PennFuture

Here Comes the Sun:

A Municipal Guide to Grid-Scale Solar Siting

About PennFuture

Citizens for Pennsylvania's Future ("PennFuture") is a member-supported, statewide environmental advocacy nonprofit and watchdog fighting against potential threats to Pennsylvania's clean air, pure water, and healthy climate. Since 1998, PennFuture has combined legislative advocacy, educational outreach, civic engagement, and legal action at the local, state, and federal levels for just and equitable environmental outcomes that improve the quality of life for all Pennsylvanians.

PennFuture has stood at the forefront of major environmental milestones in Pennsylvania as a bold and vigilant defender of communities against pollution and environmentally harmful policies.

We have offices across Pennsylvania, including Harrisburg, Pittsburgh, Philadelphia, Erie, and the Poconos.

Acknowledgements

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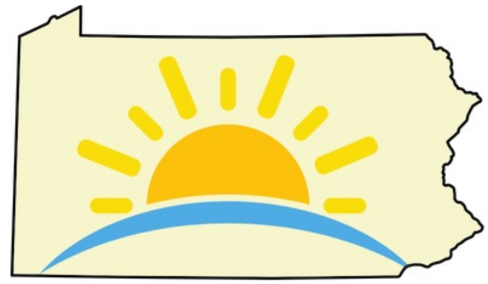
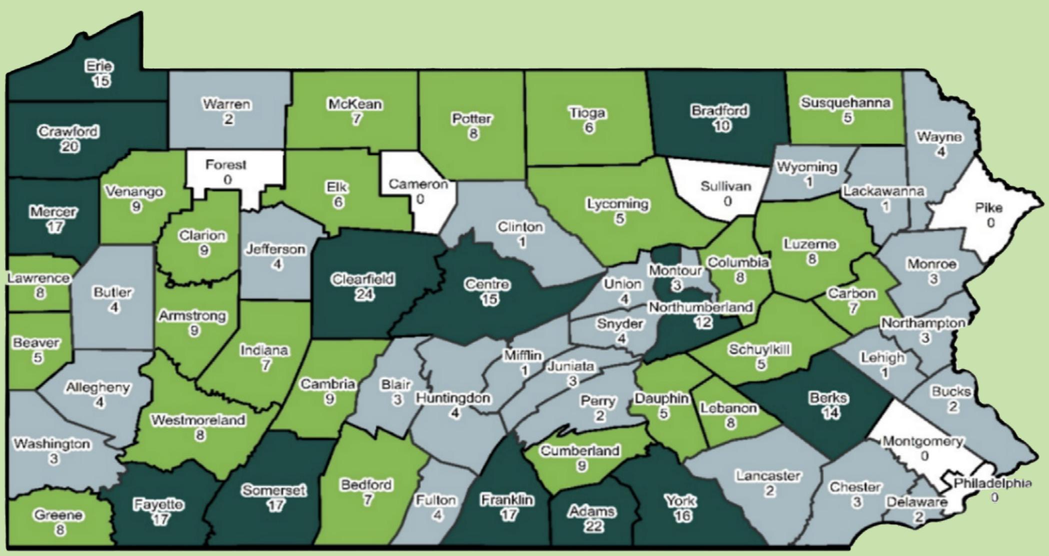


Pennsylvania has always been an energy leader, but, historically, this position has relied on polluting fossil fuels like coal and fracked gas that come at the cost of our health and environment. Today, Pennsylvania is experiencing a notable shift toward clean, renewable energy sources, particularly solar, which is now the fastest-growing and least expensive form of electric generation in the United States.[1] Pennsylvania has increased its solar power generation by over 370% in the last decade, and declining costs of installation, available tax credits, and health benefits of solar energy mean this development will be prioritized even further in the future.[2]

There are currently 46 operating utility-scale solar systems in Pennsylvania and nine additional systems under construction. This pales in comparison to the almost 500 projects that have applied for approval from the PJM regional transmission organization, the entity that controls which energy generators can connect to the grid. Grid-scale solar is proposed in almost every county.



Grid-scale solar projects awaiting PJM approval as of December 2023

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1 Landgate Corp., Pennsylvania Solar Development Analysis (2024); Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 11 (2024).

2 https://environmentamerica.org/pennsylvania/center/articles/5-surprising-facts-about-renewable-energy-growth-in-pennsylvania/; Landgate Corp., Pennsylvania Solar Development Analysis 4 (2024).

Grid-scale solar energy and other renewable resources are Pennsylvania's future as an energy leader, and municipalities are key to ushering in that future. Pennsylvania has entrusted its municipalities with vast, almost exclusive, authority to control how land is used within their boundaries. This gives municipalities an indispensable role in ensuring that grid-scale solar occurs in the most appropriate locations. In fact, Pennsylvania municipalities have a constitutional obligation to plan for grid-scale solar (and all other legitimate land uses), and municipalities that fail to proactively do so may lose control over solar siting decisions altogether through costly and time-consuming curative amendment challenges. This means that, for municipalities, taking part in Pennsylvania's energy future means planning for grid-scale solar. This requires understanding the characteristics that make a site suitable for solar development and how to address or mitigate competing land use concerns. It also means understanding common objections to solar development. This publication aims to give municipalities those resources.

What this Means for Municipalities

In addition to climate and environmental benefits, grid-scale solar development results in direct economic benefits for municipalities. When land is converted from agricultural use to grid-scale solar development and re-appraised, local governments and schools receive higher tax revenues. Payments made to farmers/landowners and local labor and businesses also generate additional economic activity in the community.

"Can't You Just Tell Me What To Do?!"

We know. . . you just want a model ordinance that tells you exactly what to do about grid-scale solar siting. We get it. Model ordinances are great for municipalities, and there are a lot of good ones out there on grid-scale solar development.

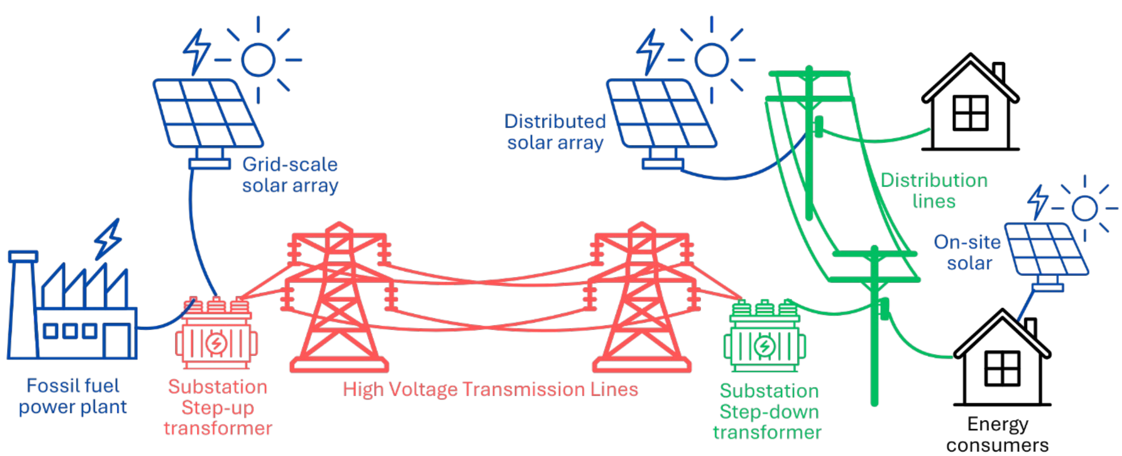
This publication, however, goes beyond the model ordinance to prepare municipal leaders for zoning and other siting considerations for grid-scale solar development and to have the tools to appropriately defend good solar siting ordinances, oppose bad or unduly burdensome requirements, and to appropriately tailor any model ordinance language to legitimate community concerns. The goal of this publication is to give context and information to help municipal leaders understand the fundamentals of how grid-scale solar operates and land use considerations that go into "good" siting at the local level.

WHAT IS GRID-SCALE SOLAR?

Solar energy systems take energy from the sun's rays and convert it to a form of energy humans can use, like electricity or heat. The most common type of solar energy system is a **photovoltaic (PV) system**, which converts sunlight directly into electricity. PV technology can be used at almost any scale, from tiny toys to solar farms covering thousands of acres.

Distributed vs. Grid-Scale Solar

PV systems that power homes and businesses can be divided into two main categories based on where they connect to the power grid: **distributed** and **grid-scale**.



Parts of the Electric Grid

Distributed Solar

Distributed solar is not the focus of this publication, but it is important to understand how it works and how it differs from grid-scale solar. Distributed solar systems are systems that generate electricity at or near where the electricity will be used.[3] They include on-site rooftop or ground-mounted solar installations that serve a single building, like this array that serves a supermarket, pictured below, and small localized grids that serve larger energy consumers like industrial facilities, military bases, or college campuses.[4] Distributed solar systems also include community solar systems, which allow local energy users to take advantage of off-site solar arrays. Most distributed solar systems are connected directly to the individual home or business using the power.[5] Distributed solar systems that do connect to the power grid, like community solar projects, do so on the distribution side (the green in the graphic above). This is the portion of the grid controlled by electric companies such as PPL, PECO, Met-Ed, Penelec, and West Penn Power, and which serves local or regional customer bases.[6]

Grid-Scale Solar

The focus of this publication is the second type of PV system: grid-scale solar (also known as utility-scale solar). There is no official definition of grid-scale solar systems, but what typically distinguishes these systems from distributed installations is that they connect to the wholesale transmission side of the power grid (the red in the graphic above) like other power plants, and the electricity is sold wholesale to utility companies. The energy output of these large PV systems is measured in megawatts (MW). Although grid-scale solar systems are typically larger than distributed systems, there is no universally accepted size threshold.

3 U.S. Envtl. Prot. Agency, *Distributed Generation of Electricity and its Environmental Impacts*, Epa.gov, https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts (last visited Oct. 4, 2023).

4 *Id.*

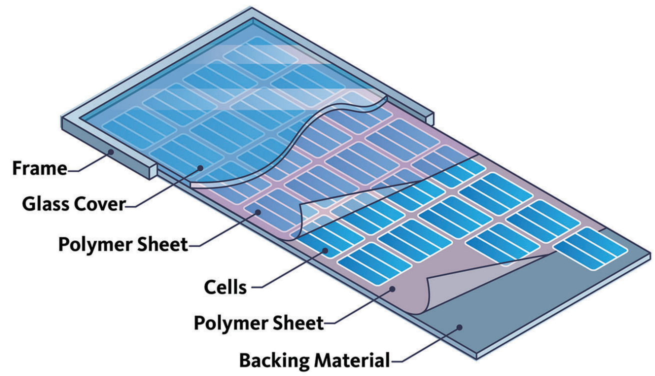
5 Talha Bin Nadeem et al., *Distributed Energy Systems: A Review of Classification, Technologies*, Applications and Policies, 48 Energy Strategy Reviews 3, (May 22, 2023), https://www.sciencedirect.com/science/article/pii/S2211467X23000469.

6 U.S. Envtl. Prot. Agency, *Electricity Delivery and Its Environmental Impacts*, Epa.gov, https://www.epa.gov/energy/electricity-delivery-and-its-environmental-impacts (last visited June 2, 2025).

PARTS OF A GRID-SCALE SOLAR SYSTEM

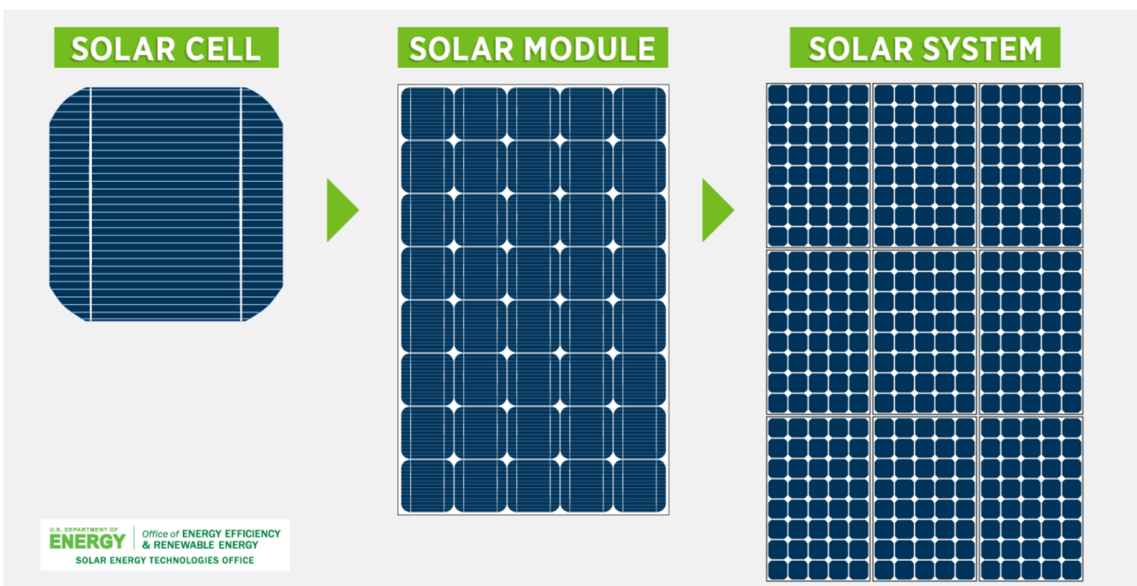
Solar Panels

The most basic unit of any PV system is the **solar cell**. Solar cells contain a semiconductor, usually silicon, that creates an electric current when struck by sunlight.[7] Because the semiconductor materials are very thin, they are sandwiched between protective materials such as glass or plastic to protect them from the elements.[8] In addition to traditional single-faced panels, manufacturers are now able to produce bifacial or two-sided panels that have energy-producing cells on both sides of the panel. This enables the panels to absorb sunlight reflected from the ground, increasing the panels' efficiency.[9]



Parts of a Solar Panel

Each solar cell produces only a small amount of electricity, so many cells are typically connected together to create a PV **module** or **panel**.[10] Panels can be connected together to form even larger units, called systems or **arrays**.



7 U.S. Dep't of Energy, Office of Energy Efficiency and Renewable Energy, *PV Cells 101: A Primer on the Solar Voltaic Cell*, ENERGY.GOV (Dec. 3, 2019), https://www.energy.gov/eere/solar/articles/pv-cells-101-primer-solar-photovoltaic-cell.

8 U.S. Dep't of Energy, Office of Energy Efficiency and Renewable Energy, Solar Volataic Technology Basics, Energy.gov, https://www.energy.gov/eere/solar/solar-photovoltaic-technology-basics (last visited Oct. 4, 2023).https://www.energy.gov/eere/solar/solar-photovoltaic-technology-basics (last visited Oct. 4, 2024).

9 Casey McDevitt & Jacob Marsh, *Bifacial Solar Panels: What You Need to Know* (Oct. 11, 2024); https://www.energysage.com/solar/bifacial-solar-panels-what-you-need-to-know/

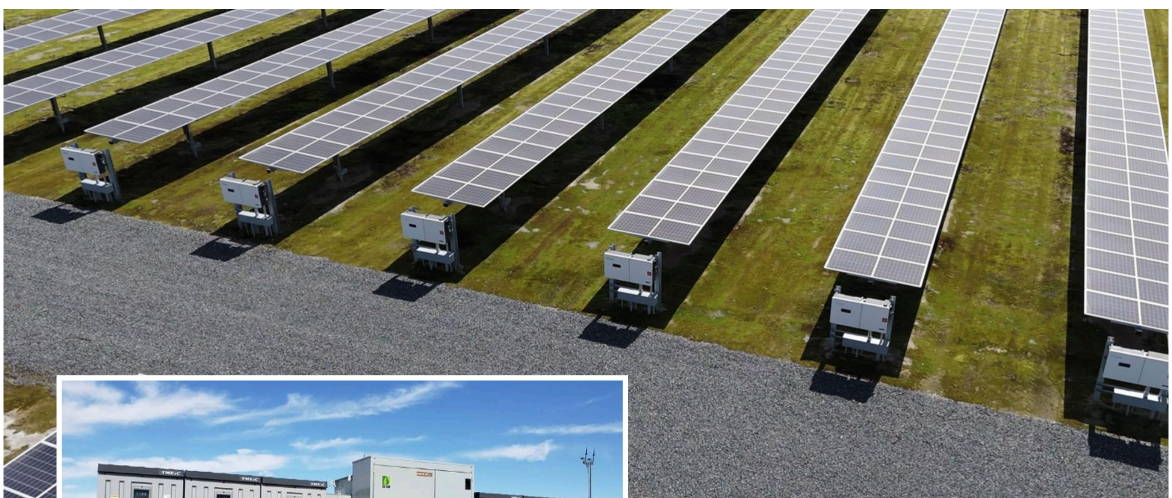
10 Delaware Valley Regional Planning Commission, Renewable Energy Ordinance Framework: Solar Pv 3 (2015).

Mounting Structures

The solar panels themselves are only part of the system required to convert the sun's energy into usable electricity.[11] Grid-scale solar systems require **mounting structures**, or racks, to support the arrays and point the panels toward the sun.[12] These are typically made of metal or other non-corrosive materials. Grid-scale solar uses ground-mounted arrays, which may also include tracking mechanisms to automatically move the panels to follow the sun across the sky.[13] These may be single-axis (moving only up and down) or dual-axis (moving up and down and side to side).[14]

Inverters

Solar systems also require **inverters** to convert the direct current (DC) created by the solar array into an alternating current (AC) that is usable for transmission of electricity.[15] PV systems either have a single central inverter or individual inverters at each row of panels, called string inverters.[16] Larger projects are more likely to have central inverters.[17]



String inverters

A central inverter

[11] U.S. Dep't of Energy, Office of Energy Efficiency and Renewable Energy, Solar Voltaic System Design Basics, Energy.gov, https://www.energy.gov/eere/solar/solar-photovoltaic-system-design-basics (last visited Oct. 4, 2023).

[12] *Id.*

[13] *Id.*

[14] Image: https://www.aces.edu/wp-content/uploads/2021/09/IMG_0864-scaled.jpg

[15] U.S. Dep't of Energy, *PV Cells 101: A Primer on the Solar Voltaic Cell*, Energy.gov (Dec. 3, 2019), https://www.energy.gov/eere/solar/articles/pv-cells-101-primer-solar-photovoltaic-cell.

[16] U.S. Dep't of Energy, Office of Energy Efficiency and Renewable Energy, Solar Voltaic System Design Basics, Energy.gov, https://www.energy.gov/eere/solar/solar-photovoltaic-system-design-basics (last visited Oct. 4, 2024).

[17] Lucas Miller, *Comparing Central vs String Inverters for Utility-Scale PV Projects* (May 14, 2024); https://www.mayfield.energy/technical-articles/comparing-central-vs-string-inverters-for-utility-scale-pv-projects/

Batteries

The energy output of the solar array doesn't necessarily match the demand for electricity at the moment it's generated. Therefore, grid-scale solar arrays are increasingly incorporating battery storage.[18] Batteries allow energy created at high-output times to be stored and used later, when the array isn't producing energy. Today, more than a third of new grid-scale facilities include battery storage.[19]

10 MW of battery storage at a 15MW solar array in Cicero, NY

Transmission Infrastructure

To get the energy a grid-scale solar array generates onto the grid, the system must connect to a high voltage transmission line or a substation.[20] Unless the solar array is right next to a substation or transmission line, a transmission line called a generation tie or gen-tie will be needed to take the power from the array to the grid. A gen-tie is a series of poles, wires, anchors and foundations, similar to other types of power lines. Some larger projects may install a new substation on site.[21]

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18 Michelle Lewis, *US Large-Scale Battery Storage Capacity is Up 35% in 2020 – And Growing*, Electrek.co (Aug. 20, 2021), https://electrekco/2021/08/20/us-large-scale-battery-storage-capacity-is-up-35-in-2020-and-growing/.

19 American Planning Association, Solar@Scale: A Local Government Guidebook For Improving Large-Scale Solar Development Outcomes 30 (2023).

20 *How Does a Solar Farm Connect to the Grid?*, Solarlandlease,Com, https://www.solarlandlease.com/solar-farm-connect-grid (last visited Oct. 4, 2023).

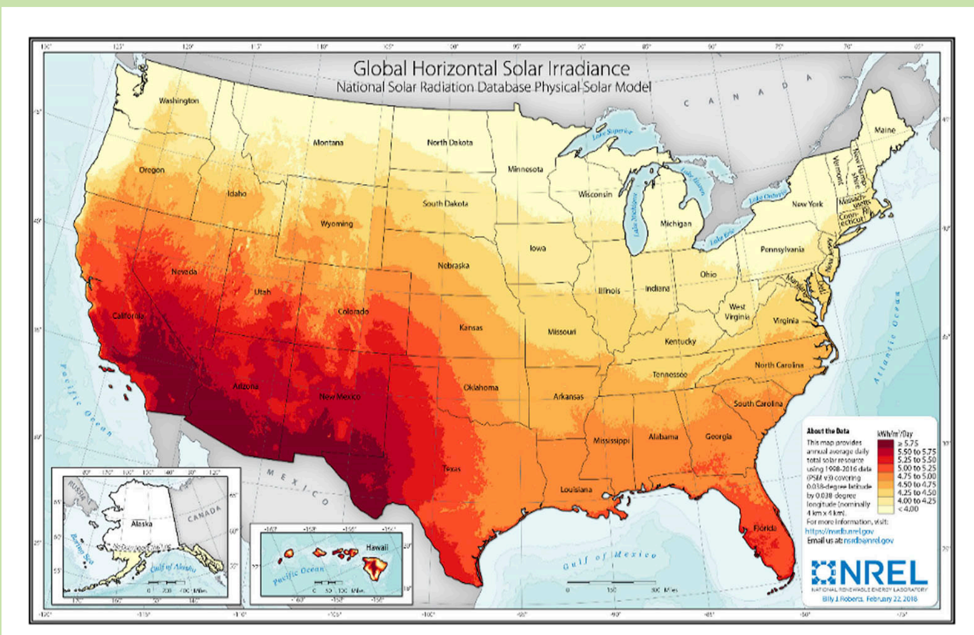
21 *What is a Gen-Tie Line?* https://selectrow.com/what-is-a-gen-tie-line/

WHAT MAKES A GOOD SOLAR SITE?

There are a number of considerations that go into whether a site is appropriate for solar development, but solar developers agree that there are four main characteristics that drive most siting decisions: (1) the "solar resource" or amount of sunlight, (2) access to transmission infrastructure, (3) the characteristics of available land, and (4) the legal landscape.

Solar Resource

In the language of solar development, the "solar resource" simply refers to the amount of sunlight that reaches the earth at a given location that can be used to create solar power. Some may believe that Pennsylvania does not receive enough sunlight to make solar power generation feasible, but this is not true. Every one of the 50 states, including Pennsylvania, has the technical potential to generate more electricity from the sun than it uses in an average year.[22]



The amount of sunlight reaching the Earth's surface can be expressed in terms of Global Horizontal Solar Irradiance (GHI), a measurement of the amount of solar energy that strikes a horizonal surface over a given time period. The map above shows the average annual GHI across the United States, measured in kilowatt hours per square meter per day (kWh/m2/day). Pennsylvania's annual average GHI is between 4.0 and 4.5 kWh/m2/day, which is between 70 and 80% of the sunlight received in the sunniest regions of the desert Southwest.

[22] Judee Burr, Lindsay Hallock & Bob Sargent, Star Power: The Growing Role Of Solar Energy In Pennsylvania 9 (2014); https://publicinterestnetwork.org/wp-content/uploads/2014/11/Solar-Potential-6.0-PENNSYLVANIA_0.pdf.

Consider this: for many years Germany had the most solar PV capacity installed in the world, despite receiving approximately the same amount of sunlight as Southern Alaska.[23] Pennsylvania receives substantially more sunlight than Germany or Alaska, meaning that the solar resource in Pennsylvania can certainly support solar power systems. One need look no further than the fact that there is already over one gigawatt (a billion watts) of installed solar generation in the Commonwealth to understand that solar works in Pennsylvania![24]

What this Means for Municipalities

Because the solar resource all across Pennsylvania is enough to support solar energy generation, every municipality should assume that solar is possible where it is located.

Proximity to Transmission Infrastructure

Next to sunlight, the most important thing a grid-scale solar system needs is a connection to the electric transmission infrastructure or "grid," This is the network of power lines that connects power generation facilities to electric consumers.[25] Grid-scale projects connect to the grid by tapping into a high voltage transmission line or a substation.[26] Often, a transmission line called a generation tie or gen-tie will be needed to take the power from the array to the grid.

Gen-ties require land and equipment and can cost up to $1 million per mile to construct.[27] In addition, the farther the distance the gen-tie has to cover, the more energy is lost in transmission, making the project less efficient and cost-effective.[28] Therefore, solar developers prioritize sites that are located near existing substations or transmission lines, generally within 2 miles of a suitable connection point.[29]

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23 Pa. Public Utility Comm'n, Solar Electricity Frequently Asked Questions 3 (2018)

24 Press Release, Pa. Public Utility Comm'n, Pennsylvania Reaches Solar Milestone (Dec. 12, 2023); https://www.puc.pa.gov/press-release/2023/pennsylvania-reaches-solar-milestone-can-now-power-residents-in-a-city-the-size-of-pittsburgh-with-in-state-solar#:~:text=In%20addition%20to%20the%20one,solar%20generation%20data%20tracked%20by

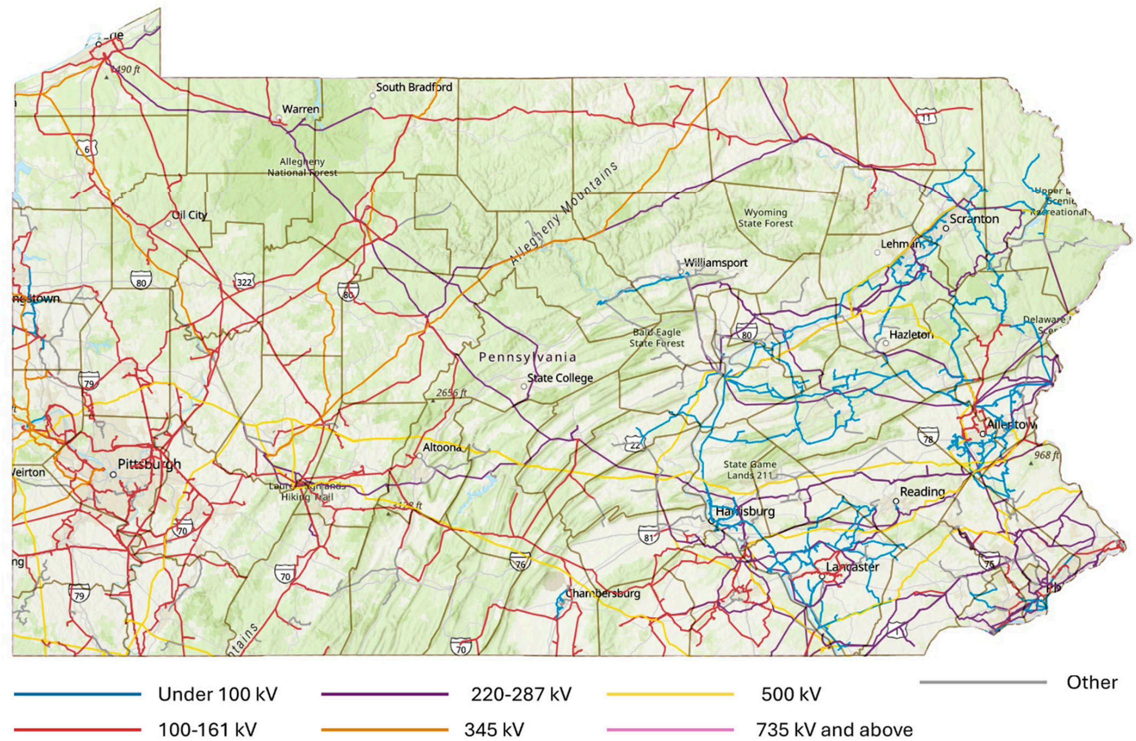
25 Brad Plumer, The U.S. Has Billions for Wind and Solar Projects. Good Luck Plugging Them In, NYT.com (Feb. 23, 2023), https://www.nytimes.com/2023/02/23/climate/renewable-energy-us-electrical-grid.html.

26 How Does a Solar Farm Connect to the Grid?, Solarlandlease,Com, https://www.solarlandlease.com/solar-farm-connect-grid (last visited Oct. 4, 2023).

27 *Id.*

28 Yoann Hispa, Landgate, *Determining Factors for Solar Site Selection and Layout* (Nov. 15, 2023); https://www.landgate.com/news/determining-factors-for-solar-site-selection-and-layout.

29 *How Does a Solar Farm Connect to the Grid?*, Solarlandlease,Com, https://www.solarlandlease.com/solar-farm-connect-grid (last visited Oct. 4, 2023); Searchland, What Makes a Site Suitable for a Solar Farm; https://searchland.co.uk/blog/land-criteria-for-solar-farms last visited Jan. 1, 2025).



This map shows the locations and voltages of existing transmission lines in Pennsylvania and can help municipalities evaluate where solar development is likely to occur. An interactive version of this map can be found at https://www.arcgis.com/apps/mapviewer/index.html?layers=d4090758322c4d32a4cd002ffaa0aa12.

What this Means for Municipalities

When choosing where to allow grid-scale solar development, municipalities should prioritize sites near existing substations and transmission lines. This reduces the amount of additional infrastructure that will need to be built.

Land Characteristics

The physical characteristics of a site play a crucial role in its suitability for a solar project.[30] Zoning for potential solar sites with these characteristics in mind is one of the key ways municipalities can facilitate appropriate solar development.

Size

The amount of land needed for grid-scale solar varies depending on the location and the technology used.[31] Typically, it is more economical to construct and operate larger facilities because they require fewer access points into the electrical transmission grid for the same amount of electricity produced.[32]

30 Yoann Hispa, Landgate, *Determining Factors for Solar Site Selection and Layout* (Nov. 15, 2023); https://www.landgate.com/news/determining-factors-for-solar-site-selection-and-layout.

31 Solar Energy Industries Association, Land Use & Solar Development, SEIA.org, https://www.seia.org/initiatives/land-use-solar-development#:~:text=Depending%20on%20the%20specific%20technology,(MW)%20of%20generating%20capacity (last visited Oct. 4, 2023).

32 https://extension.psu.edu/physical-impacts-of-grid-scale-solar-development

Proposed grid-scale solar facilities in Pennsylvania are commonly 100 acres or more, with the average size being 218 acres.[33] Land ownership also plays a role in solar site selection. Solar developers typically lease land, and the more landowners this process involves, the more complicated it is. Therefore, developers prefer to build on a small number of large parcels rather than on many small parcels under different ownership.

What this Means for Municipalities

When choosing where to allow grid-scale solar development, municipalities should designate areas of sufficient size and prioritize areas where the size of solar arrays will not be unduly limited by existing development. Areas with a few large parcels are preferable to those with many smaller parcels.

Topography and Environmental Constraints

The less site preparation a solar developer has to do, the more cost-effective a project will be. Therefore, developers prefer sites that do not require extensive site alteration like grading and tree removal. Minimal site preparation is also preferable from a community and environmental perspective because this results in minimal disruption to the existing landscape.

For these reasons, although it is possible to install solar on rolling hills and undulating terrain, the flatter a site is, the better.[34] Slight slopes to the south or east can be beneficial, as this will increase the system's exposure to the sun.[35] Steep slopes are not preferred, both because they make installation of solar panels more difficult, and because disruption of steep slopes creates more environmental concerns.[36]

The ideal solar site is also free of obstructions like trees or buildings that could cast shadows on the panels, reducing their efficiency, particularly on the southern side of the site.[37] Even if only 10% of the array is shaded, it can lead to a 50% drop in efficiency of the panels.[38] Additionally, the soil conditions must be suitable for the installation of mounting structures.[39] Corrosive or rocky soils

33 https://extension.psu.edu/physical-impacts-of-grid-scale-solar-development; Landgate Corp., Pennsylvania Solar Development Analysis 2 (2024).
34 https://www.landgate.com/news/choosing-the-best-locations-for-solar-energy-factors-to-consider
35 Pivot Energy, *Solar Farm Land Requirements* (Nov. 19, 2019); https://www.pivotenergy.net/blog/solar-farm-land-requirements.
36 Billy Lundt, *Solar Power World*, *Solar Can be Installed on Uneven, Hilly Sites with Relative Ease* (Jan. 14, 2019); https://www.solarpowerworldonline.com/2019/01/solar-can-be-installed-on-uneven-hilly-sites-with-relative-ease/
37 Searchland, What Makes a Site Suitable for a Solar Farm; https://searchland.co.uk/blog/land-criteria-for-solar-farms last visited Jan. 1, 2025); https://www.landgate.com/news/choosing-the-best-locations-for-solar-energy-factors-to-consider
38 Penn State Extension, *Environmental Impacts of Grid-Scale Solar Development* (Dec. 13, 2024); https://extension.psu.edu/environmental-impacts-of-grid-scale-solar-development.
39 https://www.landgate.com/news/choosing-the-best-locations-for-solar-energy-factors-to-consider

make construction more difficult and may damage the mounting structures. Solar developers also prefer to avoid sites with significant environmental constraints. These may include things like streams, floodplains, wetlands, the presence of threatened or endangered species and wildlife habitat, and cultural resources such as buried artifacts.[40] Sites with these features are less desirable because they typically involve additional engineering and permitting hurdles. Avoiding these areas is also preferable from an environmental perspective.

What this Means for Municipalities

When choosing where to allow grid-scale solar development, municipalities should look for areas that are flat or gently sloping and avoid areas with sensitive environmental features like streams, wetlands, and floodplains. They should also avoid areas where soils may not be suitable for construction.

Location

In addition to proximity to transmission infrastructure, there are several other locational factors that solar developers consider when choosing sites for grid-scale systems. Developers prefer sites that have access to road infrastructure so they can transport equipment and personnel to the site during construction. They also prefer to avoid sites in close proximity to cemeteries, golf courses, and residential neighborhoods where there may be public opposition to solar development within the viewshed.[41]

Legal Landscape

The final factor that influences developers' solar siting decision-making is the legal landscape. Currently, Pennsylvania lacks any statewide laws governing the siting of solar facilities. Therefore, municipalities have the primary responsibility for creating a suitable legal landscape for solar siting. This is achieved through creating ordinances that balance the need to encourage thoughtful grid-scale solar development with the unique characteristics of the local community and environmental resources. The remainder of this publication will address how municipalities might best approach this responsibility.

[40] Penn State Extension, *Environmental Impacts of Grid-Scale Solar Development* (Dec. 13, 2024); https://extension.psu.edu/environmental-impacts-of-grid-scale-solar-development.
[41] *Id.*

IMPROVING THE LEGAL LANDSCAPE FOR GRID-SCALE SOLAR DEVELOPMENT

Unfortunately, in recent years, many Pennsylvania municipalities have adopted zoning ordinance language that, intentionally or unintentionally, places unnecessary obstacles in the path of solar development. Let's look at a few common provisions and examine how they might be improved.

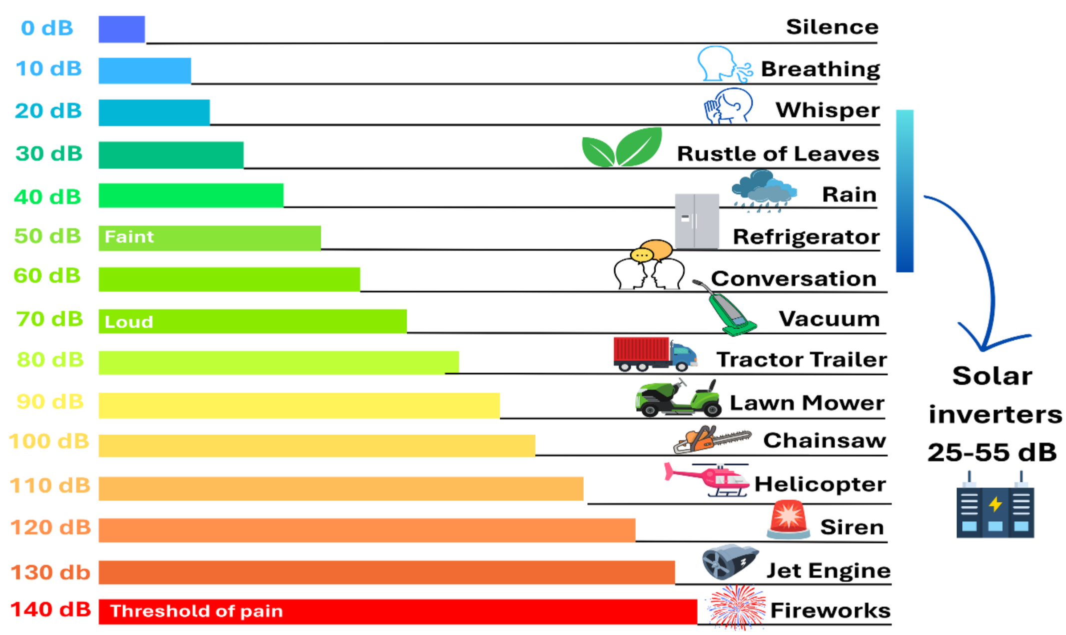
Setbacks

Some municipalities have adopted zoning ordinance language requiring 200-, 300- or even 500-foot setbacks for grid-scale solar development. This has the effect of greatly restricting the portion of any given tract that can be used for solar development. When considering whether such large setbacks are appropriate, it is important to consider their purpose. Setbacks primarily serve to shield neighboring properties from the disruptive impacts of a land use. However, when it comes to grid-scale solar as compared to other land uses, these concerns are minimal, making large setbacks unnecessary in most cases. Let's look at why.

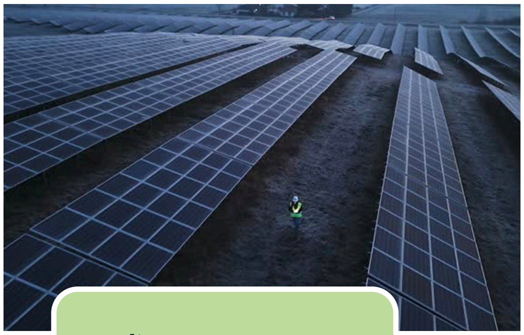
One common reason for large setbacks is to mitigate the noise impacts expected to result from a land use. Noise may come from the use itself (e.g. a noisy factory, racetrack, or outdoor music venue) or from traffic being generated by the use (e.g. truck traffic and loading machinery for a distribution center, car traffic for a shopping mall, or heavy machinery for agriculture). Neither of these sources of noise is a significant concern with grid-scale solar development. When it comes to traffic, grid-scale solar facilities generate less traffic than almost any other land use. They do not have on-site employees, customers, or deliveries, and traffic is generally limited to occasional maintenance staff visiting the site. In addition, the majority of the components at a grid-scale solar facility, including the PV panels themselves, are silent. While inverters do make noise, most operate within the range of 25 to 55 decibels.[42] This is about the level of a normal conversation and well below the level of even the quietest outdoor residential HVAC condenser units.[43] In addition, inverters only make noise when electricity is being generated, so are silent at night.

[42] Debby Cao, *Solar Inverter Noise Levels: A Comprehensive Analysis* (Feb. 2, 2024); https://www.solarctrl.com/blog/solar-inverter-noise-levels/

[43] *Id.*; ServiceOne Air Conditioning and Plumbing, Does it Really Matter How Loud Your Air Conditioner Is? (Sept. 19, 2022), https://www.serviceoneac.com/blog/2022/september/does-it-really-matter-how-loud-your-air-conditio/.



It is possible that sound from inverters would be noticeable to neighboring property owners, but many factors that influence whether this is the case, including the placement of the inverters within the property, topography, and the use of barriers or enclosures to dampen sound. Rather than blanketly imposing huge setbacks to mitigate noise impacts that may or may not affect neighboring properties (especially when other, noisier uses are not subject to the same requirements), municipalities can require that developers demonstrate how any potential noise impacts will be addressed for their project. In many cases, this can be done though less restrictive means than extremely large setbacks.



Glint is a momentary direct reflection of light. **Glare** is an indirect reflection.

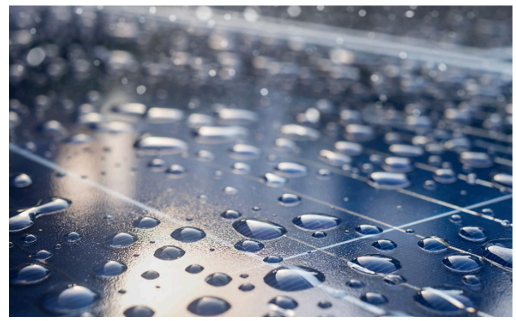
Undesirable light impacts, another common reason for large setbacks, are also unlikely to be a problem with grid-scale solar arrays. Because solar arrays are unmanned, there is little to no reason for developers to incorporate project-wide lighting. Typically, solar arrays only light the areas around transformers, not the panels themselves. Any concerns about this limited lighting can be addressed through specific requirements (e.g. requiring lights to be on motion activation or be downward-pointing) rather than excessive setback distances. Similarly, concerns about glare, to the extent that glare is a legitimate issue (see "Debunking Solar Myths" below), it can be addressed by requiring developers to conduct a glint and glare study and devise methods of controlling any glare, as needed.

Finally, we must acknowledge that excessive setback requirements are often driven by residents' distaste for the appearance of solar arrays, especially when compared to the landscape they are accustomed to seeing. When regulating based on aesthetics, municipalities must decide where to draw the line between legitimate concerns and accommodating an unreasonable desire to avoid seeing changes to the existing landscape. In doing so, it may be helpful for municipalities to consider the aesthetic qualities of a solar array as compared to other uses permitted in the same zoning district. Other impacts to neighboring properties, or lack thereof, should also be part of this calculation. Finally, municipalities should consider whether aesthetic concerns can be adequately addressed by other means, such as a reasonable landscape buffer.

What this Means for Municipalities

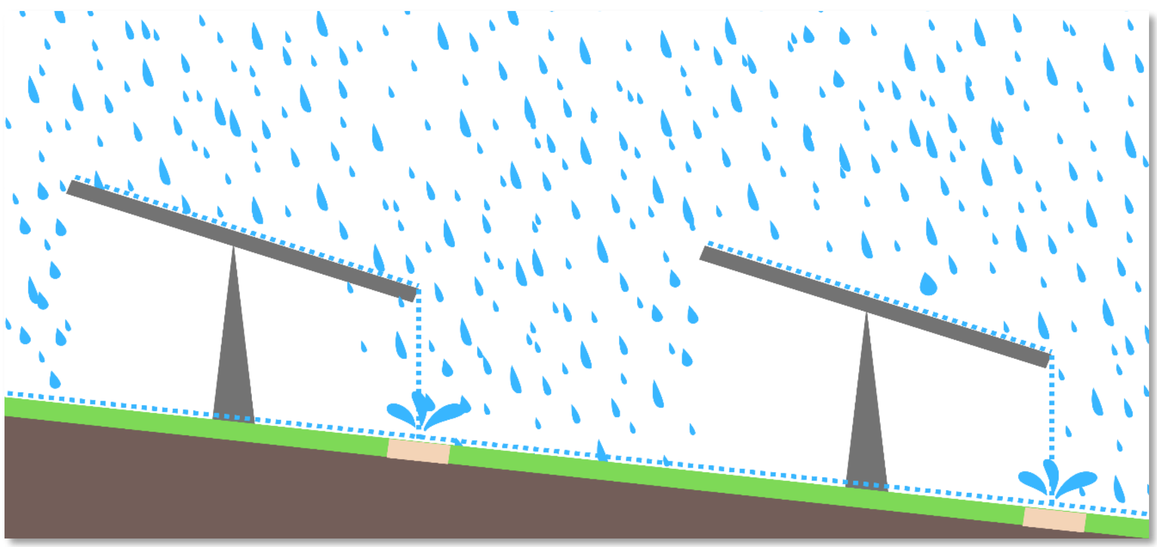
Municipalities should avoid reflexively imposing large setback requirements on grid-scale solar development. Instead, municipalities should consider the purpose of setbacks and what is reasonable given the nature of solar development. Municipalities should also consider less-restrictive means of addressing concerns about noise and lighting.

Solar Panels as Impervious Coverage



Most municipalities rightfully restrict the amount of impervious coverage that can be developed on any given property. The main reason for this is to manage stormwater runoff. Impervious surfaces—those that water cannot penetrate—increase the rate, volume, and velocity of stormwater runoff because the water rushes off the hard surface instead of soaking into the ground. If not properly managed, this runoff can cause erosion and flooding on neighboring properties and pollution in waterways. However, impervious coverage limitations also restrict the amount of development that can occur on a property. In order to properly balance the community's interest in stormwater control and private property owners' interest in making the best use of their property, impervious surface limitations should be tailored to achieve the purpose of controlling stormwater without unduly burdening development.

Solar panels present a unique situation when it comes to impervious surface because they are themselves impervious but are elevated above the ground.[44] This means they do not behave like other impervious surfaces that rest directly on the ground like buildings, parking lots, or roadways. When precipitation hits solar panels, it runs off onto the largely intact pervious surface directly underneath.



Rainfall strikes solar panels, runs off and is absorbed into the ground below. Splash pads at the base of panels helps prevent erosion at the point where water drips off the edge of panels.

44 Kennedy Jenks, *A Rainy Dat at a Solar Farm* (Nov. 10, 2017); https://www.kennedyjenks.com/2017/11/10/a-rainy-day-at-a-solar-farm/

For this reason, as long as good vegetative cover is maintained below the panels, the addition of solar panels to a vegetated field does not have a meaningful effect on the field's stormwater runoff characteristics.[45] One study used computer models to compare a field covered in native grass and the same field with solar panels. It found that there was a less than 1% difference in the total runoff volume, the maximum rate of flow, and the time between the start of rainfall and when peak discharge occurred, even when different storm magnitudes and durations, ground slopes, soil types, and panel angles were considered.[46] Another study found that the four key elements that affect stormwater on a solar site are soil compaction, soil depth, ground cover, and the distance between rows of panels, not the panels themselves.[47] This same study demonstrated that, where these factors are appropriately addressed, additional stormwater infrastructure is not needed to account for the actual solar panels.[48]

This data indicates that, while other impervious surfaces that may be part of a solar development should be counted toward impervious surface limitations, the solar panels themselves need not be treated as such. This is borne out by the fact that the Pennsylvania Department of Environmental Protection (DEP) and similar agencies in other states do not consider solar panels to be impervious coverage for purposes of stormwater calculations.[49]

This is not to say that there is no need for stormwater management at grid-scale solar projects. Water running off the edge of panels can cause erosion where it hits the ground if not properly managed, and the type of ground cover under and between the panels can significantly affect the runoff characteristics.[50] Surfaces like gravel roadways or compacted earth that are incorporated into a solar development should be considered impervious, just as they are with any other development. Avoiding soil compaction and ensuring adequate distance between rows of panels are also important ways of controlling stormwater runoff. However, none of this necessitates treating solar panels as impervious coverage. By and large, this is not needed to control stormwater at a grid-scale solar development.

What this Means for Municipalities

Municipalities should not count solar panels toward a parcel's impervious coverage limitation. Only ground-level improvements at a solar array such as roadways or concrete pads should be considered impervious surface. Important storm water management requirements include requiring measures to control erosion at the drip line of panels and preventing soil compaction.

Bonding and Decommissioning Requirements

Currently, most PV panels have a useful life of 25 – 30 years.[51] This has led some municipalities to impose requirements related to the decommissioning and removal of the panels when they reach the end of their life.[52] These typically include a requirement that the solar developer submit a plan detailing the steps that

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45 Lauren M. Cook & Richard H. McCuen, Hydrologic Response of Solar Farms, 18 J. Hydrol. Eng. 536, 540 (2013).

46 *Id.*

47 Great Plains Institute, Best Practices: Photovoltaic Stormwater Management Research And Testing, 3 (2023).

48 *Id.*

49 Kennedy Jenks, *A Rainy Dat at a Solar Farm* (Nov. 10, 2017); https://www.kennedyjenks.com/2017/11/10/a-rainy-day-at-a-solar-farm/.

50 Lauren M. Cook & Richard H. McCuen, *Hydrologic Response of Solar Farms*, 18 J. Hydrol. Eng. 536, 538–40 (2013); Kennedy Jenks, A Rainy Dat at a Solar Farm (Nov. 10, 2017); https://www.kennedyjenks.com/2017/11/10/a-rainy-day-at-a-solar-farm/.

51 *Emily Glover*, Forbes.com, *How Long Do Solar Panels Last* (Sept. 18, 2024); https://www.forbes.com/home-improvement/solar/how-long-do-solar-panels-last/.

52 *Emily Glover*, Forbes.com, *How Long Do Solar Panels Last* (Sept. 18, 2024); https://www.forbes.com/home-improvement/solar/how-long-do-solar-panels-last/.

will be taken to decommission the facility and/or a bond or other form of financial security to cover the costs of decommissioning should the developer fail to abide by the plan. Often, municipalities impose these requirements on solar development but not on other forms of development

There are several problems with this approach. First, the fact that solar panels have a known lifespan does not necessarily mean that they are any more likely to be abandoned than any other structure. The overwhelming majority of all U.S. solar capacity has not yet reached the end of its lifespan, so we have little hard data on decommissioning practices,[53] but there is no reason to believe that solar developers are worse neighbors than any other developer or more prone to leaving their property in disrepair. In fact, solar arrays may be even less likely to be abandoned than other types of development because most solar development occurs on leased land, and lease agreements typically require the developer to return the property to its previous condition at the end of the array's useful life. In addition, the materials in decommissioned solar panels can be valuable and unlikely to be abandoned by the owner. For these reasons, it makes little sense to single out solar developers for onerous bonding or decommissioning requirements when other land uses (particularly fossil fuel energy generation) are not subject to the same requirements.

In addition, even if solar panels were to stop generating electricity, the impact to the surrounding community is virtually the same as operational panels. Most people would not even be able to tell if solar panels were to cease operating and be abandoned. Finally, in the event that abandoned solar panels became an eyesore or a nuisance, most municipalities have ordinances such as property management ordinances that would allow them to take enforcement action to abate any detrimental impacts.

All of these factors weigh against singling out solar developers for bonding or decommissioning requirements. However, if municipalities do find it necessary to regulate the decommissioning of solar facilities, care should be taken to ensure that regulations are fair and reasonable.[54] Municipalities should also be aware that pending legislation in in the General Assembly would preempt their authority to impose bonding and decommissioning requirements if passed.

What this Means for Municipalities

Municipalities should not impose bonding and decommissioning requirements on grid-scale solar when other forms of development are not subject to the same requirements. Municipalities should be aware that pending legislation in the General Assembly would impose statewide bonding and decommissioning requirements and would preempt local ordinances if passed.

53 Heidi Kolbeck-Urlacher, Center for Rural Affairs, Decommissioning Solar Energy Systems Resource Guide 1 (2022).

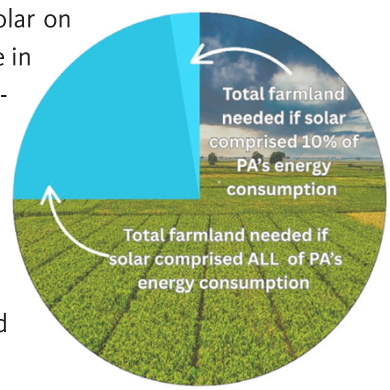
54 https://www.palegis.us/legislation/bills/2023/sb211

Solar on Farmland

Given the characteristics that make for a good solar site, it is not surprising that agricultural land is at the top of most grid-scale solar developers' wish lists. Agricultural land tends to be flat, level, cleared of trees, consolidated into large parcels under single ownership, and lacking significant environmental constraints. Most grid-scale solar development in Pennsylvania occurs on farmland, but this conversion of farmland into other uses is often unpopular, whether out of a concern for the local economy or simply because people prefer the aesthetics of farmland.[55]

The main drawback of converting agricultural land to any other land use, whether grid-scale solar, warehouses, or low-density residential development, is the obvious one—it removes that land from agricultural production. Agriculture is an important part of Pennsylvania's history, economy, and way of life. It employs over 500,000 people and generates over $135 billion in annual economic impact.[56] Farmland also provides environmental benefits, such as flood mitigation, groundwater recharge, air pollution removal, open space amenities, and carbon storage and sequestration.[57] For these and other reasons, Pennsylvanians often recoil at the idea of using farmland for grid-scale solar, and in an effort to preserve farmland, some municipalities have outright prohibited solar development on all prime agricultural lands or on certain classes of soil.

It is entirely appropriate for municipalities to consider the relative benefits and detriments of converting agricultural land to other uses and to draft ordinances accordingly. However, municipalities have too often approached the matter with a hatchet when what is needed is a scalpel. Municipalities considering a broad prohibition of solar on farmland should consider whether such limitations ultimately benefit or harm farming families. Let's look more closely at the relationship between solar development, farmland, and farmers.



The first thing to note is the scope of the "problem" of grid-scale solar on farmland. There are over seven million acres of land devoted to agriculture in Pennsylvania.[58] Pennsylvania's Solar Future Plan sets a goal for in-state solar facilities to provide 10 percent of in-state electricity consumption by 2030.[59] If all of the solar needed to achieve this goal was built on farmland, it would require no more than 180,000 acres, less than 2.5% of Pennsylvania's current farmland.[60] Even if Pennsylvania generated all of its power from solar (which is well beyond what anyone has proposed) and all the necessary solar development occurred on agricultural land, it would use no more than a quarter of the Commonwealth's farmland.

55 Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 3 (2024).

56 https://www.palegis.us/legislation/bills/2023/sb211

57 Penn State Extension, *Mitigating the Impact of Declining Farms in Pennsylvania* (July 13, 2022); https://extension.psu.edu/mitigating-the-impact-of-declining-farms-in-pennsylvania.

58 U.S. Dep't of Agriculture, 2022 Census Of Agriculture: Pennsylvania State And County Data, Table 1 (2024).

59 Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 16 (2024).

60 *Id at 11.*

It is also important to understand that solar developers do not take over farmland against the farmer's will. Farming is extremely competitive, with low profit margins that are vulnerable to fluctuations in market prices or crop yields.[61] In 2022 (the last year for which data is available), 58% of farms in Pennsylvania reported a net loss for the year, and another 24% reported gains of less than $50,000.[62] This means that less than one in five Pennsylvania farms earns a substantial profit. Grid-scale solar leasing can earn farmers 3 to 4 times more income per acre than any crop or commodity production at current market prices, making leasing land for solar development attractive to many farmers.[63] Farmers who add solar to all or a portion of their property can get a long-term, steady income, typically more than they can earn by leasing or farming the land.[64] This income may be the difference between the farmer being able to stay on the land and continue farming the remaining acreage and having to sell the farm to a developer who will take it permanently out of agricultural production by building housing developments, data centers, or warehouses/distribution centers.[65]

The reality is that prohibiting solar on farmland may be harming farmers more than helping them by cutting off a potential income stream that can help keep farms afloat and keep farming families in the community. Furthermore, unlike almost all other forms of development, solar projects have a relatively minor and impermanent impact on farmland.[66] As discussed above, solar development does not permanently convert the land to impervious surfaces and has little to no light or noise impacts on neighboring properties. Installed solar facilities today have a useful life of approximately 30 years, after which they can be removed, and the land returned to agricultural use if that is what the landowner desires. In fact, farmland that has been temporarily used for solar development may return to agricultural production even better than before, improved by many years of lying fallow. Although it is too early to know how frequently solar development will revert to agricultural use in practice, it is more likely that land used for solar facilities will revert to farmland than land that is paved over and developed for other uses.[67]

[61] Solar Energy Industries Association, Solar & Agricultural Land Use 2 (2019).
[62] U.S. Dep't of Agriculture, 2022 Census Of Agriculture: Pennsylvania State And County Data, Table 5 (2024).
[63] Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 28 (2024).
[64] Solar Energy Industries Association, Solar & Agricultural Land Use 2 (2019).
[65] Penn State Extension, *Landowner Leasing for Utility Scale Solar Farms* (March 9, 2023); https://extension.psu.edu/landowner-leasing-for-utility-scale-solar-farms https://www.pahomepage.com/video/watch-hundreds-of-turkeys-trek-through-snowstorm-2822-news/10384870
[66] Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 3, 23 (2024).
[67] Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 24 (2024).

Lastly, a blanket prohibition against solar development—and only solar development—on farmland ignores the more pressing threat to agricultural land in Pennsylvania: low-density, large lot housing developments and associated "sprawl." Between 2001 and 2016, 70% of the farmland lost in Pennsylvania—nearly a quarter million acres—was lost to this type of development.[68] By comparison, at the end of 2024, there were a total of 46 operating grid-scale solar projects in Pennsylvania averaging 218 acres in size.[69] This amounts to just over 10,000 acres of grid-scale solar statewide.[70] Even if every one of the 480 solar projects currently seeking approval from the regional grid operator were developed at comparable sizes, the total acreage used would still be less than half of the farmland lost to low-density housing.[71] Imposing strict limitations on grid-scale solar development without imposing comparable limitations on other land uses unduly burdens a type of development that can be compatible with agricultural use while ignoring forms of development that are much more likely to remove land from agricultural production forever. If a municipality chooses to prioritize farmland preservation over other forms of development, restrictions should apply to *all* land uses that remove farmland from agricultural production, not just solar.

Agrivoltaics

In addition, land used for grid-scale solar development can be used simultaneously for agriculture, thereby enhancing and diversifying agricultural production. This practice of harnessing solar energy while cultivating crops or raising livestock beneath or between rows of PV panels is called **agrivoltaics**.[72] While agrivoltaics on grid-scale solar projects have not yet become common in Pennsylvania, it is proposed for many of the projects awaiting approval.[73]

The two most popular methods of agrivoltaics in the northeastern United States are pollinator meadows and sheep grazing.[74] The pollinator approach involves seeding the area under the panels with a pollinator-friendly mix of flowers and other plants, which then attract and feed pollinators like bees and butterflies that are critical to the success of crop production.[75] Nearly 75% of all food crops benefit from animal pollination, and 35% rely exclusively on pollinators for crop production.[76] Pollinators are also vital to pollination of other plants. Sadly, pollinator populations are decreasing as a result of habitat loss, degradation, and fragmentation.[77] Seeding grid-scale solar properties with pollinator-friendly plant mixes provides habitat needed to halt the decline of these species while benefitting nearby land in agricultural production. One large solar field or perimeter screen area seeded with pollinator-friendly plants is akin to planting thousands of backyard pollinator gardens.[78] In addition to pollinator meadows, other crops that can co-exist with solar panels include broccoli, leafy greens, root vegetables, berries, and shade-tolerant herbs.[79]

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68 Penn State Extension, *Mitigating the Impact of Declining Farms in Pennsylvania* (July 13, 2022); https://extension.psu.edu/mitigating-the-impact-of-declining-farms-in-pennsylvania

69 *See* Landgate Corp., Pennsylvania Solar Development Analysis 2 (2024).

70 *See* Landgate Corp., Pennsylvania Solar Development Analysis 2 (2024).

71 *See* Landgate Corp., Pennsylvania Solar Development Analysis 2 (2024).

72 Penn State Extension, *Agrivoltaics: What Does That Mean?* (Dec. 4, 2023); https://extension.psu.edu/agrivoltaics-what-does-that-mean

73 Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 24 (2024).

74 Penn State Extension, *Agrivoltaics: What Does That Mean?* (Dec. 4, 2023); https://extension.psu.edu/agrivoltaics-what-does-that-mean

75 Michele Boyd, *U.S. Dep't of Energy, Buzzing Around Solar: Pollinator Habitat Under Solar Arrays* (June 21, 2022); https://www.energy.gov/eere/solar/articles/buzzing-around-solar-pollinator-habitat-under-solar-arrays.

76 Pennsylvania Pollinator Health Task Force, The Pennsylvania Pollinator Protection Plan 2 (2017).

77 Pennsylvania Pollinator Health Task Force, The Pennsylvania Pollinator Protection Plan 2, 8 (2017).

78 Solar Energy Industries Association, Solar & Multiuse Farming 2 (2019).

79 Mark Richardson, *US Light Energy, Agrivoltaic Farming in PA: What Crop is Best for Agrivoltaics* (May 1, 2024); https://uslightenergy.com/agrivoltaic-farming-in-pa-what-crop-is-best-for-agrivoltaics/

Another type of agrivoltaics is solar grazing, a method of grazing livestock, primarily sheep, underneath and among solar panels.[80] This practice benefits both the farmer and the solar company. The solar field provides pasture for the sheep while the sheep provide a means of vegetation control for the solar company that has been found to be more cost-effective than chemical or mechanical means.[81] Meanwhile, as the herd grazes, it spreads manure, cycling nutrients, carbon, and water back into the soil.[82] One site in Pennsylvania where solar grazing is being used is Nittany 1, one of three solar sites providing power to Penn State University.[83] There, a neighboring Amish farmer grazes almost 500 sheep among the solar panels, using a rotational system to feed his flock and maintain the land.[84] While solar grazing has not yet become commonplace in Pennsylvania, it is becoming more popular, with numerous companies planning to contract grazing services under solar panels after they are constructed.[85] Pennsylvania already hosts one of the largest sheep markets in the United States, and sheep farmers are seeing agrivoltaics as an opportunity to get additional revenue from solar leasing and increase the size of their flocks and match emerging demand.[86]

A sheep grazing at the Nittany 1 solar array

What this Means for Municipalities

Municipalities should be aware that grid-scale solar development is compatible with farming in many ways. In a highly competitive, low profit-margin business like farming, leasing land for grid-scale solar often earns farming families supplemental income that allows them to stay on the land and continue farming instead of selling land off for permanent development. In addition, land under solar panels can be used for agriculture or practices that benefit agriculture, like sheep grazing and pollinator habitat. Solar panels require minimal earth disturbance and can be easily removed at the end of their useful life, unlike the other land uses that farmland is more often converted to, like low-density residential subdivisions, warehouses, and shopping centers.

For these reasons, municipalities should not overly restrict grid-scale solar development on agricultural land, and should not place greater restrictions on solar development than they place on other land uses that result in permanent loss of agricultural land.

80 Solar Energy Industries Association,Solar & Multiuse Farming 1 (2019).
81 Solar Energy Industries Association, Solar & Multiuse Farming 1 (2019); Penn State Extension, *Agrivoltaics – What Opportunities Exist for Livestock Producers?* (2024); https://extension.psu.edu/agrivoltaics-what-opportunities-exist-for-livestock-producers
82 LightSourceBP, *First Lightsource bp U.S. Agrivoltaics Program Launches in Pennsylvania* (Aug. 17, 2021); https://lightsourcebp.com/us/news/first-light-source-bp-u-s-agrivoltaics-program-launches-in-pennsylvania/.
83 LightSourceBP, *First Lightsource bp U.S. Agrivoltaics Program Launches in Pennsylvania* (Aug. 17, 2021); https://lightsourcebp.com/us/news/first-light-source-bp-u-s-agrivoltaics-program-launches-in-pennsylvania/.
84 *Id.*
85 Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 24 (2024).
86 Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 24 (2024).

Solar on Woodlands

Although developers typically prefer farmland, in some areas, potential sites for grid-scale solar include woodlands. As with farmland, municipalities must balance the benefits of forested land against the benefits of solar development when considering whether, and to what extent, to permit grid-scale solar development in these areas.

Several principles can help guide this balancing. The first requires recognizing that not all forests are created equal. Mature forests provide many valuable ecosystem services such as carbon storage, climate stabilization, soil formation, watershed services, habitat for game, pollinators, and other wildlife, and scenic landscapes.[87] These forests are particularly valuable when they part of a connected network of landscapes that allow wildlife to move freely from one place to another without encountering human development.[88] There is also an important relationship between forested areas and water resources. Vegetated areas adjacent to lakes, ponds, streams, and wetlands protect waters from impacts related to human land use.[89] Wooded areas along waterways in particular provide many irreplaceable benefits, including flood control, erosion control, pollutant removal, temperature regulation, habitat for plants and animals, and aesthetic and recreational opportunities. For these reasons, municipalities should avoid allowing solar development (or any large-scale development) on forested land that is home to high native biodiversity and high-quality natural communities, especially where it would result in fragmentation and disconnection of habitat corridors, or in the critical buffer area around streams, wetlands, ponds, and lakes.

Compared to mature, interconnected forests, other forested land may have lesser ecological value due to limited biodiversity or the fracturing of the forest into disconnected parcels.[90] The benefits of clean, renewable energy that grid-scale solar development provides may outweigh the drawbacks of development on these small, isolated parcels of woodland, making these locations suitable candidates for solar development. Municipalities can limit the impact of development on these parcels by limiting tree clearing to only what is necessary for the development, and by requiring the space between panels to be planted with a pollinator mix or other native plant mix that provides ecosystem benefits.

Finally, as with farmland, municipalities should avoid inappropriately singling out grid-scale solar when it comes to restricting development on forested land. If a municipality wants to use zoning restrictions to protect mature, connected forested areas, these restrictions should apply to *all* development, not just solar.

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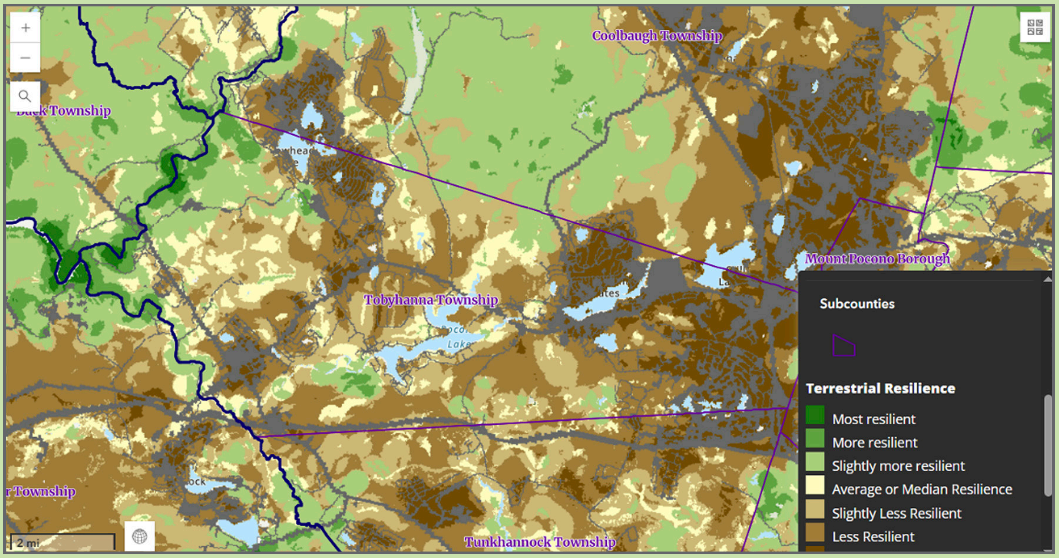
87 Guillermo Martínez Pastur et al, Ecosystem Services From Forest Landscapes: An Overview 4–5 (2018).

88 https://www.arcgis.com/apps/mapviewer/index.html?webmap=b84ba9cf2fdf41dba4d913ed53385374&extent=-85.5759,32.2955,-74.271,38.004

89 Ellen Hawes and Markelle Smith, Yale School of Forestry and Environmental Studies, Riparian Buffer Zones: Functions And Recommended Widths 3 (2005).

90 Penn State Extension, *Land Conversion Issues with Grid-Scale Solar Development* (Jan. 8, 2025); https://extension.psu.edu/land-conversion-issues-with-grid-scale-solar-development



A resource that can help municipalities identify areas with high biodiversity and connectivity is the Nature Conservancy's Resilient Land Mapping Tool. This map incorporates data about landscape, species diversity, habitat diversity, and connectedness between natural areas to identify areas of high resilience, biodiversity value, and connectivity. Another tool is the Pennsylvania Natural Heritage Program's Pennsylvania Conservation Explorer map, which allows users to see many features, including important bird areas and Natural Heritage "Core Habitat" Areas, which are areas of essential habitat that can absorb very little activity or disturbance without substantial impact.

What this Means for Municipalities

Municipalities should limit grid-scale solar development in mature forests that are home to high native biodiversity, where development would result in fragmentation and disconnection of habitat corridors, and along streams, wetlands, and other water resources. By contrast, the benefits of clean, renewable energy may outweigh the drawbacks of development on small, isolated patches of woodland or areas of young growth, making these areas suitable sites for grid-scale solar development. Municipalities should not single out grid-scale solar when restricting development on forested land. If this form of development is prohibited or restricted, other large-scale development should be similarly restricted.

WHAT ABOUT BROWNFIELDS?

We hear it all the time. "Why can't they just put solar on landfills/abandoned mines/shuttered factories instead of on farms and forests?" Developing grid-scale solar on previously-developed sites, known as brownfields, may sound like an easy way to avoid development on agricultural land and forests, but it is not quite so simple as that.

he Foul Rift solar project in Warren County, New Jersey, was built on an environmentally degraded site that had been home to a composting facility for nearly thirty years.

In general, brownfields are difficult to develop for grid-scale solar (or any other type of development) because they are more complicated and expensive to develop than undeveloped "greenfield" sites.[91] Brownfield sites typically require more site preparation than farmland and often have significant environmental constraints like soil contamination that must be remediated before construction can begin.[92] A solar developer that purchases a brownfield site may even face legal liability for problems caused by contamination due to previous activities at the site. Furthermore, brownfield sites do not necessarily have the other characteristics needed for solar development, such as size and proximity to electric transmission infrastructure. An analysis of over 500 grid-scale projects awaiting approval from the regional grid operator in 2023 indicated that only 4% of these projects would be on brownfields, as opposed to 82% on open land.[93]

This is not to say that brownfield development is impossible. State and federal funding is available for brownfield redevelopment, and this helps defray some of the additional costs of developing these sites. Several brownfields solar developments in Pennsylvania have benefitted from this funding. The U.S. Environmental Protection Agency has even created a map of contaminated lands, landfills and mine sites that may be suitable for renewable energy development (link in footnote).[94] All things considered, brownfield development can and should be a key part of Pennsylvania's solar future. However, municipalities and residents should not expect it to be a "silver bullet" solution that eliminates the need for greenfield projects.

91 Zachary Goldberg, et. al, Center for Rural Pennsylvania, Understanding And Addressing The Impact Of Solar Development On Pennsylvania Farmland 25 (2024).
92 *Id.*
93 *Id* at 22.
94 https://www.epa.gov/re-powering/re-powering-mapper#search-renewable

What this Means for Municipalities

Municipalities should be aware that developing brownfields for grid-scale solar (or any other type of development) is possible, but comes with many obstacles. Municipalities should allow grid-scale solar development on brownfields sites, but should not expect all such development to occur in these places. Other suitable locations for grid-scale solar should also be chosen.

Brownfields Solar Development in Pennsylvania

Several sites in Pennsylvania have already benefitted from funding for brownfields development. In 2022, Pennsylvania's Bureau of Abandoned Mine Reclamation issued over $6 million in grant funds to repurpose 185 acres of abandoned mine land in Luzerne and Schuylkill Counties as a 30.5 MW solar facility. In 2024, the U.S. Department of Energy awarded $90 million to build a 402 MW solar facility on a former coal mine in Clearfield County.

WHAT ABOUT PARKING LOTS AND WAREHOUSE ROOFS?

Another common refrain is, “Why can’t they just put it on all the parking lots and warehouse roofs?” Like solar development on brownfields, the reality of solar atop existing development is more complicated than simply slapping solar panels on existing structures.

While large existing structures like warehouses and parking lots can provide opportunities for solar development , many of these types of facilities simply are not large enough for grid-scale solar energy development, and few are located close enough to electric transmission infrastructure to make grid-scale solar a feasible option. In addition, when it comes to warehouses and other large structures, the roof structures of most existing buildings are not designed to hold the extra weight of solar panels, meaning retrofitting solar panels on these facilities would require costly building upgrades. Often, the benefits of installing solar do not offset the cost of doing so, and municipalities have little to no power to force landowners to install additional improvements on existing development.

Even installing solar panels to supply a building’s own electricity is complicated. Most warehouses and distribution centers are owned by a landlord, who rents to a company operating out of the warehouse. Usually, it is the tenant to pays the electric bill, but the landlord who is responsible for making improvements to the building. Therefore, the landlord would bear the cost of installing the solar, but would not get any direct benefit, as it is the tenant who sees the energy savings on their electric bill. It is possible for landlords and tenants to work out agreements that allow the landlord to benefit from the energy savings, but this can be complicated, and landlords may not consider it to be worth the effort.

Like solar development on brownfields, solar arrays atop large structures like warehouses and parking lots can be a part of Pennsylvania’s future, but will not eliminate the need for new, ground-level grid-scale solar development.

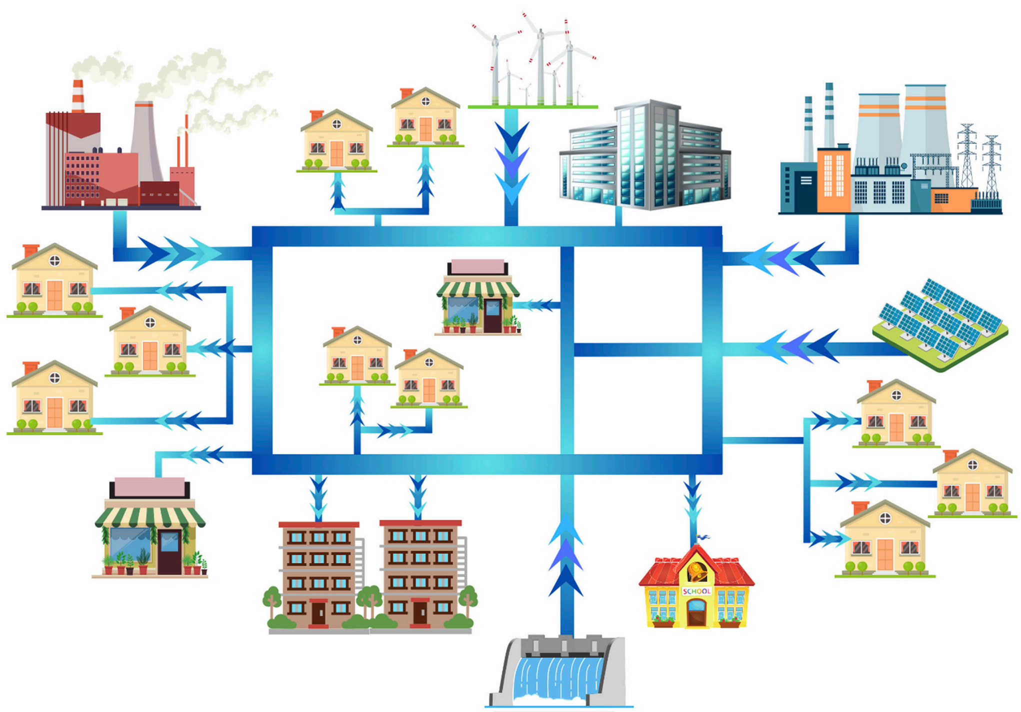
What this Means for Municipalities

Municipalities should be aware that, while large buildings and parking lots provide opportunities for solar development, this does not eliminate the need for municipalities to allow ground-level, grid-scale solar arrays. In addition, municipalities have little power to require landowners to install additional improvements on existing development.

“WE’RE NOT GETTING THE POWER.”

Opponents of solar development are often frustrated by what they see as a negative change in their environment without a direct benefit to their community. “We’re not getting the electricity, so why would we allow this?” However, this objection is rooted in a misunderstanding about how electricity gets from where it is generated to where it is used.

The electric wire connecting a home or business to the nearest utility pole is actually part of a huge, complex, and interconnected system of wires and other electrical infrastructure that connects energy generators and energy users across more than a dozen states. This engineering marvel is what we call “the grid.” It allows electricity produced in one part of the grid to reach users anywhere else in the grid. It also means that, unlike distributed energy systems like rooftop solar arrays, there is not a direct line between grid-scale electric generators and any individual user.



In the most basic sense, electricity is a flow of electrons. To visualize this, it helps to think of electricity flowing around the grid in the same way water would flow around a system of interconnected canals, with generators adding water to the system and users withdrawing it. Grid-scale energy generators like solar arrays, wind farms, gas, nuclear and hydroelectric plants located all over the region put this flow of electrons into the grid, while energy users like homes, businesses, offices, and institutions withdraw it. Regardless of where the energy generator is located, once its electrons enter the system, they flow around freely and mix with the electrons added by all the other generators, just like water molecules from different sources would mix together upon being poured into the same canal. When energy users withdraw energy from the grid, the energy they take is made up of electrons that may have originated from any number of generators all over the grid.[95] This means no electricity user or group of users gets its energy from any particular grid-scale energy generator, whether solar or otherwise.

95 For a more in-depth discussion of this idea, we recommend the video Which Power Plant Does My Electricity Come From? on the channel Practical Engineering on YouTube. https://youtu.be/sH1PVVJuBtE?feature=shared

This is not to say that there is no benefit to a solar array when it comes to energy costs. Not only is solar a clean, non-polluting form of energy, it is cheaper to generate energy from grid-scale solar than almost any other source, and this means solar generators can sell that electricity to distributors like PPL, PECO, MetEd, and Pennelec for a lower price. These savings are then passed on to the distributors' customers. The workings of energy markets are very complex and beyond the scope of this publication, but, suffice it to say, when there's more cheap energy being put into the grid, it lowers energy prices overall. Therefore, even though a grid-scale solar array does not feed power directly into surrounding homes and businesses, those local energy users still benefit from solar being part of the grid.

What this Means for Municipalities

Municipalities should not expect grid-scale solar arrays to feed power directly to local homes and businesses. This is not how the electric grid works. The fact that the benefits of grid-scale solar development are not localized is not a reason to disfavor it. Adding solar to the electric grid benefits everyone!

Energy Choice in Pennsylvania

In Pennsylvania, utilities like PPL, PECO, Met-Ed, and West Penn Power purchase electricity from generators (power plants, solar arrays, wind farms, etc.) and distribute it to customers through the grid. Pennsylvania law requires utilities to allow their customers to choose where their electricity comes from. Customers can go to PaPowerSwitch.com to compare generators (called "suppliers" in this context) based on price, payment structure, or the type of energy generation. Choosing a specific energy generator doesn't mean that a customer will be directly connected to the chosen supplier—electricity from each generator will still combine with electricity from other generators and flow through the grid. But, it does mean that the portion of the electricity entering the grid for that customer must come from that supplier.

Energy choice means that Pennsylvania electricity users can (and should!) choose renewable energy sources if they can afford it. When many customers choose solar or other renewable sources of energy, it means a greater portion of the electricity entering the grid will come from clean, renewable generators like solar and wind power instead of polluting fossil fuel plants!

PAPowerSwitch
Pennsylvania Public Utility Commission

DEBUNKING SOLAR MYTHS

Finally, we want to prepare municipal officials to respond to concerns residents may voice regarding grid-scale solar. While many of these concerns may feel real, oftentimes a full understanding of what is really happening is enough to alleviate concerns of the community. It is important to have these conversations early and often, sometimes even before a solar development may be proposed in your municipality, so that the community is prepared.

MYTH: Solar arrays create excessive glare

REALITY First, it is important to distinguish between PV systems and concentrating solar power (CSP) technologies that use mirrors and lenses to concentrate light onto a central receiver.[96] CSP systems are much less common than PV systems, and almost all existing CSP systems in the United States are in the Southwest.[97] PV systems do not use mirrors or any other highly-reflective surface. PV panels are designed to absorb light, not reflect it.[98] Therefore, panels generally have textured glass and/or antireflective coatings to reduce reflectivity and increase the panels' electric output.[99] Remember, solar companies do not want glare, as this reduces the project's efficiency and cost-effectiveness.[100] As a result, PV panels are generally less reflective than windows, snow, or water.[101]

It is also important to distinguish between glint and glare. Glint is a momentary direct reflection of light, whereas glare is an indirect reflection.[102] PV arrays typically do not cause glint either.[103]

If a municipality remains concerned about glare, it may consider requiring solar developers to submit a glint and glare study under certain circumstances. These studies are created using computer software and look at various points of interest, such as points on roadways or neighboring houses, to assess whether they will experience glint or glare.[104]

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96 Evan Riley and Scott Olson, *A Study of the Hazardous Glare Potential to Aviator from Utility-Scale Flat-Plate Photovoltaic Systems*, Hindawi.com (Dec. 11, 2011), https://www.hindawi.com/journals/isrn/2011/651857/.

97 *Concentrated Solar Power*, Wikipedia, https://en.wikipedia.org/wiki/Concentrated_solar_power.

98 Megan Day & Benjamin Mow, National Renewable Energy Laboratory, NREL.Gov, *Research and Analysis Demonstrate the Lack of Impacts of Glare from Photovoltaic Modules* (July 31, 2018), https://www.nrel.gov/state-local-tribal/blog/posts/research-and-analysis-demonstrate-the-lack-of-impacts-of-glare-from-photovoltaic-modules.html.

99 National Renewable Energy Laboratory, *Analyzing Glare Potential of Solar Photovoltaic Arrays* (Nov. 2016), https://www.nrel.gov/docs/fy17osti/67250.pdf.

100 Penn State, Municipal Officials' Guide To Grid-Scale Solar Development In Pennsylvania, Sec. 3, p. 5 (2022).

101 Penn State, Municipal Officials' Guide To Grid-Scale Solar Development In Pennsylvania, Sec. 3, p. 5 (2022); National Renewable Energy Laboratory, Analyzing Glare Potential of Solar Photovoltaic Arrays (Nov. 2016), https://www.nrel.gov/docs/fy17osti/67250.pdf.

102 National Renewable Energy Laboratory, Analyzing Glare Potential of Solar Photovoltaic Arrays (Nov. 2016), https://www.nrel.gov/docs/fy17osti/67250.pdf.

103 *Id.*

104 Penn State Extension, *Solar Panel Glare: Is It an Issue?* (April 18, 2024), https://extension.psu.edu/solar-panel-glare-is-it-an-issue

MYTH: Solar panels create a harmful electromagnetic field (EMF)

REALITY EMFs are invisible areas of energy, often called non-ionizing radiation, that are associated with the use of electrical power and lighting.[105] People have expressed concern about the potential health consequences of EMF since the 1970s, but no study has ever shown that EMF causes health problems.[106] Even if EMF were cause for concern, EMF levels at the perimeter of a solar array are significantly lower than a typical American's average EMF exposure and are considered "generally negligible."[107] Researchers in Massachusetts found the EMF of grid-scale-scale inverters at solar arrays to be 0.5 mG (milligauss) or less.[108] This is less than one-sixth the EMF one would encounter standing three feet from a refrigerator (6 mG) and one one-hundredth of the EMF experienced standing three feet from a microwave (50 mG).[109]

MYTH: Toxic metals from solar panels contaminate ground and water

REALITY There is virtually no risk that toxic metals will leach from solar panels during the construction or operation of a solar array. The most common type of solar panels, comprising 95% of the market, are made using non-toxic crystalline silicon.[110] The other type of solar panel, thin-film panels, consist of thin layers of cadmium telluride (CdTe) embedded on glass, polymer or metal.[111] All of the materials within solar panels are enclosed using a weatherproof seal and cannot vaporize into the air or combine with water. The material encasing the panels is the same material used in car windshields. In normal operation, solar panels pose a negligible toxicity risk to public health and safety, and that risk is miniscule when compared to water pollution generated by fossil fuel energy, or even other land uses like homes, warehouses, and, yes, even agriculture.

[105] Nat'l Institute of Envt'l & Health Sci., *Electric & Magnetic Fields*, https://www.niehs.nih.gov/health/topics/agents/emf (last visited Apr. 8, 2025).
[106] Tommy Cleveland, North Carolina State University, Health And Safety Impacts Of Solar Photovoltaics 14 (2017).
[107] *Id* at 15.
[108] *Id.*
[109] *Id.*
[110] U.S. Envt'l Prot. Agency, *End-of-Life Solar Panels: Regulations and Management*, https://www.epa.gov/hw/end-life-solar-panels-regulations-and-management (last visited May 9, 2025).
[111] *Id.*

MYTH: Toxic substances will leech into landfills when solar panels are thrown away

REALITY Like any source of energy, there are wastes associated with solar panels that need to be properly recycled or disposed of when solar panels reach their end of life.[112] Some solar panels contain small amounts of metals in their semiconductors or solder that can be hazardous to human health and the environment at high levels, although this varies from manufacturer to manufacturer and even model to model.[113] If these harmful metals are present in high enough levels, panels cannot simply be tossed in a landfill. They will be subject to Environmental Protection Agency regulations governing disposal of hazardous waste that ensure such materials are discarded properly.[114]

In addition, the US Department of Energy estimates that 90% of a solar panel's components are recyclable at the end of their lifetime. The majority of the panel is made from glass and aluminum, materials for which there exist large and established recycling market.[115] Racking components can often be recycled with other scrap metals, inverters with electronic waste recycling, and battery grid storage systems with battery recycling programs.[116] Various efforts supported by the US Department of Energy are underway to improve end-of-life concerns associated with solar technologies, including material recovery and recycling.[117] Retired grid-scale solar panels can also be reused for generating additional renewable energy at a new location long after their design life, e.g. powering electric vehicle or bike charging stations, disaster relief, or on boats or campers.

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112 *Id.*
113 *Id.*
114 *Id.*
115 U.S. Envt't Prot. Agency, Solar Panel Recycling, https://www.epa.gov/hw/solar-panel-recycling (last visited May 9, 2025).
116 *Id.*
117 *Id.*

MYTH: Solar arrays harm birds and wildlife

REALITY As with the concerns about glint and glare, it is important to distinguish between PV solar systems and concentrating solar power (CSP) technologies. Unlike CSP systems, PV systems do not concentrate the sun's rays on a single point to create heat. Therefore, concerns about birds or other animals being burned or "incinerated" by a solar array, while potentially valid when it comes to CSP systems,[118] are not a concern with the PV systems used in Pennsylvania.

Research into the risk of birds colliding with PV solar panels has been inconclusive.[119] It is possible that waterfowl and shorebirds may perceive the surface of PV panels as bodies of water and collide with them, but even if this does occur, the mortality rate is low compared to other causes such as collisions with buildings, vehicles, and power lines, or even predation by domestic cats![120] In addition, recent studies have found that fatalities may not be as common as initially suspected.[121] A study conducted at a research facility in Illinois used artificial intelligence to analyze more than 17,000 hours of video of birds interacting with solar facilities and did not record a single collision.[122] Instead, researchers found that birds were perching on and flying around the panels, and even foraging, nesting, and roosting under them.[123]

As for other wildlife, minimizing the land cleared for solar panels and following the guidance in the rest of this guidebook is the best way to mitigate the impacts on wildlife. Additional measures can also be incorporated to help wildlife. These may include wildlife permeable fences that allow small- to medium-sized animals to pass through or creating wildlife passageways that allow larger wildlife to cross through the site.[124]

A fox passes through wildlife permeable fencing at a grid-scale solar array in North Carolina. Photo Credit: Liz Kallies, The Nature Conservancy

Finally, it is important compare the risks that grid-scale solar arrays pose to wildlife to the risks of the alternative: fossil-fuel energy generation. Fossil fuel energy generation not only reduces habitat and causes pollution, including catastrophic spills, it drives climate change, which is expected to replace habitat loss as the leading threat to the world's biodiversity in the coming years.[125]

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118 https://www.sciencealert.com/this-solar-plant-accidentally-incinerates-up-to-6-000-birds-a-year

119 U.S. Dept. of Energy, Artificial Intelligence Camera Captures Bird Behavior Around Solar Panels to Inform Siting and Conservation—Success Story (Oct. 24, 2024); https://www.energy.gov/eere/solar/articles/artificial-intelligence-camera-captures-bird-behavior-around-solar-panels#:~:text=Research%20on%20the%20risk%20of,birds%2C%20and%20even%20provide%20habitat.

120 Anker, Do Solar Panels Kill Birds? Debunking the Myths and Facts (Jan. 1, 2023); https://www.ankersolix.com/blogs/solar/do-solar-panels-kill-birds.

121 U.S. Dept. of Energy, Artificial Intelligence Camera Captures Bird Behavior Around Solar Panels to Inform Siting and Conservation—Success Story (Oct. 24, 2024); https://www.energy.gov/eere/solar/articles/artificial-intelligence-camera-captures-bird-behavior-around-solar-panels#:~:text=Research%20on%20the%20risk%20of,birds%2C%20and%20even%20provide%20habitat.

122 *Id.*

123 *Id.*

124 Liz Kalies, The Nature Conservancy, Making Solar Wildlife-Friendly (Oct. 19, 2019); https://www.nature.org/en-us/about-us/where-we-work/united-states/north-carolina/stories-in-north-carolina/making-solar-wildlife-friendly/

125 Catrin Einhorn, The New York Times, The Planet Needs Solar: Can We Build It Without Harming Nature? (Feb. 11, 2024); https://www.nytimes.com/interactive/2024/02/11/climate/climate-change-wildlife-solar.html?smid=em-share.

MYTH: Grid scale solar arrays destroy property values

REALITY To date, studies investigating the property value impacts of grid-scale solar projects have been inconclusive.[126] One study investigated over 1.5 million housing transactions among 2,000 solar projects across the country and found that property values declined about 1% depending on proximity to nearby solar projects.[127] Another study looking at 956 solar projects in the U.S. found no significant association between property values and nearby solar projects.[128] A third study found that average home values in both rural and metropolitan areas in ten midwestern states actually increased 0.5 to 2.0% when there was a grid-scale solar project nearby.[129] In short, studies that explore the effects of large-scale solar facilities on property values have mixed findings but suggest that any positive or negative effect on property values is limited in magnitude and geographic extent.[130] This is likely no different, or even better in some cases, than other types of large scale development like warehouses, data centers, or fossil fuel energy projects that could be located in the same area.

[126] Simeng Hao & Gilbert Michaud, *Assessing Property Value Impacts Near Utility-Scale Solar in the Midwestern United States*, 12 Solar Compass 100090 at 3 (2024).
[127] *Id.*
[128] *Id.*
[129] *Id.*
[130] American Planning Association, *Solar@Scale: A Local Government Guidebook for Improving Large-Scale Solar Development Outcomes* 19 (3d ed. 2023).

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