



Average Annual Daily Potential Solar Energy

This EnviroAtlas national map estimates the average annual daily potential kilowatt hours of solar energy that could be harvested per square meter within each 12-digit hydrologic unit (HUC). This calculation is based on environmental factors and it does not take into account land cover, ownership, land use, or viability of solar power systems.

Why is solar energy important?

Solar energy represents a freely available, seemingly inexhaustible, [ecosystem service](#). More solar energy strikes the earth's surface in 1½ hours than all the energy consumed worldwide in the year 2001.¹ The earth's surface in the temperate zone receives about 150 watts of solar energy per square meter.¹ This solar potential is expressed in the EnviroAtlas map, Average Annual Daily Potential Solar Energy, measured in kilowatt hours per square meter per day (kWh/m²/day). Though it overestimates actual electricity generation capacity, gross potential is a good indicator of regional solar resources. The Average Annual Daily Potential Solar Energy map shows that the best opportunities for commercial solar power generation are located in the southwestern U.S. Large commercial solar developments are most profitable in areas with average annual daily potential greater than 6 kWh/m²/day.²

Since 2009, the U.S. federal government has been promoting large industrial solar energy projects on federal land in California, Arizona, and Nevada as part of an overall climate change mitigation strategy. Fossil-fuel-generated electricity contributes about 40% of carbon dioxide emissions in the U.S.³ Increasing the contribution of renewable energy sources is expected to reduce future carbon dioxide emissions. The main obstacle to capturing abundant but diffuse solar energy for power generation is converting it to electrical power in a cost-effective manner. One common commercial technology uses arrays of photovoltaic (PV) cells to directly convert solar energy into electricity (see image). Concentrating solar energy plants (CSPs, such as power towers or parabolic troughs) concentrate reflected sunlight into an intense direct beam to create steam.^{2,4}

Though they create clean energy, commercial solar projects can be very land-intensive. Two new solar projects in California, