DISTRIBUTED SOLAR PV

Solar photovoltaic (PV) panels and films contain thin wafers of silicon crystal, and when sunlight hits this material, it causes electrons to move around and produce an electric current. Solar PV can either be installed in large arrays producing more than 10 MW (utility-scale solar) or can be placed on existing rooftops, carports, parking garages, or other flat surfaces that have sun exposure (distributed solar PV). Distributed solar can either generate electricity for use on-site or deliver electricity into the grid.

A 2016 study estimated that there are over 8 billion square meters of rooftops in the U.S. on which solar panels could be installed, and that if installed, these panels would represent over 1 TW of generation capacity.[1] For comparison, at the end of 2020, the U.S. had a total energy capacity of 1.117 TW[2] and only 0.032 TW of small-scale solar photovoltaic capacity.[3]

However, since the capacity factor of solar energy is far lower than that of the current U.S. mix of energy sources, it is perhaps more helpful to look at the technical energy generation potential of rooftop solar PV, which is estimated at 819 TWh.[4] To put that in perspective, in 2020, the U.S. generated 4,007 TWh of electricity from utility-scale sources, and only 42 TWh from distributed solar PV.[5]

All of these comparisons indicate that distributed rooftop solar could theoretically meet a large proportion of the nation's energy needs, but that it has a long way to go to get there. One major challenge is that sunlight is intermittent, and peak sunlight often occurs at different times of day or the 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.

Distributed solar PV has a number of co-benefits that make it attractive. Business and home owners who install grid-connected rooftop solar can reap economic benefits in states that have net metering or feed-in tariff programs, enabling them to recoup expenses in the form of lower energy bills and even to profit by selling energy to the grid. In off-grid applications, homes and businesses can become self-sufficient and keep the lights on even when storms knock out power to surrounding grid-connected homes (called "energy resilience"). Distributed solar projects also create a lot of jobs: 26.6 jobs per megawatt (jobs/MW) of electricity generated for

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[1] Gagnon, Pieter, Margolis, Robert, and Phillips, Caleb (2019). *Rooftop Photovoltaic Technical Potential in the United States*. https://www.osti.gov/biblio/1575064-rooftop-photovoltaic-technical-potential-united-states

[2] EIA. "Electricity explained: Electricity generation, capacity, and sales in the United States." https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php

[3] EIA (November 2021). "Electric power monthly." https://www.eia.gov/electricity/monthly/

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

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

residential rooftop solar and 19.1 jobs/MW for commercial rooftop solar, compared with only 2.1 jobs/MW for utility-scale solar[6] and 5.24 jobs/MW for offshore wind.[7]

Rooftop solar panels have come down in price dramatically due to policy incentives and improvements in manufacturing efficiency. In 2016, the levelized cost of energy for residential rooftop solar in the U.S. was $0.16/kWh (down from $0.52/kWh in 2010), and the DOE projects that costs may be as low as $0.05/kWh by 2030.[8] For commercial rooftop solar, the 2016 levelized cost of energy was $0.11/kWh (down from $0.40/kWh in 2010), and the DOE projects that costs may be as low as $0.04/kWh by 2030.[9]

Although the up-front costs of distributed solar PV installation are relatively high, there are ways to make these costs more manageable. For instance, there are now a number of solar financing banks that exist specifically to finance solar PV projects.[10] In some states, utilities can finance solar PV projects and allow customers to pay them back over time through on-bill repayment or financing.[11]

In addition, there are third-party leasing arrangements that can help homeowners or businesses avoid the up-front costs of going solar. Leasing does not provide the same long-run savings to home and business owners as purchasing PV panels, and any state or federal tax incentives or grants accrue to the leasing company rather than the home or business owner.[12] Nonetheless, it makes solar PV accessible to people who otherwise would not be able to access it, either because they do not have adequate credit history, do not have sufficient tax liability to be eligible for government tax incentives, or do not plan to remain in their homes long enough to reap the payoffs from purchasing a system of their own. At least 26 states and D.C. authorize third-party ownership of solar PV systems. In states where third-party financing has been in place for a long time, up to 80% of residential solar PV systems are procured using this method.[13]

Although solar PV does not generate any emissions once installed, a moderate amount of 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

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[6] Freeing Energy. "Energy fact – Residential solar installations create the most jobs per megawatt." https://www.freeingenergy.com/facts/jobs-solar-installation-residential-utility-g207/

[7] Global Wind Energy Council (2021). *Wind power and green recovery.* https://gwec.net/wp-content/uploads/2021/04/Jobs-Note-April-2021-2.pdf

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

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

[10] Energy Sage. "Get a loan to finance your solar energy system." https://www.energysage.com/solar/financing/loan-providers/

[11] Center for the New Energy Economy. 2016. "On-bill repayment and on-bill financing." https://spotforcleanenergy.org/wp-content/uploads/2016/03/9b01946799e4b5aa2ad36382efb3d1e4.pdf

[12] Hunter, Samantha and Pelchen, Lexie (November 3, 2021). "What is solar leasing? Here's what you should know." *Forbes*. https://www.forbes.com/home-improvement/outdoor/solar-leasing-explained/

[13] Center for the New Energy Economy. 2016. "Third party financing." https://spotforcleanenergy.org/wp-content/uploads/2016/05/ff5c108c070020d3ed779350e45e2b77.pdf

