UTILITY-SCALE SOLAR PV

Utility-scale solar arrays contain hundreds, thousands, and in some cases millions of PV panels. A general definition of "utility-scale" solar is any installation producing 10MW or more of solar PV electricity.[1] Installations can be located in deserts, fields, military bases, atop closed landfills, and in some cases on or over the water. The owners of these solar "power plants" are independent power producers or infrastructure funds, who typically own a portfolio of renewable energy investments; traditional utilities may also own solar arrays.[2]

Utility-scale solar PV can work everywhere in the U.S., but optimal locations are those with a lot of sunny, clear days, those with higher elevation (the flatter, the better), and those in closer proximity to transmission lines and the point of electricity consumption.[3] Texas and California have the highest estimated technical potential, thanks to their combination of good solar resource and large populations.[4]

Rural utility-scale PV leads all other renewable energy technologies in the amount of electricity it could theoretically generate, with an estimated U.S. technical potential of 153,000 TW.[5] This is partly a result of the availability of large swaths of land in rural areas for development. Urban utility-scale solar PV in the U.S. is estimated to offer an additional technical potential of 1,200 TW.[6] At present, the U.S. has a total installed capacity of 0.056 TW of utility solar PV (urban and rural combined).[7]

The growth of solar PV in the last fifteen years has been astounding, and it is now cost-competitive with fossil fuel combustion as a source of electricity in many parts of the world.[8] Utility solar can generate electricity slightly more affordably than rooftop solar. In 2020, the levelized cost of energy for utility-scale solar power in the U.S. was $0.06/kWh (down from $0.28/kWh in 2010), and the DOE projects that costs may be as low as $0.03/kWh by 2030.[9] When located on farms, solar panels can help reduce energy expenses and diversify revenue streams for farmers.[10]

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[1] Project Drawdown. "Utility-scale solar photovoltaics." https://drawdown.org/solutions/utility-scale-solar-photovoltaics

[2] Wiki-Solar. "Leading utility-scale solar power plant owners" https://wiki-solar.org/company/owner/

[3] DOE. "Large-scale solar siting." https://www.energy.gov/eere/solar/large-scale-solar-siting

[4] NREL. 2012. *U.S. renewable energy technical potentials: A GIS-based analysis.* https://www.nrel.gov/docs/fy12osti/51946.pdf

[5] NREL. 2012. *U.S. renewable energy technical potentials: A GIS-based analysis.* https://www.nrel.gov/docs/fy12osti/51946.pdf

[6] NREL. 2012. *U.S. renewable energy technical potentials: A GIS-based analysis.* https://www.nrel.gov/docs/fy12osti/51946.pdf

[7] EIA. "What is U.S. electricity generation by energy source?" https://www.eia.gov/tools/faqs/faq.php?id=427&t=3

[8] Project Drawdown. "Utility-scale solar photovoltaics." https://drawdown.org/solutions/utility-scale-solar-photovoltaics

[9] DOE. "Sunshot 2030." https://www.energy.gov/eere/solar/sunshot-2030

[10] DOE. "Farmer's guide to going solar." https://www.energy.gov/eere/solar/farmers-guide-going-solar

Recently, there has been growth in the "community solar" model, in which individual customers or businesses may buy or lease a share of the panels in a utility-scale solar array and receive credit or compensation for the electricity generated by their shares, in much the same way as they would if the panels were on their rooftops. About a third of U.S. states have enabling policies that support community solar by requiring project developers and utilities to make it available to customers. In other states, community solar programs can be developed and managed by local utilities. Community solar allows everyone to benefit from solar, even if they can't put solar panels on their roof (for example, renters and people living in shaded areas).[11]

As with wind energy, a challenge facing solar PV is that sunlight is intermittent, and peak sunlight often occurs at different times of the day or season than peak electricity demand. To be most useful at scale, solar electricity will need to be paired with other sources of electricity or with widespread energy storage. Demand flexibility can also help, by modifying peak usage to conform to peak solar availability.

A primary environmental concern related to utility solar PV is its land use. Solar arrays can require up to thousands of acres.[12] In some cases, solar farms face opposition from nearby residents or from conservationists who are concerned about displacement of forests (and the carbon sequestration services that forests naturally provide). This can be remedied through proper siting.[13] A large proportion of the U.S. solar resource is located in the desert southwest, where water is scarce. Solar PV does require some water for cooling and for washing off the dust that accumulates on the panels—usage that may represent a significant strain on available water resources needed to support surrounding ecosystems and wildlife.[14] Construction of solar arrays, which often includes the clearing of all vegetation and sometimes the leveling of the grade, can fragment habitat and impact wildlife.[15] The reflective surfaces of the panels can sometimes be mistaken for water by birds, giving rise to collisions.[16]

Although solar PV does not generate any emissions once installed, lifecycle emissions take place during the manufacturing and construction of solar panels and thin films. The median published estimate of life cycle emissions for solar PV is 43 grams CO_2e/kWh,[17] which is greater than for

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[11] DOE. "Community solar basics." https://www.energy.gov/eere/solar/community-solar-basics
[12] USFWS. "Energy technologies and impacts: Solar energy." https://www.fws.gov/ecological-services/energy-development/solar.html
[13] Mass Audubon. "Solar energy siting." https://www.massaudubon.org/our-conservation-work/policy-advocacy/alternative-energy/solar
[14] USFWS. "Energy technologies and impacts: Solar energy." https://www.fws.gov/ecological-services/energy-development/solar.html
[15] USFWS. "Energy technologies and impacts: Solar energy." https://www.fws.gov/ecological-services/energy-development/solar.html
[16] USFWS. "Energy technologies and impacts: Solar energy." https://www.fws.gov/ecological-services/energy-development/solar.html
[17] NREL. 2021. "Life cycle greenhouse gas emissions from electricity generation: Update." https://www.nrel.gov/docs/fy21osti/80580.pdf

wind power and hydropower, but still orders of magnitude less than for natural gas, coal, and oil.

A final concern relates to the material inputs for solar PV, which include minerals such as aluminum, cadmium, copper, gallium, indium, iron, lead, nickel, silica, silver, tellurium, tin and zinc. Global supplies of these minerals are not fully known and may present a constraint on deployment of solar PV.[18] Copper use for solar PV is around 1,822 kg/MW for solar, which is higher than for conventional fossil fuel energy, but lower than for onshore and offshore wind.[19] Some solar panel components are fairly easy to recycle, including the glass, copper wire, and plastic junction box.[20] Others are more difficult to recycle, including lead and cadmium (which are toxic) as well as critical minerals such as aluminum, tin, tellurium, and antimony, as well as gallium and indium that are present in some thin-film modules.[21] More work is needed to develop recycling programs for these minerals.[22]

- Fishery friendliness: During operations, utility solar PV is most fishery friendly if sited on deserts, fields, military bases, atop closed landfills, or on working farms, and perhaps less fishery friendly when sited in forested areas or locations where fishery resources depend on scarce water supplies. However, the precise impacts of utility-scale solar PV depend on the type and sensitivity of the location of installation. Like many renewable energy and energy storage technologies, solar PV depends on minerals, including copper, the sourcing of which can have negative implications for the health of fishery ecosystems and resources.[23] Solar PV requires less copper than onshore and offshore wind energy, but more than fossil fuel-based energy.
- Co-benefits: Utility-scale solar PV can provide a sideline income for farmers when located on agricultural land.
- Environmental externalities: In some instances, installation of utility-scale solar arrays causes deforestation, which impairs natural carbon sequestration potential and other environmental services that forests provide to wildlife and humans. This can be avoided by preferentially siting arrays on working and developed lands. Lifecycle environmental externalities of concern include the sourcing, disposal, and recycling of mineral inputs. As solar PV becomes more widespread, it will be vital to ensure that all components are reused, recycled, and safely disposed of when necessary.

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[18] Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (February 15, 2018). “Minerals in the green economy: Solar panels and lithium-ion batteries.” https://www.igfmining.org/minerals-green-economy-solar-panels-lithium-ion-batteries/

[19] IEA. 2021. *The role of critical minerals in clean energy transitions.* https://iea.blob.core.windows.net/assets/24d5dfbb-a77a-4647-abcc-667867207f74/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf

[20] EPA. “Solar panel recycling.” https://www.epa.gov/hw/solar-panel-recycling

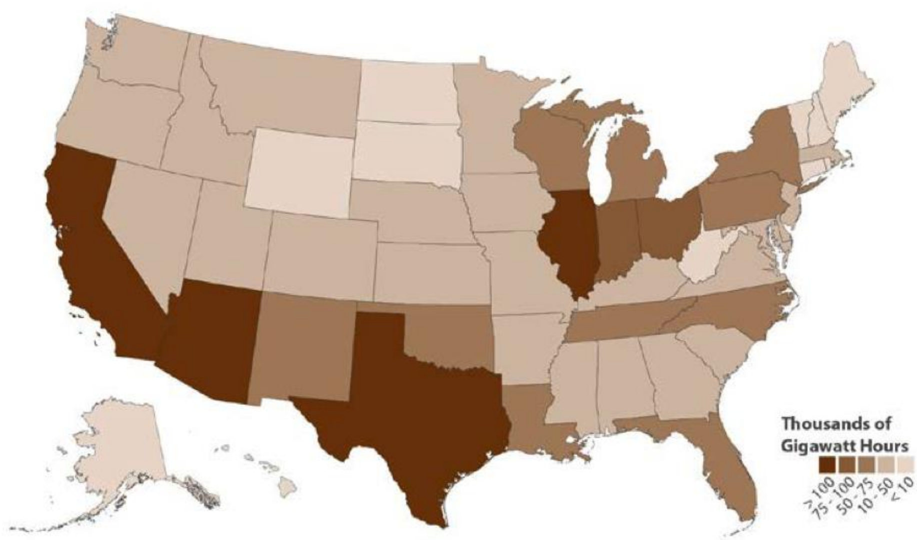
[21] EPA. “Solar panel recycling.” https://www.epa.gov/hw/solar-panel-recycling

[22] EPA. “Solar panel recycling.” https://www.epa.gov/hw/solar-panel-recycling

[23] Woody, Carol Ann and Sarah Louise O’Neal. 2012. *Effects of copper on fish and aquatic resources.* Prepared for The Nature Conservancy. https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/alaska/sw/cpa/Documents/W2013ECopperF062012.pdf

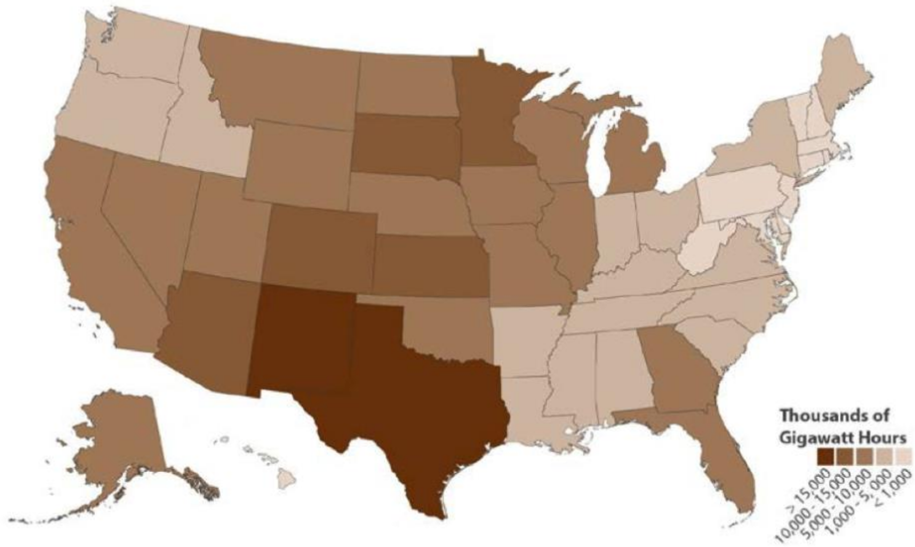
- Policy catalysts: Utility-scale solar PV can be supported through standard offer contracts including feed-in tariffs, interconnection standards, tax incentives, grants, loans, on-bill repayment/financing, carbon pricing, and renewable/clean energy standards, and DER/solar carveouts.
- More information:
    - Drawdown: Utility-scale solar photovoltaics
    - DOE: Community solar basics
    - DOE: Large-scale solar siting
    - Energy Sage: What is community solar?
    - Union of Concerned Scientists (March 3, 2013): "Environmental impacts of solar power."
    - DOE: Farmer's guide to going solar
    - Held, Lisa (June 29, 2021). "Can land conservation and dual-use solar on farms co-exist?" *Civil Eats.*
    - Harmon Courage, Katherine (August 28, 2021). "Solar farms are often bad for biodiversity – but they don't have to be." *Vox.*

Figure 1. Total estimated technical potential for urban utility-scale photovoltaics in the United States. Source: NREL 2012.[24]



[24] NREL. 2012. *U.S. renewable energy technical potentials: A GIS-based analysis.* https://www.nrel.gov/docs/fy12osti/51946.pdf

Figure 2. Total estimated technical potential for rural utility-scale photovoltaics in the United States. *Source: NREL 2012.* [25]



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[25] NREL. 2012. *U.S. renewable energy technical potentials: A GIS-based analysis.* https://www.nrel.gov/docs/fy12osti/51946.pdf