Name of Solar Facility	Developer	Location	Megawatts Capacity	Year First in Service
Elk Hill #1	Lightsource bp	Peter Township, Franklin County	20	2022
Whitetail Solar #3	Lightsource bp	St. Thomas Township, Franklin County	20	2021
Whitetail Solar #2	Lightsource bp		20	2021
Elk Hill #2	Lightsource bp	Peters and Montgomery Townships, Franklin County	15	2020
PA Solar Park	Green Capital Partners	Nesquehoning Borough, Carbon County	20	2020
Whitetail Solar #1	Lightsource bp	Lurgin Township, Franklin County	13.5	2019
Keystone Solar	Community Energy	East Drumore Township, Lancaster County	5	2012
Exelon Epuron Solar Energy Center	Epuron	Falls Township, Bucks County	3.3	2008

Figure 2 summarizes the data from Table 1 in a map-based format.

Figure 2: Fully and Partially Operational Utility-Scale Solar Facilities in Pennsylvania as of February 13, 2024 (Pennsylvania Department of Environmental Protection, 2024a; PJM, n.d.) 9F [8]



Several of the existing utility-scale solar developments listed in Table 1 are on farmland, including the most recently constructed developments. For example, Gaucho Solar, Great Cove Solar 1 and 2, and Cottontail 2 have been reported to be on farmland (Crable, 2024; Kaplan, 2021; and Wagoner, 2023). Pennsylvania does not require utility-scale solar developers to report the specific type of land or soil on which their development is located, so these are examples rather than a comprehensive list of the utility-scale facilities on farmland in Pennsylvania. [9] Many new solar projects will occupy

[8] Data provided by PJM; analysis provided by the Pennsylvania Department of Environmental Protection. Map prepared by Jonathan Johnson, Center for Rural Pennsylvania, using DEP analysis.
[9] It appears that most states lack formal requirements for solar developers to report the specific types of land—for example, agricultural lands or specific soil types—on which proposed solar farms are located. Solar developers do, however, have to prepare detailed assessments of the habitat potentially affected by development and whether this habitat houses endangered or threatened species, wetlands, and surface waters on the proposed site (NY Office of Renewable Energy Siting, 2024).

farmland, however. Farmland tends to present lower rental or purchase costs and offers unfragmented (large) parcel ownership, relatively low slope grades, and greater depth to bedrock–and therefore greater ease of installing the posts that support solar panels (Daniels & Wagner, 2022). Agricultural sites also tend to allow solar developers to avoid wetlands and other protected habitats. [10]

To achieve Pennsylvania's Solar Future Plan, new solar projects would require between 86,300 and 172,600 acres of total land, representing 1.2 to 2.4 percent of Pennsylvania's farmland if solar were exclusively built on farmland (Spangler et al., 2024, p. 3). Nationwide, the American Farmland Trust estimates that approximately 83 percent of new solar installations are on farmland, with 50 percent of those projects "placed on the most productive, versatile, and resilient land" (Sorenson et al., 2022, p. 10). Other experts similarly project that as much as 80 percent of new nationwide solar development by 2040 will occur on farmland (Beck et al., 2022).

With such a large number of utility-scale projects potentially on the horizon—many of which would be constructed on farmland—it is important to assess the potential impacts of a large expansion of a new industrial sector in Pennsylvania. This report addresses utility-scale solar development opportunities and obstacles on rural, agricultural land in the short and long term, current solar policies relevant to rural communities and agriculture across states, and how policies may need to evolve to achieve renewable electricity benefits and mitigate negative impacts on rural communities.

Goals and Objectives

The goals and objectives of this report are as follows, using data from interviews and the existing literature:

1. Identify and analyze the existing and potential physical land-based impacts of utility-scale solar development in Pennsylvania, with a focus on rural communities and farmland;
2. Identify and analyze the existing and potential economic impacts of utility-scale solar development on Pennsylvania farmland, farming operations, communities, and the state;
3. Identify and analyze the existing and potential social impacts of utility-scale solar development on Pennsylvania farmland, farming operations, and communities;
4. Explore local governments' and other states' policy approaches to the economic, social, and land-based impacts of utility-scale solar energy;

Studies that estimate the amount of agricultural land occupied by or likely to be occupied by solar use datasets such as the National Land Cover Dataset (Hernandez et al., 2015, p. 13584).

[10] The report authors evaluated the correlation between solar proposals and available farmland in Pennsylvania. We plotted the number of proposed solar projects from a county in the PJM queue (as of Dec. 7, 2023, based on data obtained from the DEP) against the acreage of farmland in a given county (as of 2022, based on data obtained from the Center for Rural Pennsylvania). We then used Microsoft Excel to generate a best-fit (linear) trendline for the data. The R2 value of that trendline was only 0.2151, indicating a very weak statistical correlation between solar proposals and available farmland in Pennsylvania based on current data.

5. Identify a range of policy options at the state level and local options with state guidance to mitigate negative impacts and achieve positive outcomes for farmland owners, communities, and the growth of solar energy production in Pennsylvania.

Methodology

This study presents information compiled by experts on solar energy development in Pennsylvania. The key methods that were utilized to present this data were: 1) a literature review and interviews of utility-scale solar experts in other states; 2) interviews with stakeholders for four case studies and other Pennsylvania stakeholders; and 3) document identification and analysis, including analysis of court documents in contested Pennsylvania solar cases, local solar energy ordinances, and other states' policies.

Literature review and expert interviews:

We conducted a literature review of the peer-reviewed and gray literature (governmental, nonprofit, and academic/agricultural extension reports) on the proven impacts of utility-scale development in Pennsylvania and other states. Most of this literature addresses the impacts of more extensive utility-scale development in other states—impacts that are likely to also arise in Pennsylvania if solar development expands. Many of these impacts are similar across all states due to the nature of solar development, including solar developers' preference for siting utility-scale farms on farmland and near existing transmission lines. Solar farms will have similar aesthetic impacts across states, although varied regulations among states and local governments will affect the amount of fencing, landscaping, or other infrastructure around solar sites that reduces aesthetic impacts, and community residents' reactions to aesthetic impacts will differ. Additionally, general agricultural impacts such as increased competition for land available for agricultural rentals, displacement of agricultural land in the absence of agrivoltaics, and lease benefits to farmers (although varying in amount) are present across states (Grout & Ifft, 2018). These impacts will have differences in Pennsylvania that we explore, such as different approaches to removing agricultural conservation tax benefits when solar is installed.

We augmented this literature review with interviews with experts in other states, such as Ohio and North Carolina, where more solar development has occurred than in Pennsylvania, and experts who have researched such states. We focused on Ohio, North Carolina, and other states that, like Pennsylvania, have relatively large amounts of farmland and rural areas and that have substantial amounts of local government control over solar energy development. We asked these experts about solar tax policy, farmer-specific impacts, community impacts, methods for ascertaining impacts on residents' "sense of place," and local regulation of utility-scale solar development.

Case studies:

To further augment data from the literature and experts and to substantiate and provide examples of findings, this report draws upon case studies of solar energy projects at different stages of development that demonstrate different outcomes in Pennsylvania. General case study selection criteria included project diversity with respect to geographic location in Pennsylvania; stage of development (including projects proposed but not built); impacts on agriculture and agricultural operations; and conditions within communities, including level of community support for opposition. We selected two completed utility-scale solar developments (one involving agrivoltaics in the form of sheep grazing and one with no agrivoltaics), one proposed development in a community interested in utility-scale solar, and one proposed development in a "contested" community with substantial opposition to solar.

Our goal in applying these criteria to specific case study sites was to highlight developers' interest in a variety of regions in Pennsylvania. These four case studies are in four different counties in two different regions of the Commonwealth (South Central and North Central), where the bulk of grid-scale solar energy development is in progress due to access to transmission, low population densities, and land availability. The Northwest region is a third region of interest; we did not pursue a case study in this area but did have conversations with stakeholders in this area and conducted a full interview with one stakeholder in this area. We also endeavored to explore substantially different agricultural community dynamics, including insights into the local siting processes at the township and county levels of government. Further, we selected these case studies to demonstrate that some utility-scale solar projects better integrate agricultural, social, and ecological functions than others.

Interviews of individuals in case study areas and other Pennsylvania stakeholders:

For each of our case studies, and to glean data from stakeholders throughout Pennsylvania (beyond case study locations), interviews were conducted to understand the development narrative and different stakeholders' perspectives and to gather details relevant to our research questions involving land-based, economic, and social impacts. Individuals were identified through publicly facing websites, attendance at conferences (i.e., Pennsylvania State Association of Township Supervisors), snowball sampling (i.e., asking interviewees to identify additional people who could provide additional perspectives or information), and through mediators (i.e., individuals who have access to key contacts). Individuals were recruited through email, phone, or text-based contact based on their involvement in the project. Please see Appendix 3 for a full description of the interview protocol.

Document identification and analysis:

Pennsylvania predominantly regulates solar energy at the local level, so understanding the impact of solar development on farmland in Pennsylvania requires an investigation of local approaches to the regulation of solar projects. To identify local solar regulations—including borough, city, county, town, and township regulations—we conducted an electronic review of each local government's zoning code (if any) through eCode 360®, a digital compilation of local ordinances. We also searched for zoning codes and ordinances specific to solar energy through general web search engines and on the websites of Pennsylvania local governments. After locating zoning codes and solar ordinances, we searched these documents for language specific to utility-scale or commercial-scale solar and tagged any language that included this type of solar energy.

To identify and analyze other states' solar policies, we relied on the expertise of two report authors who have researched states' solar policies for more than a decade. These authors reviewed already-known policy sources and identified more recent policies through consultation with experts and regular analysis of solar policy news publications.

Finally, for the contested solar case study, we conducted an in-person review of court documents pertaining to the case.

Results and Findings

Physical Land-Based Impacts

Pennsylvania has abundant farmland, and some utility-scale solar development occurs on this farmland. Farmland is an attractive location for utility-scale solar development because it is already cleared and has a relatively flat grade, fewer wetlands or preserved wildlife habitats than other sites, good drainage, and few physical impediments or hazards such as ditches. Farmland is also often close to transmission lines with which to interconnect—a priority for utility-scale solar developers (Spangler et al., 2024, p. 2). This section describes Pennsylvania farmland and Pennsylvania's programs for preserving farmland. It then analyzes the ways in which utility-scale solar development is impacting farmland not enrolled in preservation programs.

<u>Pennsylvania's preserved and protected farmland:</u>

Pennsylvania has more farms and total farm acreage "permanently preserved for agricultural production" than does any other U.S. state, totaling nearly 700,000 acres (Pennsylvania Department of Agriculture, 2023b). In this report, agricultural preservation refers to land voluntarily preserved through an agricultural conservation easement; no utility-scale solar development is allowed on this land. Agricultural "protection" refers to land voluntarily enrolled in programs that incentivize agricultural uses of land through, for example, tax benefits; farmers may lease their "protected" land for utility-scale solar and simply lose or risk losing protection status for their land, as discussed in this section.

The Commonwealth has four farmland protection and preservation programs that include financial incentives for farmers, as summarized in Table 2. These programs discourage or prohibit utility-scale solar development on preserved farmland. When farmland is permanently preserved through a conservation easement, the land can be used only for agricultural or open space uses. However, in the case of solar, a small solar array producing electricity for use only on the farm could be allowed on preserved land. Utility-scale solar is a commercial or industrial use that, so far, is not permitted under a conservation easement acquired through the State of Pennsylvania farmland preservation program.

In contrast to conservation easement lands, utility-scale solar is allowed on lands enrolled in the protection programs noted below. In the case of Clean and Green, the land loses its Clean and Green status if utility-scale solar is built on the land. In the case of Agricultural Security Areas, the land may lose its protection status if utility-scale solar is built on the land and the local government removes the land from the Agricultural Security Area.

Table 2: Pennsylvania Farmland Protection and Preservation Programs [11]

Name of Program	Governing Statute(s) and Regulation(s)	Eligible Lands	Program Incentives	Intersection with Utility-Scale Solar
Agricultural Security Area (protection program)	3 P.S. 905, 911	At least 250 acres of "viable agricultural land," with each tax parcel at least 10 acres and meeting yearly gross income requirements.	Enhanced state review before land can be condemned; some protection from local ordinances and lawsuits that restrict normal farming. Makes landowners eligible to sell agricultural conservation easements to the county/state farmland preservation program.	Land potentially removed from ASA in township's seven-year review. No financial penalty for removal (Pennsylvania Department of Agriculture, 2022).
Clean & Green (protection program)	72 P.S. 5490	At least 10 acres (or capable of generating $2,000 in annual income); in Agricultural Use, Agricultural Reserve, or Forest Reserve	Property taxes-use value	Penalty of "[s]even years of rollback taxes at 6% interest per year" on entire property if solar is installed (Pennsylvania Department of Agriculture, 2023a). Solar developer pays.

[11] This table excludes the Century & Bicentennial Farm Program, which recognizes and celebrates long-time farming families but does not include financial incentives.

Agricultural Conservation Easement Purchase (preservation program)	3 P.S. 914.1	Land in Ag. Security Areas or lands meeting other criteria established by counties.	State, counties, local governments, and eligible nonprofits may purchase perpetual agricultural conservation easements.	County criteria vary; requirement that energy be used on site to qualify for easement is guidance but is followed by counties (Pennsylvania Department of Agriculture, 2022). [12]
Beginning Farmer Realty Transfer Tax Exemption (preservation-related program)	72 P.S. 8102-C.3	Lands under agricultural conservation easements in an Agricultural Security Area.	Exemption from real estate transfer tax of one percent of real estate value, 72 P.S. 8102-C.	No utility-scale solar permitted on conservation easement lands (Pennsylvania Department of Agriculture, 2022).

[12] The standard language in easements includes a broad prohibition on commercial and industrial uses, and utility-scale solar is a commercial or industrial use. However, neither Pennsylvania's agricultural conservation easement purchase program's enabling legislation, nor its implementing regulations, specifically permit or prohibit the use of land subject to an agricultural conservation easement for the production of electricity for transmission off-site and use by third parties. That determination is made by reference to the individual county program requirements adopted by each county farmland preservation program governing board, which define in that county the "customary part-time or off-season minor or rural enterprises and activities" that an agricultural conservation easement "shall not prevent" pursuant to 3 P.S. 914.1(c)(6)(v). According to that statutory section, uses that may be allowed in a county as a "rural enterprise" are to be "provided for in the county Agricultural Conservation Easement Purchase Program approved by the State board[.]" A compilation of the rural enterprise criteria of the 58 county programs in Pennsylvania is contained in Appendix 5 hereto. Each county program's language must be individually consulted to determine specifically what is permitted as a rural enterprise—a project that we undertook and summarized in the Appendix. Where the production of energy of any form is referenced in county program definitions of allowable rural enterprises, requirements are routinely imposed in all counties that exclude the installation and operation of grid-scale solar electricity production. Examples include: 1) incidental to the agricultural use, 2) the energy produced must be available for use on site, 3) permanent structures must be located in the curtilage of existing farm buildings, and 4) coverage limitations expressed as a prohibitively small percentage of the total agricultural conservation easement area.

A long-running debate exists between advocates of preserving farmland and those who call for supporting farmers. On the one hand, farmland preservation is a voluntary process in which a landowner receives payment in return for agreeing not to develop his or her farm except for agricultural, forestry, or open space land uses. On the other hand, the farmland preservation payment goes to one generation. It is not a recurring payment. The economics of farming favor large operations with more than $500,000 a year in gross sales. Owners of smaller farms often rely on income unrelated to farming (Giri et al., 2021).

Given these economic constraints for small farmers, in particular, the opportunity to lease preserved farmland for utility-scale solar development can be an attractive option, especially for farmers nearing retirement. The State of Michigan passed a law in 2023 to allow solar projects that generate power for sale off-site to be located on preserved farmland (Michigan Legislature, 2023). The reasoning behind the law was that solar panels were a temporary (30-year) “crop,” and the land could be returned to agricultural production at some future date.

<u>Utility-scale solar development on farmland:</u>

Despite Pennsylvania’s guidance that excludes utility-scale solar from farmland preserved through voluntary agricultural conservation easements and the removal of utility-scale solar sites from preferential tax assessments for farmland, energy facilities are sited on a variety of land types, including farmland. This is because a large amount of Pennsylvania farmland is not preserved under voluntary agricultural conservation easements. For farmland that is not under an agricultural easement but is enrolled in Pennsylvania’s “Clean and Green” preferential tax assessment program, the land will be removed from the preferential tax assessment program when the owner leases the land for solar development. Following this removal, farmers are required to pay penalties in the form of roll-back taxes. The solar developer typically pays these penalties under the lease agreement.

The percentage of utility-scale facilities located on farmland versus other types of land varies substantially among states. For example, in California through 2015, 28 percent of utility-scale solar installations “are located in croplands and pastures,” with the majority of such installations found on “shrublands and scrublands (Hernandez et al., 2015). In North Carolina, approximately 78.5 percent of utility-scale solar farms were located on farmland as of December 2016, the most recent complete analysis in that state (NC Sustainable Energy Association, 2017).

A substantial percentage of the land that hosts existing utility-scale development in Pennsylvania is farmland. The Pennsylvania DEP does not track the type of land on which solar energy facilities are sited, and applications from solar developers to the Pennsylvania Public Utility Commission only roughly describe the land type on which solar energy facilities are proposed to be sited, using terms such as open land, wooded land, or brownfields. However, the four case studies that highlight and expand upon our findings all involve utility-scale solar projects on former farmland. Additionally, much of the land on which solar development is proposed is farmland. A mid-2023 analysis of the 546 utility-scale projects in the Pennsylvania portion of the PJM queue indicated 82 percent of them would be on open land, 5 percent on forested land, 4 percent on brownfield sites, and 9 percent on "other" lands (Pennsylvania Department of Environmental Protection, 2023). The same review identified a significant amount of open land that was farmland of some classification. Also, as noted in the Introduction, if all of the new solar energy envisioned in Pennsylvania's Solar Future plan were built on farmland, solar would occupy 1.2 to 2.4 percent of Pennsylvania farmland. In comparison, in North Carolina in 2017, utility-scale solar developments occupied 0.28 percent of agricultural land in the state (NC Sustainable Energy Association, 2022, p. 4). Nationally, the US Department of Energy estimates that "0.3% of farmland is expected to be used for solar energy by 2035" (US Department of Energy, n.d. a).

Some of the farmland on which utility-scale solar may be built in the future in Pennsylvania includes prime agricultural land. The Pennsylvania Municipalities Planning Code section 107 defines "prime agricultural land" as "land used for agricultural purposes that contains soils of the first, second, or third class as defined by the United States Department of Agriculture natural resource and conservation services county soil survey." A limited survey of members of the West Branch Crop Management Association who had leased land for potential solar development indicated that fields with Class I, II, and III soils were the lands most commonly under agreement for solar (Laughner, 2023). These classes represent the types of soils that are easiest to manage for crop production and other agricultural activities.

The use of farmland for utility-scale solar development is an important issue because farmland protection and preservation are a policy priority in the Commonwealth, as shown by the protection and preservation policies summarized in Table 2. As noted above, utility-scale solar development *can* and sometimes does occur on farmland that has been protected through Clean and Green or an Agricultural Security Area Program. In this case, the farmland will be removed from the Clean and Green Program and roll-back taxes paid, and the land will likely also be removed from an Agricultural Security Area by the municipality upon its next seven-year review of agricultural security areas. Farmland faces many development pressures beyond utility-scale solar development, including residential and warehouse development. These forms of development impact soils more than utility-scale solar development—placing pavement and large structures on those soils—and tend to more permanently displace farmland.

Despite the less permanent nature of utility-scale solar projects as compared to other development types, there is a possibility that solar facilities, which have highly valuable established approval to interconnect to the electric grid at a particular site, will continue to be used as energy facilities after the end of the useful life of the first-installed panels (after 20 to 50 years or more of operation) [13] (US Department of Energy, n.d. b). At the end of the useful life of the solar facility, there is a reasonable possibility that new solar panels will be placed on the property—a process called "repowering"—or another developer might seek other energy-based uses for the land. Furthermore, if the remainder of the property not in solar production does not continue to be farmed by the farmer who leased it to the solar developer, the farmer's children, or a tenant farmer

[13] As noted above, solar leases often total 50 years (20 to 25 years initial lease term, with an approximate 20- or 25-year extension option). For a solar farm to last more than approximately 30 years, "repowering" (placing new panels on the existing racks) is required (Sorenson et al., 2022, p. 3).

during the life of the first solar facility, there may be little interest in returning the solar property to farmland at the end of the solar facility's useful life. Farming activity within the community also may have declined over the 20 to 50 years during which a solar lease may be active, thus further reducing the likelihood of the solar site returning to farmland. [14]

Dual-use agrivoltaics:

The development of utility-scale solar on farmland is of lesser concern if farming practices continue below and between solar panels—a practice called dual-use agrivoltaics. There are many types of agrivoltaics. In some cases, farmers can continue farming practices that preceded utility-scale solar development, but in other cases, these uses are not compatible with solar panels. For example, although hay crops can grow beneath solar panels, the machinery required to mow and bale the hay is more difficult to operate beneath solar panels, depending on how they are installed. [15] Additionally, although cattle can graze beneath solar panels, it is more expensive to build solar farms at heights that are compatible with cattle. As a result of these challenges, farmers sometimes change farming practices in order to farm beneath and between solar panels, such as starting to raise sheep. It may take time for necessary supply chain services, such as sheep and wool processing, to emerge to support these new practices. It is worth noting, however, that Pennsylvania already hosts one of the largest sheep markets in the United States (Petrosemolo, 2022).

Several of Pennsylvania's predominant types of farming are not fully compatible with solar panels. In 2022, 34 percent of agriculture sales were from crops, and 36 percent of sales were from "livestock, poultry, and products" (USDA, 2024). Hay and haylage and corn for grain were the predominant crops (*Ibid.*). As noted above, harvesting equipment for these types of crops is often not compatible with solar panels. In 2022, the most common livestock in Pennsylvania were broilers and other meat chickens, followed by layers, pullets, and turkeys (*Ibid.*). Turkeys and chickens in Pennsylvania tend to be raised within enclosed structures. There were 94,370 sheep and lambs in Pennsylvania in 2017 (a type of livestock that is very compatible with solar panels), as compared to 1.6 million cattle and calves (*Ibid.*).

Agrivoltaics on utility-scale solar projects are uncommon at existing Pennsylvania utility-scale solar facilities and elsewhere, but they are now proposed for many new utility-scale solar projects in Pennsylvania (Horowitz et al., 2020, p. 2; inSPIRE, n.d.). Current agrivoltaic practices in PA are centered on grazing sheep and raising pollinator crops. Grazing is trending as more common, with numerous companies planning to contract grazing services for vegetation management under solar panels after they are constructed and after the vegetation is established to the point of potentially withstanding the impact of the animals. There is currently a shortage of sheep available for this form of agrivoltaics, but a small number of farmers are seeing an opportunity, increasing the size of their flocks, and attempting to match emerging demand (Crable, 2022).

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[14] *See supra* note 15 for an explanation of the length of operation of solar facilities as compared to the length of solar leases.

[15] Farmers have harvested hay under conventional ground-mounted solar panels in New York and Ohio.

Costs associated with grazing in solar energy developments include purchasing and transporting sheep, veterinary services, site preparation (fencing, water); soil and forage testing to ensure a successful grazing environment; and some supplemental mechanical mowing and weed removal. The revenue associated with agrivoltaics comes from both the vegetation management contracts with solar companies (grazing in lieu of mowing to control the vegetation beneath and between solar panels) and from the sales of sheep.

In parallel with grazing as a growing form of agrivoltaic practice in Pennsylvania and elsewhere, there are new agrivoltaic systems from EU countries showing potential under and between solar panels, which allow more conventional usage of the farmland for expensive crops such as corn, soybeans, and wheat (EU Science Hub, 2023).

<u>Siting on disturbed lands:</u>

One way to reduce the amount of farmland used for utility-scale solar development is to site solar facilities on disturbed lands—those previously used for commercial or industrial development, such as landfills, or for resource extraction, such as coal mining, among other types of lands. Utility-scale solar developers do not prioritize these sites, however, because they are more expensive to develop. Although the land itself is sometimes less expensive to lease than farmland, there are typically more environmental regulations to navigate, and some sites require more preparation prior to development than flat, already-graded farmland. For example, former coal mines often require grading, and they pose subsidence concerns (US EPA, 2011, p. 11). The Pennsylvania DEP has partnered with the Eastern Pennsylvania Coalition for Abandoned Mine Reclamation to provide information that eases solar developers' use of former mine lands, including maps with multiple layers of data and permitting roadmaps (EPCAMR, n.d.). Limited numbers of brownfield sites are under consideration for utility-scale solar development in several Pennsylvania locations, with sites in Clearfield and Lehigh counties being the most recent examples. The US Department of Energy has funded the Clearfield project, slated to be the largest solar development in Pennsylvania.

<u>Facilities' end-of-life decommissioning:</u>

Regardless of where utility-scale solar development occurs—whether on farmland, disturbed lands, or elsewhere—removal of all of the solar equipment and associated equipment, such as on-site transmission lines, is important both for safety and for the productive re-use of the site. Decommissioning is particularly important on farmland if communities wish to prioritize returning former solar sites to agricultural uses.

There is currently no statewide regulation of decommissioning in Pennsylvania, although many local governments regulate decommissioning, as shown in Table 5 below. As of 2023, however, there was solar bonding legislation pending in both the House and Senate (S.B. no. 211, 2023; H.B. no. 925, 2023). If enacted, this legislation would supersede local solar bonding language and, by extension, be the basis for much of the locally required decommissioning of financial securities and the physical remediation of utility-scale solar sites in Pennsylvania. Language in the state bonding legislation is modeled in large part on similar solar decommissioning processes and protocols found in other eastern US states.

Decommissioning is one of the primary concerns of municipal officials as they consider proposals for utility-scale solar facilities. Many local governments in Pennsylvania require a decommissioning plan from a solar project developer before the local government will issue a zoning permit or approve a land development plan. The local government can require the solar developer to post a bond to ensure that there will be adequate funds available to complete the removal of the solar facility should the developer go bankrupt or not perform the decommissioning work (Daniels & Wagner, 2022, p. 4). Because the decommissioning will happen in 25, 30, or more years in the future, it is a good practice for the local government and the solar developer to re-visit the decommissioning plan every few years (two to five years is common) and update it as needed.

Economic Impacts

Farming Practices

Background:

The economic impacts of utility-scale solar development on farming practices are best understood in the context of the broader economic challenges facing farmers. Most US farms are officially considered to be small—by one definition, those with less than $350,000 of gross cash farm income (Giri et al., 2021; USDA ERS, 2020, p. 3). Small farms comprise 90 percent of US farms and operate nearly half of the nation's farmland (USDA ERS, 2020, p. 4). Moreover, nearly all US farms are "family farms" (98 percent), regardless of their operational scale (*Ibid.*).

The economics of farming are challenging for most farmers. As per the 2017 Census of Agriculture (the 2022 data is scheduled to be released in February of 2024), 56 percent of all farmers reported a net loss for the year (USDA National Agricultural Statistics Service, 2017, p. 244). Only 15 percent achieved $50,000 or more in net income gain (Id.). Further, the Economic Research Service (ERS) estimates that between 62 and 81 percent of different kinds of small farms have an operating profit margin that places them in a financial high-risk zone (USDA ERS, 2020, p. 6). While midsize and large-scale farms are comparatively more secure, the ERS estimates that large fractions of these farms (36 to 47 percent) are similarly at high risk (Id., p. 8).

This data highlights why so many farmers already depend on off-farm income for their family's overall economic well-being. It similarly underscores why revenue for energy production might be attractive to many farmers. Almost all (96 percent) of farm households derived some income from off-farm sources in 2019, according to the ERS (Giri et al., 2021). It is perhaps even more notable that, on average, off-farm income constituted 82 percent of total income for all family farms in that year (Id.).

Altogether, this economic portrait of US agriculture and its reliance on non-farming income underscores the extent to which the longer-term viability of farming must be understood in the context of the longer-term viability of rural economies as a whole.

Opportunities

Utility-scale solar development can positively impact farmers' practices by providing supplemental income in the form of lease payments (rental income from land) paid by the solar developer. This income can provide stability, especially for farmer landowners who rely on agricultural revenue as their primary source of income (Buckley Biggs et al., 2022, p. 7). Specifically, the constant revenue stream provided by a solar lease can help stabilize the finances of farmers who describe revenue from crops to be "often delayed, unpredictable, or infrequent" (Id.). Farmers use this stabilizing revenue in a variety of ways. It can provide income to support existing activity on non-solar land or new types of agriculture on non-solar land.

Professor Kaitlyn Spangler, an expert on solar energy on agricultural land in Pennsylvania, observes that farmers "enter into solar leases for a variety of reasons," including financial stability and others, such as financial gain due to the high margin for profit compared to traditional crop production, keeping their farms in the family for future generations, protecting land from industrial development, and letting their land "rest" for the length of the lease to restore soil quality (Spangler, 2023).

Our interviews yielded data suggesting that decisions to lease often revolve around whether a farmer lacks an individual to succeed them in managing the farm. In these cases, leasing the land for solar development is a way to keep the land—if not long-term farming practices—in the family.

Leases of land to utility-scale solar developers are typically for 20 to 30 years, with an option to extend, thus causing some leases (if a lease extension is exercised) to last 50 years. A 2020 report from Penn State's Center for Economic and Community Development estimates that annual lease rates for solar development in Pennsylvania range from $700 to $1,000 per acre (Kelsey, et al., 2020, p. 5). Lease rates can vary by location and electrical service provider. (Id.) Lease rates for utility-scale solar range from $800 to $2,200 per acre per year in many areas of Pennsylvania (Kiessling, 2023). In the Northern Tier (not included in Table 3 below), utility-scale solar lease rates tend to range from $1,300 to $1,500 per acre annually, with a typical 2 percent annual inflation escalator built into the 20- to 30-year lease. [16] In some cases, however, farmers' land is too valuable to lease to solar developers. One farmer interviewed by Spangler et al. noted a neighboring dairy farmer's need for, "every acre we got to produce silage and feed for our cows" (Spangler et al., 2024, p. 4).

Table 3 summarizes typical solar lease rates in Pennsylvania.

[16] Lease rates paid for solar in 2023 advanced to nearly $1,500 per acre per year in some parts of Pennsylvania for projects designated as "community-scale solar" (Kiessling, 2023). Although not currently allowed to be built and operated in PA, "leasing" for community-scale solar is occurring through long option agreements in lieu of formal leases, which some solar energy companies are offering while waiting for a favorable outcome to pending community solar legislation.

Table 3: Typical Solar Lease Rates in Pennsylvania (Kiessling, 2023)

Project Type	**Eastern PA**	**Western PA**
Utility Scale	$1,200 to $1,500 per acre	$800 to $1,400
Utility Scale (fast tracked PJM interconnection in areas with smaller existing capacity – projects about 10 to 15 MW in size)	$1,800 to $2,200	$1,500 to $1,800
Community Scale (no longer being pursued by most)	$1,700 to $2,300	$1,500 to $2,000
Net Metered (small scale)	$2,500 to $3,000	$2,000 to $2,500

Although Pennsylvania solar lease rates vary, Spangler et al. note that "solar leasing can earn [farmers] substantially (3 to 4 times) more income per acre than any crop or commodity production at current market prices" (Spangler et al., 2024, p. 4).

Beyond leasing, farmer landowners can realize a secondary income stream when they add provisions to a solar lease, giving the farmers the right of first refusal to provide vegetation management services to the solar energy company. Vegetation control must be conducted annually during the growing season at all sites. This can be done mechanically by mowing or through the use of grazing animals, like sheep, in an agrivoltaic-type system. If this right is retained by the landowner, they can contract it out to a third party or provide the service to the solar company themselves. Our conversations with individuals aware of farmers and vendors signing vegetation management contracts suggest that rates paid by companies in PA in early 2024 range from $300 to $700 per acre per year. This would be paid in addition to any lease payments made to the landowner.

Obstacles

Although leases provide important income for farmer landowners, it is not uncommon for odd-shaped fields to remain outside the fenced-in solar facility. Typically, solar developers do not make lease payments for this residual acreage, and it can be challenging to farm due to access and field shape issues.

Solar leases can also be detrimental to farmers who rely on rented farmland, especially dairy farmers. Anecdotally, rents for cropland in Pennsylvania typically vary from no annual payment to as much as $250 an acre.[17] Our interviews with farmers indicated that in more productive regions of Pennsylvania, river bottom ground can be leased for up to $350 per acre. At the local level, the leasing of property for solar energy can reduce the land available to farmers who farm using leased land and can potentially raise land leasing prices. In areas that are under high solar energy development pressures, many farmers cite this pressure as one factor (among many) for increasing land rents. One interviewee indicated that the individual believed that leasing prices for farmland had increased due to solar. Even where farmer landowners do not raise rents, lessees sometimes choose to increase rental payments annually (such as by $20 per acre) to appease landowners and retain the leased land. Anecdotally, there are also concerns about reduced land availability for manure application and disposal. We recommend further study to disentangle the impact of solar, housing development, and other pressures on farmland leasing prices.

Communities and the State

The community- and state-based economic impacts of utility-scale solar can include increased tax revenue for local governments; job production; "multiplier effects," when the income generated by the development induces additional spending in other economic sectors such as retail; and the inducement of economies within the solar energy industry supply chain, such as solar panel manufacturing. Utility-scale solar development can also affect property values within communities. These effects, of course, vary depending on the magnitude of the development. In Pennsylvania, few of these effects have been measured, and some, such as solar manufacturing, are not present.

Local Tax Revenues

Rural communities in Pennsylvania benefit from enhanced real property (land-based) tax revenue generated by utility-scale solar development. When land is converted from agricultural to commercial use and re-appraised, local governments and schools receive higher tax revenues for these lands. When re-appraisal is slow or does not occur, however, the benefits can be delayed. There is inadequate data to determine how local government property tax revenues have changed as a result of utility-scale solar development in Pennsylvania. Numbers from other states, however, suggest the impacts that widespread, utility-scale solar development can have. In 2020 through 2022 in North Carolina, one association estimates that property taxes "paid on parcels with utility-scale solar PV systems were $12.7 million, compared to $1.4 million before installation" (NC Sustainable Energy Assoc., 2022, pp. 3-4).

In Ohio, solar developers can opt out of paying separate personal property and real property taxes and substitute a Payment in Lieu of Taxes (PILOT) (Ohio Rev. Code 5727.75; Ohio Dept. of Development, n.d.). Landowners leasing their land, solar developers, and local governments often prefer this approach (anonymous interview, Oct. 18, 2023). Landowners wish to avoid potential increases in real property taxes, and savvy landowners therefore include a provision in the lease making the solar developer

[17] Rents for specialty crops and diversified production can exceed $500 per acre annually.

responsible for the payment of all taxes (*Ibid*.). Solar developers, in turn, prefer the PILOT because it is a predictable, fixed payment calculated from the nameplate capacity of the solar project (*Ibid*.). And finally, local governments benefit from knowledge of fixed revenue that they will receive for the life of the solar project–approximately 30 years and 50 years if a lease extension is exercised and the project is repowered (*Ibid*.).

The revenue to Ohio local governments under the PILOT program is substantial. Governments can opt for two ways of calculating payments from the solar developer: first, they can solely implement a base fee of approximately $7,000 annually per megawatt of solar capacity installed, and second, they can opt to add a $2,000 per megawatt annual service payment to the base fee. Revenues from the base fee are distributed in the same manner as local property taxes, flowing to entities such as school districts and special districts. Revenues from the service fee go to the county general fund, with no restrictions on how these revenues are spent.

Somewhat similar to Ohio, in New York, local governments can opt out of state solar tax exemptions to receive PILOT (NYSERDA, 2024b). If they choose to tax at full value, local governments must tax residential and industrial solar identically. However, if they negotiate payment in lieu of taxes, local governments can tax different entities differently. Municipalities often have their school district, or a local industrial development authority, negotiate a PILOT on their behalf.

Beyond real property taxes, additional tax revenue benefits include roll-back taxes paid when land previously within the Clean and Green preferential tax assessment program is converted to utility-scale solar. The Clean and Green program allows landowners to retain preferential tax assessment when they lease their land for oil and gas development or wind energy (with the exception of the lands directly used for energy production), but there is no such provision for solar energy (Penn. Statutes Tit. 72 § 5490.5a). The development of a utility-scale solar farm makes the land ineligible for preferential assessment and triggers the roll-back tax payment requirement. This requirement involves seven years of roll-back taxes at 6 percent annual interest (Pennsylvania Department of Agriculture, 2023a; Penn. Statutes Tit. 72 § 5490.5a), and revenues primarily flow to school districts.

Although Clean and Green roll-back taxes provide revenue for local governments, the loss of Clean and Green tax status has negative economic impacts for landowners who lease solar energy. Due to the fact that solar energy does not receive the same treatment as wind energy and oil and gas in the Pennsylvania Statutes, landowners who wish to retain Clean and Green status for the non-solar (residual) portions of their property must allow their entire property to fall out of compliance, pay roll-back taxes for the entire property, and then re-enroll the residual property in Clean and Green. Landowners who lease their land to solar developers typically include a provision within the lease that makes the developer responsible for the roll-back tax payments.

Jobs

The overall economic growth that communities and states can experience from utility-scale solar development has perhaps best been tracked in North Carolina, which ranks fourth among the US states for installed solar energy capacity. The North Carolina Sustainable Energy Association estimates that "the solar industry employs nearly 7,000 North Carolinians and has delivered over $15 billion in investments" (Brookshire et al., 2022, p. 3). Researchers have noted in other contexts, however, that studies funded by industry or industry associations may overestimate economic benefits (Hoy et al., 2017).

In Pennsylvania, there were 5,770 jobs in solar electric power generation in 2021 and 6,304 jobs in 2022. Note that these numbers include all scales of solar, including residential solar energy (BW Research Partnership, 2022; E2, 2023). According to our interviews, jobs created by utility-scale solar development in Pennsylvania include minor construction, concrete work for setting posts, land excavation and grading, hospitality (all temporary—during project development), and some long-term routine maintenance jobs. For one of our case study sites, which was approximately 100 acres, there were a total of 151 personnel working on the site during construction, with 41 percent being local hires from within 60 miles of the site.

It is common for solar contractors to build large facilities to employ specialized individuals, particularly at the manager level, who have experience constructing and bringing projects to the operational phase on time. Depending on the size and scope of the project, some companies will hire a segment of their labor locally, if it is available. If a community labor agreement is in place as part of the project, local organized labor will likely be a part of the workforce. In most cases, the majority of the contractor's labor will be transitory and move to where the projects are being developed, other than some potential tasks that might be contracted to local companies, such as a local engineering firm, and materials that could be locally sourced, such as a concrete supplier. Local spending by the workforce during construction is part of the multiplier effect described below. Local sourcing of goods and services is an additional component of the overall multiplier.

Multiplier Effect

In the case of utility-scale solar development, the multiplier effect describes the added economic activity that results within a community from lease payments to farmers/landowners and payments to local labor and businesses. The multiplier measures "how much additional economic activity is generated from an initial expenditure" (Natl. Renewable Energy Lab., 1997). It can be expected that farmers who lease land for solar projects will spend at least some of the lease payments within the local community or within Pennsylvania. The multiplier effect will be higher the more local jobs are created or supported by the construction and operation of a solar project and the greater the spending of lease payments in the community. Solar developers who hire local labor and buy from local businesses add to the multiplier effect. An indirect boost for the multiplier occurs when workers employed by solar developers and local businesses spend their wages within the community.

The converse of local spending is leakage, which can and does occur. Leakage in multiplier effects arises, for example, when a landowner spends the lease payments out-of-state. The percentage of the lease payments that will be spent within the community or region depends in part on whether the landowner decides to continue farming or is retiring. Investment in a farm has an estimated multiplier of about 2.5, depending on the type of farming activity. That is, for each dollar invested in the farm, another 2.5 dollars of spending results. If solar lease payments are reinvested in the farm or not spent locally, the multiplier will likely be less than 2.

The multiplier effect of utility-scale solar development in Pennsylvania is not yet adequately researched and would require an in-depth, well-funded study. Multiplier effects from shale gas development in Pennsylvania are estimated to be 1.86 to 1.90 (Hoy et al. 2017, p. 184).

Supply Chain Impacts

Utility-scale solar development has not yet created documented supply-chain benefits in Pennsylvania, such as the inducement of solar panel manufacturing, and, as we discuss here, it is unlikely to generate substantial impacts in this area.

The solar panel manufacturing market is dominated by China. Overall, US manufacturing jobs in renewable energy, including solar energy, have declined due to "globalization and automation" (Foster et al., 2020). The US government is working to expand US manufacturing of solar panels, with the Department of Energy recommending that "[t]o reestablish domestic solar manufacturing in the United States, companies that produce and sell solar components will require financial support to offset the 30 to 40% higher cost of domestic solar production" (US Department of Energy, 2022, p. iv). The federal Inflation Reduction Act of 2022 gives solar developers (and other renewable energy developers) a two percent higher tax credit if they can demonstrate that the manufactured product in the installed facilities was made in the United States. This is called the "domestic content bonus" (IRS Notice 2023-38). The Inflation Reduction Act also expanded two tax credits that manufacturers of solar energy equipment and other renewable energy manufacturers may choose between. These include an up-front (at the point of investment) credit of 30 percent for the cost of the manufacturing facility and equipment (awarded selectively after manufacturers apply for the credit) or a tax credit based on the amount of equipment that the manufacturer produces (26 U.S.C. § 48C; 26 U.S.C. § 48X).

Data from the wind energy industry shows that utility-scale renewable energy development at sufficient scale can expand local supply chain economies. Sweetwater, Texas, a home to extensive wind farms, now provides specialized manufacturing and service for the wind energy industry (Wind Energy Turbine Services, n.d.; Sweetwater Economic Development, n.d.).

Although high rates of renewable installation can positively impact economies in the solar supply chain, including manufacturing, increased solar development is unlikely to lead to in-state solar panel manufacturing in Pennsylvania. There are only 20 solar panel manufacturers in the US as of 2023 (IBIS World, 2023), and Ohio, Georgia, and California are already leaders in solar manufacturing (Energy Sage, 2024). The manufacture of batteries for storing electricity, which addresses overcoming the intermittency of solar, is concentrated from Michigan, Indiana, and Ohio through Kentucky and Tennessee to Georgia and the Carolinas (Spector, 2023).

Property Values

We have not identified any literature on the impact of utility-scale solar development on property values in Pennsylvania, and collecting this data would require substantial resources. Studies of the impacts of solar on land values in other states have involved researchers collecting extensive data on land transactions over long time periods or interviewing appraisers (Guar & Lang, 2020; Al-Hamoodah et al., 2018; American Society of Farm Managers & Rural Appraisers, 2021). One of the most in-depth studies investigated “1.8 million residential property transactions that occurred within six years before and after” large-scale solar development in six states (Elmallah et al., 2023). The study found that homes within 0 to 0.25 miles of a large-scale solar facility, sold after facility installation, experienced average property value declines of 2.3 percent. Homes within 0.5 to 1 mile of solar sites experienced average property value declines of 0.8 percent, and homes more than 1 mile from these sites experienced no effects (*Id.*).

Social Impacts

Communities

Solar development poses social impacts within communities during the development, construction, and, potentially, operation phases. First, debates over the siting of solar energy facilities can cause friction between community members, especially between vocal opponents and those who see potential benefits to the community. Second, construction poses the most material disturbance to the community in terms of noise (and vibrations) and possible soil erosion and stormwater runoff. Finally, solar energy can create viewshed aesthetic concerns, which some residents believe impacts rural character because they associate large solar installations with industrial development.

Of those impacts, changes to the viewshed are one of the most common concerns expressed by local stakeholders during interviews as well as during local government meetings where permitting decisions are being considered. Viewshed changes are connected to home values and a sense of place. Residents located closest to the solar energy development express concern over the diminished value of their property due to the viewshed, saying that they would not have purchased the home if the large solar development was already present (even if their home was built to obstruct another’s view). Other residents share that looking at solar panels would make the area feel more industrial. For these reasons, developers often look towards less densely populated areas in order to limit community engagement costs, along with trying to locate sites near available transmission capacity and on relatively flat and well-drained soils to reduce engineering and construction costs.

In conversations with farmers, the opinion is common that it is not their obligation to preserve other landowners’ views by avoiding solar development on their farmland. This sentiment suggests that if residents want to preserve solar-free viewsheds, they should buy the property surrounding their houses or pay higher taxes for public parks. However, some farmers who are impacted by solar development share that they are upset by looking at panels because it reminds them of land that they might otherwise be able to farm.

Other individuals who are more supportive of renewable energy or who stand to benefit from solar energy development see more positive outcomes of development, including, among other benefits, lease payments to landowners. For example, one local resident interviewed, who grew up in the area and currently farms on some of the land that they own, believes that solar energy development is an opportunity to potentially preserve farmland and support local schools, while observing that many opponents of solar energy development have recently moved to the area. This has also been described by a county planner as a trend where people move into new rural housing developments and then, in turn, seek to shut out any new developments. Another individual—a business owner and farmer—was not clear on the distinction between solar "farms" and other types of farms, since they are both land-intensive types of production. While they mentioned the importance of a visual buffer around solar installations, they emphasized that the land can still be farmed with sheep and is not being permanently taken out of agriculture.

Case Study Findings

The following four case studies helped us develop the above-described findings on economic, social, and land-based impacts and augmented our findings from the literature review. We summarize these case studies here to provide more specific examples of the impacts analyzed above. We have omitted mention of specific acreage, megawatts, municipalities, counties, and regions to help protect the anonymity of interviewees. For a complete summary of case study interview questions and findings, see Appendix 4.

Completed Solar, Non-Agrivoltaic

- 5 to 10 MW solar capacity, 25 to 50 acres, in a municipality with zoning.
- Landowner farmer: previously a dairy farmer and then corn and soybeans, prior to solar lease. Was on course toward retirement when the farmer leased a portion of their land to a solar company. The case study did not involve leased cropland being taken out of production.
- Land is classified as prime farmland (100 percent) and made up of class I (57 percent) and II (43 percent) soils.
- Site surrounded by preserved farms, housing developments, and industrial uses.
- Solar company gave the site maintenance contract to a relative of the farmer, who leased the land. This has precluded a neighboring sheep farmer, who expressed interest in grazing sheep on the site, from using the site. Vegetation under solar panels would have had to have been of higher quality to support sheep, as it is maintained as turf grass.
- Mixed community perceptions, including concerns over aesthetics, loss of prime farmland, and the preclusion of sheep grazing. Several farmers noted that they would be interested in agrivoltaics. Farmers both believed that the land could go back to farming if infrastructure was removed and, sometimes simultaneously, were concerned about what was going to happen to the site in the future.
- There are no proposed solar energy developments nearby.

Completed Solar, Agrivoltaic

- 10 to 20 MW solar capacity, 100 to 200 acres, in a municipality without zoning. There was limited community engagement when the development was proposed and approved as a permitted use.
- Solar site was previously rented out for corn, soybeans, and hay, to a nearby dairy farmer, so this case study involved solar displacing rented cropland.
- Land is classified as farmland of statewide importance (96 percent). It is made up of class II (58 percent), III (36 percent), and IV (6 percent) soils.
- Solar site currently grazed by sheep—approximately 500 ewe sheep.
- In interviews with adjacent farmers, there were mixed community perceptions, including concerns over aesthetics and loss of cropland. Some farmers were less concerned about the impact of one solar farm nearby than the solar facilities farther away, in more productive farming regions that have more animal operations, and shared that solar energy development increased the importance of farmland preservation.
- There is at least one major proposed solar energy development nearby.

Contested Solar Community

- 20+ MW solar capacity, 500+ acres; proposed project covering two different zoning districts, with ongoing litigation.
- Proposed on cropland that is both rented out to two farmers, who farm much of the land in the area, and farmed by landowners, who are retiring or shifting to non-farming jobs. The exception is that one of the farmers who rents some farmland–land that is prospectively leased for solar–also owns land that will possibly be developed for solar.
- Land is classified as farmland of statewide importance (54 percent) or prime farmland (37 percent). It is made up of primarily class II (62 percent), III (28 percent), and IV (2 percent) soils.
- Farmers in the area are also facing more competition in bidding for farmland, including from farmers who leased land to solar in nearby townships.
- Business owners in the area were concerned that the solar farm would change the character of the town and affect tourist-related businesses, but business owner interviewees indicated that they did not feel that the rural identity of the town would be compromised.
- Primary concerns expressed by residents are negative impacts on land values.
- Certain business owners are impacted in the sense that they are cautious to talk about the project or voice any opinion on it—positive, negative, or neutral—for fear of losing clients. Several business owners noted that the area already has a large industrial presence, so the project is unlikely to substantially visually impact that immediate area in terms of the mix of land uses.
- There are at least two other solar energy projects in development nearby.

"Solar Interested" Community

- 20+ MW solar capacity, 500+ acres, in two municipalities with zoning and one municipality without zoning. Located in a generally low-population area with consolidated landholdings. The two municipalities with zoning enacted a solar ordinance when solar was first proposed, and developers wanted them to enact an ordinance that addressed setbacks, fencing, buffers to limit visibility, along with decommissioning.
- Land is classified as prime farmland (54 percent), farmland of statewide (35 percent) and local (11 percent) importance. It is made up of class II (73 percent), III (16 percent), and IV (11 percent) soils.
- Area with a lot of transmission capacity available.
- Productive cropland (mostly leased, not farmer-owned), so proposed solar farms, if built, would displace leased cropland.
- Solar project would generate significant tax revenue from Clean and Green roll-back payments, which might be designated to the county farmland preservation program.
- In public hearings, many concerns were expressed about impacts on land values, water quality, wildlife, and buffers with neighboring properties conforming to the solar energy ordinance.
- Proposal was withdrawn and might be strongly opposed if it were reproposed, since it is regulated as a conditional use similar to the contested case study. Conditional uses are land uses that are listed as potentially being allowed within a particular area of a local government's territory (a zoning district, such as an agricultural district) but which must be reviewed on a case-by-case basis by the local government for their potential conflict or fit with other nearby land uses. The decision whether to approve a conditional use permit for a utility-scale solar project is made by the local elected government officials: the local supervisors, commissioners, council, or similarly named elected body.
- There is at least one other solar energy project in development nearby.

Table 4: Summary of Case Study Sizes, Zoning and Lease Arrangements, and Land Classifications

Case Study	Size (MW)	Land Area (Acres)	Zoning	Multiple Owners	Primary Farmland Classification	Primary Land Capability Classification
Completed, non-agrivoltaic	5-10	25-50	Yes	No	Prime farmland	Class I
Completed, agrivoltaic	10-20	100-200	No	No	Farmland of statewide importance	Class II
Contested	20+	500+	Yes	Yes	Farmland of statewide importance	Class II
Solar Interested	20+	500+	Partially	Yes	Prime farmland	Class II

Pennsylvania's and Other States' Regulation of Utility-Scale Solar Development

Pennsylvania and other states have taken steps to harness the benefits of solar energy development noted above, including, for example, land lease income to farmers and tax revenues for local governments, while mitigating challenges associated with utility-scale solar development, such as use of farmland and risks associated with the inadequate decommissioning of facilities at the end of their useful lives. Here we briefly summarize how states and local governments regulate utility-scale solar development generally and how they specifically address the impacts of utility-scale solar development on farmland.

State Regulation

There are three primary approaches to regulating the siting (location) of utility-scale solar development. Twenty-one states include the state government in the siting decision and require a review of utility-scale solar projects by the State Public Utility Commission or other state agency (Daniels & Wagner, 2022). Many of these states preempt local regulation that conflicts with state review of the project.

One example of the centralized approach is New York. In 2020, New York created a streamlined state-level review process for the siting and permitting of renewable energy projects with a generating capacity of 25 megawatts (MW) or more (State of New York, III, section 4, 2020). A newly established Office of Renewable Energy Siting (ORES) within the New York Department of State oversees the siting and certification procedures (New York Dept. of Public Service, 2024). Local governments participate in the state-centric siting process, but New York preempts any local regulation that is "unreasonably burdensome" in light of the state's renewable energy targets and the environmental benefits of renewable energy (N.Y. Exec 94-c 5(e)).

Ohio requires the developer of a 50 MW or more solar project to obtain a certificate of environmental compatibility and public need from the Ohio Power Siting Board, a state agency (OPSB, 2024b). However, in 2021, the Ohio State Legislature enacted a law allowing county commissioners to ban solar and wind development; as of August 2022, 10 counties had banned solar energy development (Zuckerman, 2022; Ohio S.B. 52 (2021)).

A few other states, such as Illinois, Michigan, and Wisconsin, take a hybrid approach, in which the state sets standards for which local governments may not issue more stringent standards absent a justification on the basis of highly localized conditions or safety issues (Davis, 2024). These standards are often referred to as a ceiling. For example, in Wisconsin, "[n]o political subdivision may place any restriction... on the installation or use of a solar energy system" unless the restriction is justified by three exceptions (Wisconsin Statutes, Chapter 66, section 0401). [18] Other "hybrid" states do not set a ceiling on local regulation but require approval by both local governments and the state for the utility-scale solar project to proceed (Essa et al., 2021).

Finally, the majority of states, including Pennsylvania, leave all siting decisions for utility-scale solar energy to local governments. In the majority of states where local governments may regulate utility-scale solar through zoning, local governments take several approaches to this zoning. Some local governments ban utility-scale solar altogether or ban it in agricultural zones (Daniels & Wagner, 2022, p. 4). Others list utility-scale solar as a permitted (as-of-right) use in only limited zones, such as industrial zones; a few list utility-scale solar as a permitted use in all zones (Daniels & Wagner, 2002, p. 4). Another approach is to list utility-scale solar as a special exception use within specific zones–a use allowed if specific, listed criteria are met. Alternatively, local governments list utility-scale solar as a conditional use–one that is allowed within a zone if approved by the elected local government (Daniels & Wagner, 2022, p. 3).

Table 5 summarizes the three state approaches to regulating utility-scale solar development—including centralized (state-level), hybrid (state and local), and nearly fully localized regulation. Federal approvals are omitted because they are the same in all states. Any utility-scale solar energy developer using lands on which endangered or threatened species are present, or which house the habitat of such species, must obtain an incidental take permit from the federal Fish and Wildlife Service under the US Endangered Species Act.

[18] There are few 50-state reviews of state solar siting policies, and those that do exist do not specify the number of "ceiling" states. The most detailed source on this topic does, however, specify states that are "hybrid," meaning that either the state or local governments have siting authority depending on the megawatt capacity of the project, and states with "dual" authority, in which both the state and local government must approve solar projects (Essa et al., 2021).

Table 5: Types of Land Use Approvals Required for Utility-Scale Solar Projects

Regulatory Approach	Local Approvals Required	State Approvals Required	Additional Regulatory Steps
Localized	1. Zoning approval 2. Site plan approval	National Pollution Discharge Elimination System (NPDES) stormwater permit (e.g., Pennsylvania Department of Environmental Protection, 2021).	Erosion and sedimentation control plan review of utility-scale projects by county conservation districts.
Centralized	Developer consultation with local government	Siting approval, environmental impact review in some states (e.g., New York), NPDES stormwater permit.	In some states, purchase of offsets for impacts on wildlife habitat (e.g., New York).
Hybrid	Land use approval (zoning, site plan if applicable within state), may not be more stringent than state limits.	Environmental impact review in some states, NPDES stormwater permit. In some states, additional land use approval at state level.	See rows above.

Local Regulation of Utility-Scale Solar Development in Pennsylvania

In Pennsylvania, there is no statewide regulation of utility-scale solar facilities, with the exception of state control over measures to channel and prevent the flow of water from solar sites. This section discusses this division of authority and explores how local governments control most aspects of utility-scale solar development in Pennsylvania.

State, County, and Local Roles: Stormwater Permitting

The Pennsylvania Municipalities Planning Code, Article VI, Section 603(b)(5), allows local governments to employ zoning ordinances for the "[p]rotection and preservation of natural and historic resources and prime agricultural land and activities." However, there are no statewide policies that either encourage or prohibit the construction of utility-scale solar facilities on farmland. At the local level in Pennsylvania, there is also no uniform approach to the regulation of utility-scale solar facilities or utility-scale facilities on farmland. Local governments' primary mechanism for regulating activities that may or may not occur on farmland—or any other type of land—is land use regulation in the form of zoning ordinances and subdivision and land development ordinances.

Local governments that choose to regulate land development require approval of landowners' proposals to divide ("subdivide") large lots into smaller ones—typically for the purpose of commercial or residential development; require approval of "site plans" when development is proposed; and regulate the areas ("zones") in which different types of land uses may occur. Through zoning, local governments designate all portions of their territory as a particular area in which similar land uses are allowed—e.g., agricultural, residential, commercial, and industrial zones. Local governments then specify which land uses are permitted by right, are not permitted, or are only conditionally permitted in each zone.

A large amount of farmland in Pennsylvania tends to be in local government areas zoned as "agricultural" or "rural," but farmland is also located in other zoning districts, including even industrial districts. Some local governments do not allow utility-scale solar as a permitted (allowed "as-of-right") use or conditional or special use (approved on a case-by-case basis) in agricultural zones, but others do. Beyond zoning, local governments also influence the location, size, and design of utility-scale solar development by approving or denying site plans that show the proposed layout, size, and design of the solar facility.

Currently, the state's sole regulatory authority over utility-scale solar relates to stormwater runoff. Stormwater is the water that flows over land during rain or snow melt; this water can pick up and carry pollutants, such as eroded soil, leaked diesel and gasoline, and other substances, which can pollute water in streams and lakes. The state's regulatory authority over stormwater comes from the portion of the federal Clean Water Act under which stormwater runoff is regulated—the National Pollutant Discharge Elimination System (NPDES). The federal Environmental Protection Agency has delegated NPDES stormwater permitting to the Pennsylvania Department of Environmental Protection. In turn, in many counties, the Pennsylvania Department of Environmental Protection partners with County Conservation Districts to administer NPDES permits and associated erosion and sedimentation plans for solar projects. If the earth disturbance associated with the construction of a utility-scale solar project will be 1 acre or greater, a NPDES permit is required.

Local governments also often consult with County Conservation Districts when reviewing site plans to address potential concerns about stormwater runoff and soil erosion. Conservation Districts assist local governments in the preparation of stormwater management plans for utility-scale solar facilities and other types of development. These stormwater management plans may be required in addition to NPDES controls. In either a state- or local government-issued stormwater management plan, a solar developer or other type of developer might be required to re-grade a site to reduce slope and potential erosion, to implement erosion controls during construction such as haybale or fabric fencing to prevent soil runoff, and to develop ponds or similar structures to retain stormwater runoff.

Local Land Use Regulation of Utility-Scale Solar Development In Pennsylvania

The regulation of land use in Pennsylvania, including the regulation of utility-scale solar development, occurs wholly at the local level, with the exception of the NPDES permitting noted above. There are 2,560 municipalities in the state, and many of these have the power to comprehensively plan for future land uses and regulate such land uses under the Municipalities Planning Code (Pennsylvania Department of Community and Economic Development, 2023). Pennsylvania counties and municipalities are taking a more active role in solar ordinance development and adoption as they become increasingly aware of the number of proposed solar projects collectively in the Commonwealth (Pennsylvania Department of Environmental Protection, 2023). As of early 2024, fewer than 10 percent of municipalities had language in their land use ordinances to specifically address utility-scale solar (Badissy, 2023). This percentage is rapidly changing, however, as more municipalities add solar language to their ordinances. Many of these ordinances address the impacts that we discuss above, including aesthetics (by requiring screening with vegetation, burial of on-site transmission lines, setbacks of solar farms from property lines, limited lighting, and minimal/limited signage, for example) and decommissioning.

Table 6 uses five sample locations in Pennsylvania to highlight ten of the more common issues associated with solar developments that local governments have chosen to address. As indicated by the table, some local governments have primarily adopted others' ordinances verbatim (e.g., Clarion and Forest Counties), whereas others have used their own language.

Some requirements for principal (utility-scale) solar facilities vary substantially among local governments. For example, of the ordinance examples in Table 6, the required setbacks of the edge of the solar facility from the property lines of the lot on which the facility is located range from 30 to 300 feet. The maximum permissible height of solar equipment ranges from 10 to 20 feet, or the maximum building height allowed in the relevant zoning district. Minimum lot sizes for the lots that house utility-scale solar facilities range from one to three acres, or the minimum lot size allowed in the relevant zoning district. Additionally, required amounts for financial security or decommissioning bonds that solar developers must post up front in the event they do not properly remove equipment and restore sites at the end of a facility's useful life are defined differently among local governments. Some define the required amount as a percentage of total decommissioning costs, others use a percentage and set a minimum bond or security amount (such as $500,000), and still others allow the county to determine the proper financial security, with no defined bounds on the amount.

There are other important variations in local government regulation of utility-scale solar beyond those highlighted in Table 6. For example, for the purpose of calculating the maximum percentage of lots that may be occupied by impervious structures, local governments take different approaches to defining what portions of a solar facility are impervious. For example, Clarion and Forest counties treat "the surface areas of the arrays" as "impervious coverage" if foundation systems and mechanical equipment are not counted as impervious coverage (Clarion County s. 3B4b; Forest County s. 3B4b). Adams County refers to Pennsylvania DEP guidance for impervious coverage at solar facilities (Adams County Zoning Ordinance s. 1028G).

Some local governments limit the amount of permitted land conversion for principal solar energy systems and require that solar developers take measures to offset land disturbance. For example, Adams County prohibits developers from removing more than

2% of wooded acreage. Tree planting to replace 2 times the area of "wooded acreage removed" is also required, with a minimum of 55 trees per acre (Adams County Zoning Ordinance s. 1028B., C).

Beyond land conversion regulations, some local governments in Pennsylvania place noise limitations on solar sites, which are not relevant to the panels but apply to inverters, trackers (which adjust solar panel positioning throughout the day to ensure maximum exposure to sunlight), and battery storage equipment if solar panels are co-located with batteries. Butler County limits decibel levels at the nearest property line to 55dBA (Butler County Subdivision and Land Development Ordinance s. 620.12.9). Hopewell Township in York County requires a baseline noise study and another noise study within six months after a solar facility begins operating (Township of Hopewell Municipal Code s. 19-105 1.L).

Table 6 provides limited examples of Pennsylvania local ordinances addressing solar. The team has compiled a list of local ordinances that address solar that will be available to the public by approximately June 2024.

Table 6: A Case Study of Five Sample Locations in Pennsylvania with Solar Ordinances

Local Government	**Local Ordinance Requirement**
Artificial Illumination Limits	
Adams County	No artificial illumination with the exception of illumination required for safety (s. 1028I).
Butler County	No artificial illumination with the exception of illumination required for safety (s. 620.12.12).
Decommissioning and Bonding	
Adams County	• Must dismantle and remove facility within 12 months of discontinuance of abandonment. • Re-sell or salvage materials "[t]o the extent possible." • Stabilize any exposed soil. • Leave paved access drive aprons that connect to public roads. • Restore facility to "pre-existing condition suitable for its prior use" unless landowner authorizes in writing keeping accessing roads and buffer vegetation (Adams County Zoning Ordinance s. 1028P). • Minimum financial security $500,000 (s. 1028P.8.d).
Butler County	• Must decommission facility within 12 months after end of useful life (s. 620.14.1). • Grade and re-seed disturbed earth (s. 620.14.3). • Post and maintain minimum decommissioning funds of 25% of decommissioning costs (s. 620.14.5).
Clarion and Forest Counties	• Must dismantle and remove facility within 12 months of discontinuance of abandonment (Clarion County s. 3A 10b; Forest County s. 3A10b). • Re-grade and re-seed any earth disturbance (Clarion County s. 3B10; Forest County s. 3B10). • Post and maintain decommissioning funds at 100 or 110 percent of identified decommissioning costs (Clarion Count s. 3A10d; Forest County s. 3A10d). • Post financial security "in the form and amount acceptable to the County" (Clarion County s. 3A10c; Forest County s. 3A10c).

Hopewell Township (York County)	• Must remove system within six months of abandonment (s. 19-105R(2)). • Earth disturbed by removal restored, regraded, and reseeded "or immediately returned to another use" (s. 19-105R(3)). • Post financial security "in the amount of 110% of the net decommissioning costs" (s. 19-105 1.R(5)).
Glare	
Adams County	"[D]esigned and located in order to prevent reflective glare" toward adjacent inhabited buildings and streets (s. 1028N).
Butler County	"[P]laced such that concentrated solar radiation or glare does not project onto nearby structures or roadways" (s. 620.12.8).
Clarion and Forest Counties	"[S]ituated to eliminate concentrated glare onto nearby structures or roadways" (Clarion County s. 3A9; Forest County s. 3A9).
Hopewell Township (York County)	"[L]ocated to minimize glare on adjacent properties or streets"; glare study may be required (s. 19-105 1.K).
Height Limits for Solar Equipment	
Adams County	Highest point no more than 10 feet in height (s. 1028F).
Butler County	20 feet (s. 620.12.4).
Clarion and Forest Counties	15 feet (Clarion s. 3B3).
Hopewell Township (York County)	"[B]uilding height restrictions for principal buildings of the applicable zoning district" (s. 19-105 2.A(5)).
Minimum Lot Size for Principal Solar Energy Facility	
Butler County	3 acres (s. 620.12.2).
Clarion County	1 acre or minimum lot size requirements of applicable zoning district (s. 3B1).
Forest County	1 acre (s. 3B1).

Hopewell Township (York County)	"[L]ot size requirements of the applicable zoning district" (s. 19-105 2.A(1)).
Screening/Visual Buffers (Vegetation, Fencing)	
Adams County	• Minimum 8-foot fence (s. 1028L). • 25-foot wide "densely planted, landscaped buffer" including Pennsylvania native "evergreen trees, deciduous trees, and shrubs," height equal to solar array within 1 year of planting (s. 1028M).
Butler County	• Minimum 8-foot fence (s. 620.12.11). • "Plant materials which provide an effective visual screen" if adjacent properties have residential use (s. 620.12.10).
Clarion and Forest Counties	• **"**Plant materials which provide a visual screen" *or* a fence (Clarion County s. 3B6; Forest County s. 3B6). • Minimum 8-foot security fence (Clarion County s. 3B8; Forest County s. 3B8).
Hopewell Township (York County)	• Minimum 6-foot fence (s. 19-105 2.A(10)). • "Screened from public roadways and any residential district or residential uses as required by the Board" (s. 19-105 2.A(10)).
Setbacks (Minimum Distance Between Edge of Solar Facility and Lot Line)	
Adams County	50 feet from all property lines or larger setback in underlying zoning district (s. 1028F).
Butler County	30 feet from all property lines. (s. 620.12.3).
Clarion County	100 feet from adjacent residential districts or setbacks in applicable zoning district (s. 3B2).
Forest County	100 feet from adjacent residential districts (s. 3.B.2).
Hopewell Township (York County)	300 feet from residential district or use (19-105 2.A(4)).
Signage	
Adams County	Safety and warning signs for voltage (s. 1028L).

Butler County	Safety and warning signs for voltage; no use of site for advertising (s. 620.12.6; 620.12.7).
Clarion and Forest Counties	"Signage shall comply with prevailing sign regulations" (Clarion County s. 3A8; Forest County s. 3A8).
Hopewell Township (York County)	"Signage shall comply with prevailing sign regulations" (s. 19-105 2.A(12)); clearly visible warning sign for voltage (s. 19-105 2.A (11)).
Stormwater Management	
Adams County	Stormwater management "in accordance with the local municipal Stormwater Management Ordinance" and Pennsylvania DEP stormwater guidance for solar facilities (s. 1028H).
Clarion and Forest Counties	Stormwater management plan showing that stormwater from solar facility will infiltrate into ground equal to infiltration prior to development (Clarion County s. 3B5; Forest County s 3B5).
Hopewell Township	Meet all requirements of Pennsylvania DEP stormwater guidance for solar facilities (s. 19-105 2.A).
Undergrounding of Wires and Plumbing	
Adams County	On-site power collection lines installed underground (s. 1028J).
Butler County	On-site transmission and plumbing lines placed "to the extent feasible" underground (620.12.4).
Clarion and Forest Counties	On-site transmission and plumbing lines "placed underground to the greatest extent feasible" (Clarion County s. 3A4; Forest County s. 3A4).
Hopewell Township (York County)	On-site transmission and plumbing lines "placed underground to the greatest extent feasible" (s. 19-105 1.G).

State and Local Policy Directly Addressing the Impact of Utility-Scale Solar Development on Agriculture

The policies that we describe above address the impacts of utility-scale solar wherever it is built—whether on farmland or not. But in so doing, they address many of the impacts that rural residents in our interviews most commonly focused on—namely, aesthetics. A growing number of state and local policies address the impacts of utility-scale solar development on agriculture, specifically. We explore examples of these policies here. Some of these have the effect of expressly allowing utility-scale solar development on farmland, whereas other policies endeavor to limit such development on farmland or constrain its impacts.

Policies That Allow Solar Development on Farmland

In 2009, New Jersey adopted two solar laws that promote the use of solar in general and specifically on farms. S1303/A3062 (2009) amended New Jersey Municipal Land Use Law (MLUL) to define solar technology as an “inherently beneficial use.” This means that a solar generating project is "universally considered of value to the community because it fundamentally serves the public good and promotes the general welfare." As a result, if a municipality wishes to deny a solar project, the burden of proof is on the municipality to demonstrate that a solar project causes a substantial detriment to the community or substantially deviates from the municipality’s master plan.

New Jersey S1538/A2859 (2009) extended the protections of the state’s Right to Farm Act to the generation of solar energy on commercial farms. The new law grants protection to commercial farms against restrictive local ordinances and regulations that would hinder solar production. All solar projects on preserved farmland must be reviewed by the State Agriculture Development Committee (SADC) in consultation with the holder of the conservation easement. The solar projects must be in compliance with the Agricultural Management Practices (AMPs) adopted by the SADC as well as any local municipal ordinances and siting standards.

Florida has a state statute that requires all counties to list commercial-scale solar as a permitted use in agricultural zoning districts in unincorporated areas. Similarly, local governments must identify solar facilities as “a permitted use in all agricultural land use categories” in their comprehensive plan (Daniels & Wagner, 2022, p. 4; Fl. St. 163.3205).

Similarly, Illinois prohibits counties from adopting zoning regulations that disallow “commercial solar energy facilities” in “any district zoned to allow agricultural” uses (Il St Ch 55 section 5/5-12020).

Michigan allows the development of solar projects on farmland subject to a state-acquired conservation easement (Michigan Legislature, 2023).

Policies Limiting Solar Development on Farmland or Addressing Impacts

Pennsylvania has no state policy that addresses utility-scale solar development on farmland, although legislation was introduced to prohibit utility-scale solar farms on USDA Class I or Class II agricultural soils (Pennsylvania S.B. 798, 2023). House Resolution 224 passed (and was adopted) in December 2023, which instructs “the Joint State Government Commission to study what benefits agrivoltaic farming could offer Pennsylvania and what opportunities exist for agrivoltaic farming to expand in Pennsylvania.”

In 2017, the Connecticut legislature passed a law that requires the state’s Department of Energy and Environmental Protection to consider the adverse impacts of an energy generation facility on agricultural land before it issues a development certificate (Connecticut S.B. 943, 2017). In 2019, the Oregon Land Conservation and Development Commission moved to restrict commercial solar development on soils designated as prime, unique, and Class I and II, totaling approximately 6 percent of land in the state (Profita, 2019).

The previous Governor of Maryland, Larry Hogan, established a Governor's Task Force on Renewable Energy Development and Siting that examined the percentage of agricultural land that might be impacted by solar energy (0.4 to 1.7 percent of available farmland; 0.7 to 2.9 percent of prime farmland). The Governor's Office offered recommendations on how to avoid siting on farmland (Maryland Office of the Governor, 2020). Maryland also enacted legislation for community solar projects, which included tax incentives for agrivoltaic-type development, along with projects that use rooftops, brownfields, landfills, and clean fills.

New York appointed a working group to “recommend strategies to encourage and facilitate input from municipalities in the siting process and to develop recommendations that include approaches to recognize the value of viable agricultural land and methods to minimize adverse impacts to any such land resulting from the siting of major renewable energy facilities” and to meet at least three times annually (N.Y. Exec 94-c).

Some local governments also directly address the impact of utility-scale solar development on farmland. Culpepper County, Virginia, limits utility-scale solar projects to sites of no more than 300 acres. Madison County, Virginia, restricts utility-scale solar projects to industrial zones; they are not allowed in agricultural zones. Pima County, Arizona, has the discretion to allow solar facilities on agricultural land in rural zones through a conditional use permit (Daniels and Wagner, 2022).

Table 7 summarizes some of these examples of state and local policies that directly address the impacts of utility-scale solar development on agriculture and provides additional examples.

Table 7: Examples of Policies that Address Utility-Scale Solar and Agriculture

State or Local Government	Solar-Agriculture Policy or Program
State Governments	
Connecticut	S.B. 943 (2017): Requirement that environmental protection agency consider the adverse impacts of an energy generation facility on agricultural land before it issues a development certificate
Florida	Fl. St. 163.3205: Requirement that all counties list commercial-scale solar as a permitted use in agricultural zoning districts in unincorporated areas
Illinois	Il. St. Ch. 55 section 5/5-12020: Prohibition on counties adopting zoning regulations that disallow commercial solar energy facilities in agricultural zones
Maryland	Provision of tax incentives for agrivoltaic-type development, along with community solar projects that use rooftops, brownfields, landfills, and clean fills
Massachusetts	Solar Massachusetts Renewable Target (SMART) Program–Agricultural Solar Tariff Generation Unit
Michigan	Farmland Open Space Preservation Program–solar facilities allowed under development rights agreement (Michigan Legislature, 2023)
New Jersey	New Jersey Municipal Land Use Law (MLUL)–solar technology defined as an “inherently beneficial use”
New Jersey	S1538/A2859 (2024-2025): Extends the protections of the state’s Right to Farm Act to solar energy on commercial farms, protecting them from restrictive local ordinances and regulations that would hinder solar production
Oregon	Restrictions on commercial solar development on soils designated as prime, unique, and Class I and II
Local Governments	
Culpepper County (Virginia)	Limitation on utility-scale solar projects to sites of no more than 300 acres

Madison County (Virginia)	Restriction of utility-scale solar projects to industrial zones (not allowed in agricultural zones)
Pima County (Arizona)	Preservation of discretion to allow solar facilities on agricultural land in rural zones through a conditional use permit
Township of Hopewell (York County)	"No more than 20% of the entire area for [solar] development shall consist of Class I or Class II prime agricultural soils... unless agrivoltaic production will be used," in which case the area in agrivoltaics does not count toward the 20% (s. 19-105 1.N)
Township of Hopewell (York County)	Allowance of crops in setback between edge of solar facility and residential district or use, but must be at least 25 feet from adjacent property line or street right-of-way (s. 19-105 2.A(4))
Township of Hopewell (York County)	Agricultural use, including grazing "or other agricultural or ecological practices to make beneficial use of the land underneath the solar arrays" "permitted as customarily incidental to" the utility-scale solar energy use; not treated as second principal use (s. 19-105 2.A(15))

Discussion and Policy Considerations

Based on our findings regarding the impacts of utility-scale solar development in Pennsylvania, impacts in other states, and other states' policy approaches, we offer the following policy recommendations for Pennsylvania.

Physical Land-Based Impacts

- Consider providing state incentives, such as exemptions from state taxes, for the siting of solar in locations without prime agricultural soils (USDA Class I or II).
- Provide additional incentives–beyond those currently being pursued by the Pennsylvania Department of Environmental Protection–for the development of solar on disturbed lands such as former mine lands, including, potentially, requirements for fast-tracked local government review and decisions (rejection or approval) on such projects within one year of the submission of a site plan.
- Create an advisory committee for agrivoltaics in Pennsylvania and provide resources to the Pennsylvania Department of Environmental Protection, Extension, Pennsylvania State Association of Township Supervisors, or other groups involved in disseminating solar information to conduct outreach on the implementation of agrivoltaics. Task the advisory committee with identifying a menu of agrivoltaic best practices–perhaps including a point system–that would allow utility-scale solar developers to benefit from incentives for agrivoltaics if they demonstrated compliance with a minimum total point value.

- Implement incentives to harness the opportunities for and benefits of agrivoltaics farming to be studied by the Joint State Government Commission.

Economic and Social Impacts

Provide additional funding for studies that address and track the social and economic impacts of utility-scale solar facilities in Pennsylvania over time as developers construct and continue to operate more facilities.

Require utility-scale solar developers to submit information to the Pennsylvania DEP on the acreage, type of land (farmland, former industrial), and specific type of soil on which each locally approved and under-construction utility-scale solar facility is located. Require the Pennsylvania Department of Environmental Protection to record and make public this data, and provide the resources necessary for this data collection and reporting.

Consider requiring utility-scale solar developers to submit information to the Department of Community and Economic Development or the Department of Labor & Industry on the number of short- and long-term jobs created by each utility-scale solar project and which of these jobs are completed by Pennsylvania workers. This will inform further economic studies of multiplier effects.

Consider commissioning a study of increased local tax revenues from utility-scale solar development, which will require pre- and post-project assessments.

Consider commissioning a study of the change in farmland prices and rental rates in municipalities that host approved and completed utility-scale solar projects.

Consider implementing a Payment in Lieu of Taxes (PILOT) local government option for solar energy and revising the Clean and Green preferential tax assessment program to align with wind energy and oil and gas development. This alignment would remove only the footprint of the solar energy facility from Clean and Green, allowing the remainder of the land to remain in the Clean and Green program.

Continue considering uniform, statewide regulation of bonding and decommissioning of utility-scale solar energy.

Addressing decommissioning on a state level, rather than in individual municipalities or on a case-by-case basis, may help to provide certainty to developers and municipal officials alike. The Commonwealth may choose to enact state-wide standards for decommissioning plans to ensure uniform standards for the removal of solar equipment and to set aside sufficient funds for returning the land to its original condition. Consider implementing a requirement that the Pennsylvania DEP or other agency tasked with administering decommissioning standards review the decommissioning plan every two to five years and update it as needed.

Continue and expand DEP's work, providing information for local governments to help them effectively regulate utility-scale solar development (Pennsylvania DEP undated).

Provide resources to the Pennsylvania DEP to develop a model solar development code. This code should include best practices in solar ordinances with respect to location (the zones in which a utility-scale solar project is allowed); the review process for utility-scale solar development; construction standards relating to, for example, height limits and the amount of a land parcel that may be covered by solar panels; operation standards relating to off-site impacts such as fencing and vegetation screening; and decommissioning standards (if uniform statewide decommissioning standards are not developed).

Convene a statewide session with local government officials and DEP experts at the annual Pennsylvania Association of Township Supervisors in Hershey and the County Commissioners Association of Pennsylvania Land Planner's Subcommittee. These sessions would share effective strategies for utility-scale solar regulation and the results of ongoing work to compare local regulation of utility-scale solar. Publish a white paper summarizing the session's conclusions.

Continue considering the allowance of mid-scale "community solar" projects in Pennsylvania that avoid interconnection delays and can be more strategically sited to address concerns about aesthetics and solar on prime soils.

In light of Pennsylvania's lowest-ranked status with respect to renewable energy growth in the fifty states, continue considering an increase in Pennsylvania's renewable portfolio standard to require that a larger percentage of electricity come from solar energy.

Conclusion

Utility-scale solar energy development is at a nascent stage in Pennsylvania, but some impacts of this development on farmland, farming practices, and farming communities are already visible. Much existing and proposed development is on farmland, including some prime farmland. Pennsylvania does not collect data from developers on the specific land and soil type of utility-scale solar developments, however, thus failing to provide information on the amount of farmland used for utility-scale solar development. Solar development is a temporary use of farmland—approximately 30 years—but many solar developments are unlikely to be used again for farming operations at the end of their useful lives. Although agrivoltaics—farming between and beneath solar panels—have been relatively uncommon, solar developers are seeking agrivoltaics options for new sites. [19] In some cases, however, there are not sheep or shepherds available for sheep grazing—the predominant agrivoltaic activity in Pennsylvania.

Utility-scale solar energy development can increase tax revenues for Pennsylvania local governments, but specific data is currently unavailable with respect to the amount of the increase. Solar facilities also provide lease revenue to landowner farmers, but they reduce the land available to farmers who rent farmland, and some farmers believe that solar development (along with other land pressures such as residential housing) has increased the rental cost of land for farming. There are no studies of the impact of utility-scale solar on Pennsylvania residential property values, but national studies that include neighboring states such as New Jersey show a 1.5 percent resale value decline for properties within a mile of such sites.

[19] Many solar developers propose agrivoltaics as a way to win community support because the agrivoltaics suggest that the farmland will not be wholly taken out of production. However, solar developers do not appear to view agrivoltaics as profitable (Daniels, 2023b).

With respect to social impacts, utility-scale solar development can help small farms—which face particular financial risk and rely on non-farm income—to stay in business. It can also help keep farmland, if not farming activity, within farming families when there are no children or other successors to take over the business. Residents in farming communities often express concerns about aesthetic impacts and changes to the “sense of place,” as well as glare and the materials in solar panels. Some farmers express property rights concerns, believing that residents should pay for the preservation of viewsheds rather than expecting farmers to forgo solar development to preserve viewsheds.

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Appendix 1: Authors, Collaborators, Roles, and Methodology Followed

Author	Research Role (Topics Addressed)	Methodology Followed
Mohamed Badissy	Local government regulation of utility-scale solar development	Identification, comparison, and analysis of Pennsylvania zoning codes and solar ordinances
Seth Blumsack	Economic impacts of energy development; solar policy options	-Review of existing Pennsylvania policies that impact the type and pace of solar development -Identification of benefits and resource-based constraints of models and techniques for estimating the economic impact of solar energy
Thomas Daniels	Solar siting; state and local government regulation of utility-scale solar development; economic impacts of energy development	-Literature review -Review of states' solar siting policies and solar-agriculture policies -Identification and analysis of feasible methods to estimate the economic impacts of solar development within resource constraints
Brook Duer	Pennsylvania solar energy policy; agricultural land conservation programs	-Regular tracking of Pennsylvania legislative activity throughout research period -Comprehensive compilation of county criteria for solar development on farms subject to agricultural conservation easements (collection and review of hard copy documents–Penn. Department of

		Agriculture, Harrisburg)
Zachary Goldberg	Economic, social, and physical impacts of utility-scale solar energy development on Pennsylvania farmland, farming practices, and rural communities	-Interviews (writing interview questions, identifying interviewees, leading interviews, and coding interview results) -Case study analysis
Michael Helbing	Decommissioning policy	-Tracking of pending solar bonding legislation in Pennsylvania House -Review and analysis of local government bonding and decommissioning policies
David Kay	Farmer landowners' use of lease income; farmers' and rural residents' sense of place; trends in utility-scale solar development in rural areas, including New York; New York utility-scale solar policy; economic impacts of energy development	-Analysis and comparison of existing economic estimates of the economic impacts of utility-scale solar development -Survey of New York farmer landowners -Literature review
Thomas Murphy	Farmer landowners' use of lease income; economic impacts of energy development; operational and under construction utility-scale solar facilities in Pennsylvania; Pennsylvania local ordinances addressing solar energy	-Data collection from state agency officials and local government officials -Identification of interviewees and assistance with interviews -Utility-scale solar workshops with local government officials throughout Pennsylvania -Application of results from economic analyses of Pennsylvania shale gas development to estimate potential economic impacts

		of utility-scale solar
Ross Pifer	Pennsylvania solar energy policy; agricultural land conservation programs	-Identification of experts and potential interviewees -Legal analysis of Pennsylvania solar energy and agricultural conservation policies
Hannah Wiseman	Solar siting; state and local regulation of utility-scale solar development	-Literature review -Identification and review of local ordinances addressing solar energy development -Identification and review of state policies addressing solar and agriculture -Participation in expert interviews
Collaborators/Expert Assistance		
Anonymous expert collaborators	Impacts of utility-scale solar development on farmland and farming practices in states with more mature utility-scale solar development; other states' solar taxation policies	-In interviews, description of results of state policy surveys -Description of results of interviews with and surveys of farmers -Discussion of methods to measure sense of place, including, for example, social representations theory -Discussion of the types of interview questions that can help to elicit sense of place information
Supporting partners: Adams County Office of Planning and Development; County Commissioners Association of Pennsylvania; Franklin	Local regulation of utility-scale solar development; impacts of utility-scale solar development in Pennsylvania	-Suggestions for interviewees and experts

County Board of Commissioners; Lycoming County Conservation District; Montour County Planning Commission; Penn State Erie, The Behrend College, Sustainable Food Systems Program; Pennsylvania State Grange; WeConserve PA		

Appendix 2: Definitions

- **Agricultural easement**: A legally binding agreement between a landowner and a government agency or private land trust that allows agricultural uses of a property but generally forbids non-farm commercial and residential development. Pennsylvania has over 600,000 acres of agricultural land protected by agricultural easements, more than any other state except Colorado. State policy has allowed solar projects on these "preserved" farms for energy production on the farm, not for transmission and sale off the farm.
- **Agrivoltaics**: The simultaneous use of land for both agricultural purposes (such as crop production, sheep grazing, and beneficial insect habitat) and solar energy development.
- **Clean and Green Program**: A "preferential tax assessment program" for agricultural land, which offers use-value assessment for property taxes on open land of 10 or more acres. Any land with solar panels not used primarily for on-farm electricity consumption must be removed from the program, and the landowner must pay a roll-back tax for up to seven years and will have a higher assessment on the part of the property devoted to a solar project. "The rollback tax is the difference between what was paid under Clean and Green versus what would have been paid, if the property had not been enrolled, plus 6% simple interest per year" (Pennsylvania Department of Agriculture, 2023a; Pennsylvania Statutes Title 72, section 5490.5a.).
- **Community solar:** Community solar has many definitions, but it is most concisely defined as "mid-scale" size solar. Distributed or small-scale solar is solar energy used on the site of the solar panels–such as panels on the rooftop of a home or a dairy processing operation–with some of the excess electricity "net metered" back into the electric grid if the panels are connected to the grid. Community solar projects are somewhat larger than distributed solar and typically provide electricity to a group of customers who have subscribed to the project. Community solar projects are connected to the grid, so they do not actually feed all of their electricity to subscribing customers. (Electricity in the grid simply flows

to the point of least resistance.) But community solar customers pay for the virtual power that flows to them from the project at a specified rate (NREL, n.d.).

- **Dual-use solar**: The simultaneous use of land for solar energy and other purposes, including agricultural purposes but also non-agricultural purposes such as biodiversity conservation. Agrivoltaics are one example of a type of dual-use solar project.
- **Offtakers**: Persons who buy power from a project developer at a negotiated rate.
- **PJM**: A regional transmission organization (RTO) that operates utility-owned transmission lines and schedules and manages the flow of electricity through these lines through auctions for wholesale electricity.
- **Power Purchase Agreement (PPA):** A long-term contract in which a utility-scale solar developer commits to provide electricity to an offtaker.
- **Prime agricultural land:**
  - 53 Penn. Statutes § 10107 definition (PA Municipalities Planning Code): "land used for agricultural purposes that contains soils of the first, second or third class as defined by the United States Department of Agriculture Natural Resource and Conservation Services County Soil Survey."
  - 2003 PA Executive Order definition: lands that are "in active agricultural use; lands devoted to active agricultural use the preceding three years; and fall into at least one of the categories of agricultural land described below." These categories, in order of priority highest to lowest, include preserved farmland (easements), farmland in Agricultural Security Areas, farmland enrolled in preferential tax assessment programs, "farmland planned for agriculture use and subject to effective agricultural zoning," and farmland in U.S. Department of Agriculture-designated "Land Capability Classes I, II, III, and IV" and "unique farmland" (Rendell Executive Order, 2003).
  - Natural Resources Conservation Service (NRCS) definition: Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is also available for these uses (the land could be cropland, pastureland, rangeland, forest land, or other land, but not urban built-up land or water) (Code of Federal Regulations, Title 7, section 657.5).
  - NRCS Soils Classification, 7 Code of Federal Regulations § 657.5
  - "Class I (1) soils have slight limitations that restrict their use.
  - Class II (2) soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
  - Class III (3) soils have severe limitations that restrict the choice of plants or require very careful management, or both" (NRCS 2007).
- **Utility-scale solar**: All solar installations that: 1) serve customers beyond the customers on the site of the solar installation; and 2) relatedly, are connected "in front of the meter," meaning they feed nearly all electricity produced back to the broader electricity grid rather than solely to the property on which they are located.

- **Zoning**: A set of local government regulations that can control the location and operation of a utility-scale solar facility.

Appendix 3: Interview Protocols

We conducted interviews to understand the solar development narrative and different stakeholders' perspectives, and to gather details relevant to our research questions involving land-based, economic, and social impacts. Zachary Goldberg conducted all the interviews. For interviews with experts in other states, Hannah Wiseman and Thomas Murphy also participated in interviews.

Individuals were identified through publicly facing websites, attendance at conferences (i.e., Pennsylvania State Association of Township Supervisors), snowball sampling (i.e., asking interviewees to identify additional people who could provide additional perspectives or information), and through mediators (i.e., individuals who have access to key contacts). Individuals were recruited through email, phone, or text based on their involvement in the project.

During interviews, the interviewer took notes and, in some cases when permission was given, audio recordings. Following the interview, a code was given to the notes and transcripts, and any identifying information (i.e., names, addresses, etc.) was removed from these documents and kept in a separate document. All documents are also kept on Penn State authorized servers that require a multi-factor identification sign in. In addition, when using the data to write this report, further details were removed (i.e., county or township information, company names) to provide additional protections to research subjects, while still providing critical information to provide recommendations for public policy.

During interviews, we asked questions pertaining to impacts on community agricultural character. Local residents and leaders were asked about the main attributes that they associated with their community and whether they thought solar energy development would impact the community. Farmers were asked more specific questions on how solar energy development might support or challenge farming in the area.