CO_2e/kWh,[14] which is greater than for 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.[15] Copper use for solar PV is around 1,822 kg/MW for solar (distributed and utility-scale), which is higher than for conventional fossil fuel energy, but lower than for onshore and offshore wind.[16] Some solar panel components are fairly easy to recycle, including the glass, copper wire, and plastic junction box.[17] 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. [18] More work is needed to develop recycling programs for these minerals.[19]

Some states that have implemented a renewable portfolio or clean energy standard (RPS or CES) include additional supports for DER, and sometimes specifically for solar PV. These supports either take the form of carveouts (which require that a certain percentage of qualifying generation come from DER or solar specifically) or multipliers (which promote investment in DER or solar by increasing its value for meeting the standard). The purpose of DER (or solar) carveouts and multipliers is to take advantage of the benefits that DER offers to the grid, such as reducing line losses because it is closer to the load and enhancing micro-grid capability, resiliency, and reliability.[20] Seventeen states have adopted DER carveouts and 11 have adopted DER multipliers.[21]

- Fishery friendliness: During operations, distributed solar PV is fishery friendly because the location of its deployment is within the developed footprint (i.e., it is deployed on homes and buildings, rather than in waterbodies or waterways) and it has no impacts on land use. However, like many renewable energy and energy storage technologies, solar PV depends on minerals, including copper, the sourcing of which can have negative

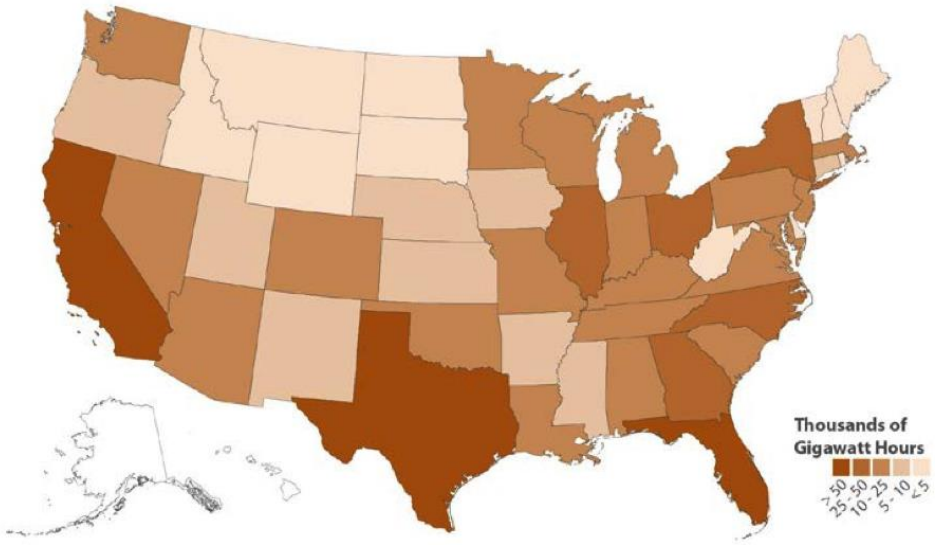
[14] NREL. 2021. "Life cycle greenhouse gas emissions from electricity generation: Update." https://www.nrel.gov/docs/fy21osti/80580.pdf
[15] Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (February 15, 2018). "Minerals in the green economy: Solar panels and lithium-ion batteries." https://www.igfmining.org/minerals-green-economy-solar-panels-lithium-ion-batteries/
[16] 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
[17] EPA. "Solar panel recycling." https://www.epa.gov/hw/solar-panel-recycling
[18] EPA. "Solar panel recycling." https://www.epa.gov/hw/solar-panel-recycling
[19] EPA. "Solar panel recycling." https://www.epa.gov/hw/solar-panel-recycling
[20] Center for the New Energy Economy. 2019. "Distributed generation / solar carveout." https://spotforcleanenergy.org/wp-content/uploads/2021/07/9a59a4fc5379971bebc6d464be5da382.pdf
[21] Center for the New Energy Economy. 2019. "Distributed generation / solar carveout." https://spotforcleanenergy.org/wp-content/uploads/2021/07/9a59a4fc5379971bebc6d464be5da382.pdf

implications for the health of fishery ecosystems and resources.[22] Solar PV requires less copper than onshore and offshore wind energy, but more than fossil fuel-based energy.

- Co-benefits: Distributed solar PV enables cost savings and profit potential for owners of homes and businesses. When installed off-grid or paired with energy storage, it increases energy resilience. Compared to other energy technologies, distributed solar PV creates a lot of jobs, and these jobs are distributed across local communities where installations take place, ensuring that the benefits of solar energy are widely distributed.
- Environmental externalities: 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.
- Policy catalysts: Broad deployment of distributed solar PV can be catalyzed through net metering programs, standard offer contracts such as 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: Distributed solar photovoltaics
    - Department of Energy: Solar rooftop potential
    - Solar Energy Industries Association: Rooftop solar
    - U.S. Energy Information Administration: Solar explained
    - Energy Sage: "The pros and cons of solar power: what are the advantages and disadvantages of going solar?"
    - DOE: Solar Futures Study
    - State Policy Opportunity Tracker (SPOT) for Clean Energy: distributed generation/solar carveout

[22] 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

Figure 1. Total estimated technical potential for distributed solar PV in the United States. Source: NREL 2012.[23]



Continue reading at https://fisheryfriendlyclimateaction.org/solutions

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