Interview completion rates:

- 54 interview requests total
- 24 interview requests not in specific case study areas (including one in Northwest PA)
- 30 interview requests in case study areas: 5 for non-agrivoltaics, 11 for agrivoltaics, 7 for solar interested, and 8 for solar contested (1 included both interested and contested)
- Overall completion rate: 73%
- Overall rejection rate: 7%
- 4 total rejections out of 54 interview requests (7% rejection rate)**:** 2 out of the 7 non-agrivoltaic requests rejected: solar developer sent non-disclosure agreement and then did not respond, and landowner could not interview because he did not receive permission from the solar energy developer.

- 1 interviewee out of the 6 “interested” case study requests asked us to follow up in Winter/Spring 2024.
- 1 interviewee out of the 21 interview requests outside of our specific case study areas suggested other people with whom to speak and has not accepted our interview request.
- 14 interviews not completed out of 54 interview requests total: 4 of these non-completions were rejections.
- Of the 10 interviews not completed, 1 non-completion was from our non-agrivoltaics case study; 1 was from our agrivoltaics case study, 1 was from our contested case study; 2 were from our solar interested case study; and 5 were from areas outside of our case study area.

Appendix 4: Summary of Interview Questions and Responses

Land-Based Impacts

- What are the current/were the previous land uses for the land that is leased for solar development? Can you describe the type and quality of the soils?
- For the two case study sites involving completed projects, both were previously cultivated for crops (i.e., corn, soy); however, the two sites varied in terms of soil quality, as one of the sites was on soil mostly classified as prime farmland, and the other site contained soil that was not.
- Can you describe the seed mixes that you use/plan to use for solar development, including plans for procurement and application (for solar developers)?
- Seeding plans vary widely at solar energy sites; however, some companies do use a Pennsylvania company, Ernst Conservation Seeds, located out of Meadville, which has become an industry leader in developing seed mixes specialized for solar sites, branded as “Fuzz and Buzz.”
- Are you planning to or have you implemented any agricultural uses within the solar development? If so, what are these uses, and what is their size (e.g., annual number of livestock or acreage with solar panels also in crop production, quantities of annual crops produced)? Did they require any changes to project design, installation, or management of the solar installation?
- For the site that implemented solar grazing as their agrivoltaic program, the grazer manages a flock of 450 ewes. The site was redesigned to include an area outside the fencing for a sheep corral, which allows the grazer to perform health checks on the sheep and facilitates transportation of sheep from the site. There was also a well installed on the site for water.
- Have the changes in aesthetics or viewsheds impacted your quality of life?
- In interviews, several people have noted the importance of rural features and views as a draw to the area for residents and tourists. There is a fear that these projects will be highly visible.

Economic Impacts

- How has solar development, including contracts and leases, impacted farm values and rental rates?
- Many farmers have indicated that they believe solar energy development has impacted farm values and rental rates, although many also acknowledge that there are a range of factors, including other land development pressures. Outside of the case studies in this report, unpublished survey data of farmers adjacent to solar energy developments in PA (n=40) found that out of nine farmers in Pennsylvania who have attempted to purchase land since solar energy development occurred, two thought that solar energy development made it harder to purchase land. More farmers are concerned about rental rates, with nine out 26 farmers who rent believe that it is becoming harder to rent land due to solar energy development, and four of those farmers losing 200 acres to solar energy development.
- How has it impacted ease of access to land to grow crops or pasture animals?
- As written above, some farmers have lost land that they used to rent for farming operations; however, there are some instances, in the case of agrivoltaics management, where solar energy development has increased access for shepherds.
- How has solar development impacted farming operations? How might it impact farming operations in the future? Have there been any differences in the availability of agricultural services and products, such as feed, seeds and equipment stores?
- Other than some farmers losing access to farmland, there is no evidence that solar energy development has impacted overall farming operations in Pennsylvania. There is some concern that large amounts of solar energy development in the region might make it harder to access some agronomic services provided by commercial agricultural providers.
- What is the interest in farming or grazing under or in between ground-mounted solar panels (i.e. agrivoltaics)? What are the costs and revenues associated with this activity?
- Across Pennsylvania, there is consistent interest in grazing sheep at solar energy sites. Some costs associated with grazing in solar energy developments are as follows: purchasing sheep, labor, transportation of sheep, veterinary services, site preparation (fencing, water), soil and forage testing, and mechanical mowing and weed removal (for plants that the sheep do not eat). The revenue associated with agrivoltaics is both from the vegetation contracts from solar companies and from the sales of sheep.
- What are your annual lease payments, total and per acre? How long does the lease run?
- Ranges for different types of lease payments were provided in the report. Only ranges of lease payments can be ascertained due to non-disclosure agreements.

- Why did you decide to lease (or not lease) your land for a solar installation? Did other farmers' activities affect your decisions to lease/not lease (for landowners)?
- Farmers' decisions to lease land for solar energy development often revolved around being a terminal farmer or not (i.e., having someone to succeed them in managing the farm). Farmers with children who live far away from the farm and have different professions indicated that solar energy development was a way to keep the farm land in the family. It is also important to note that landowners who lease to solar developers are commonly not farming the land themselves and have leased it out previously to tenant farmers.
- How many individuals did you hire during the construction phase of the project and the operations phase? How many of these individuals were local, and how many were from out of state?
- For one site that was about 100 acres, there were a total of 151 personnel working on the site during construction, with 41% being local hires, being within 60 miles of the site. Construction of solar energy sites often includes local subcontractors for concrete, land grading, and other procurement.
- What was the timeline for the project? Was the final timeline consistent with the timeline you expected at the outset of the project? Did you encounter any obstacles that delayed the project (for solar developers)?
- Solar energy development timelines often extend over larger periods of time, multiple developers, and project managers, with frequent delays caused by both interconnection queues and local permitting. For example, please see "Survey of Utility-Scale Wind and Solar Developers Report" for further analysis.
- How are solar energy projects treated through tax assessments? Do you consider solar energy projects to have a positive impact on local tax revenue that can be used for necessary community improvements (for local government officials)?
- There is a large degree of confusion around taxation and solar energy development. For example, one local government official shared how warehouses get built because "they're generating tax revenues for the community...whereas these [solar] projects don't generate tax revenues." Another planner shared that a county commissioner was against solar energy development because the tax revenue was minimal beyond "a one time impact on tax receipts for properties that were being pulled out of Clean and Green." Alternatively, local officials in areas with utility-scale solar development are generally more positive about this development. One official shared that "it is a positive thing for the township because it's bringing us more tax dollars in," and while he could not recall how much the township receives annually, he noted that the permitting revenue was $9,000 at the start of the project.

Social Impacts

- How does solar development support or impede your farming and community ideals?
- Does solar development support or challenge intergenerational farming continuity?
- Does solar development change community character or social cohesion? Is there a different "feel" to the community?
- In communities where solar energy development has occurred, there was little pushback or public debate. In interviewing farmers and residents near those projects, there was a mix of perspectives, but generally, solar energy development was not cited to have significantly changed the community. In communities where there has been pushback to solar energy development, including the case study, there was also a mix of opinions, but several individuals noted that the prospect of solar development was wearing on the social cohesion of the community.
- How is solar development treated by the local government and zoning code? Is there a fair process for public participation in determining whether and how solar energy is developed? What process did the local government apply to the proposed solar project(s) (types of public participation, such as public hearings or focus groups), and how much process was provided (e.g., number of hearings and focus groups)? How was the project permitted for stormwater?
- Among the case studies, there were a wide variety of ways municipalities treated solar energy development. Generally, in areas with completed solar energy projects, there were public meetings, but attendance was small, while for the case study that was contested, there was a series of hearings that were attended by large numbers of people.
- What arguments and/or concerns have you heard from farmers and other residents in support for or in opposition to solar projects?
- The largest concerns are typically related to viewshed (which is related to wider concerns of changing rural characteristics, sense of place, and importance of open space) and decommissioning (as projects pass through many different companies). Other concerns include noise pollution and glare, along with traffic. There are also many fears around what is in the panels and possible contamination of groundwater.

Appendix 5: Rural Enterprise Criteria for Agricultural Conservation Easements

County	Rural Enterprise Criteria That Prohibit Utility-Scale Solar Development
Adams	• Energy production shall be incidental to the agricultural use. • Energy produced shall be available for use on the farm. • Permanent equipment and structures shall be located within the curtilage of existing farm buildings. • Total acreage devoted to energy production shall be limited to 2% of the total easement area, or 0.5% of the total easement area if more than one rural enterprise exists on the preserved farm.
Allegheny	• Energy produced must be for use principally on the farm.
Armstrong	• Energy produced must be for use principally on the farm.
Beaver	• Energy produced must be for use principally on the farm.
Bedford	• Energy produced must be for use principally on the farm.
Berks	• Energy production shall be incidental to plant and animal production. • Energy produced shall be available for use on the farm. • Total acreage devoted to energy production shall be limited 0.5% of the total easement area if more than one rural enterprise exists on the preserved farm.
Blair	• Energy produced must be for use principally on the farm.
Bradford	• Energy produced must be for use principally on the farm.
Bucks	• Energy produced must be for use principally on the farm.
Butler	• Energy produced must be for use principally on the farm.
Cambria	• Energy produced must be for use principally on the farm.
Carbon	• Energy produced must be for use principally on the farm.

Centre	• Energy produced must be for use principally on the farm.
Chester	• Energy produced must be for use principally on the farm.
Clearfield	• Energy produced must be for use principally on the farm.
Columbia	• Energy produced must be for use principally on the farm.
Clinton	• Energy produced must be for use principally on the farm.
Cumberland	• The majority of energy produced must be utilized on the farm.
Crawford	• Energy produced must be for use principally on the farm.
Dauphin	• Energy produced must be for use principally on the farm. • Energy generation must be conducted by the landowner or immediate family member residing on the farm.
Erie	• Energy produced must be for use principally on the farm.
Fayette	• Energy produced must be for use principally on the farm.
Franklin	• Energy produced must be for use principally on the farm.
Fulton	• Energy produced must be for use principally on the farm.
Greene	• Energy produced must be for use principally on the farm.
Huntingdon	• Energy produced must be for use principally on the farm.
Indiana	• Energy produced must be for use principally on the farm.
Juniata	• Energy produced must be for use principally on the farm. • Energy production cannot exceed the lesser of 1% or 2 acres of the easement acreage.
Lackawanna	• Energy produced must be for use principally on the farm.

Lancaster	• Energy production shall be incidental to the agricultural use. • Energy produced shall be available for use on the farm. • Permanent equipment and structures shall be located within the curtilage of existing farm buildings. • Total acreage devoted to energy production shall be limited to 2% of the area of the property.
Lawrence	• Energy produced must be for use principally on the farm.
Lebanon	• Energy produced must be for use principally on the fa
Lehigh	• Energy produced must be for use principally on the farm.
Luzerne	• Energy produced must be for use principally on the farm.
Lycoming	• Energy produced must be for use principally on the farm.
Mercer	• No energy production is permitted as a Rural Enterprise on a preserved farm.
Mifflin	• Energy produced must be for use principally on the farm.
Monroe	• Energy produced must be for use principally on the farm.
Montgomery	• Energy produced must be for use principally (at least 50% per year) on the farm. • Energy production shall be incidental to the agricultural use. • Energy produced shall be available for use on the farm. • Permanent equipment and structures shall be located within the curtilage of existing farm buildings. • Total acreage devoted to energy production shall be limited to 2% of the area of the property.
Montour	• Energy produced must be for use principally on the farm.

Northampton	• A Rural Enterprise shall be owned or operated by the owner of or farmer in residence of the preserved farm. • Energy produced must be for use principally on the farm. • Energy production must be located within the exclusion curtilage area as designated on the easement survey and any permanent equipment or structures shall be located within the curtilage of the existing farm buildings or exclusion area.
Northumberland	• Energy produced must be for use principally on the farm. • Total acreage devoted to energy production cannot exceed the lesser of 1% or 2 acres of the easement acreage.
Perry	• Energy produced must be for use principally on the farm.
Pike	• Energy produced must be for use principally on the farm.
Potter	• Energy produced must be for use principally on the farm.
Schuylkill	• Energy produced must be for use principally on the farm.
Snyder	• Energy produced must be for use principally on the farm.
Somerset	• Energy produced must be for use principally on the farm.
Sullivan	• Energy produced must be for use principally on the farm.
Susquehanna	• Energy produced must be for use principally on the farm.
Tioga	• Energy produced must be for use principally on the farm.
Union	• Energy produced must be for use principally on the farm.
Warren	• Energy produced must be for use principally on the farm.
Washington	• Energy produced must be for use principally on the farm.
Wayne	• Energy produced must be for use principally on the farm.

Westmoreland	• Energy produced must be for use principally on the farm. • Energy production shall be incidental to the agricultural use. • Energy produced shall be available for use on the farm. • Permanent equipment and structures shall be located within the curtilage of existing farm buildings. • Total acreage devoted to energy production shall be limited to 2% of the area of the preserved farm.
Wyoming	• Energy produced must be for use principally on the farm.
York	• Energy produced must be for use principally on the farm.

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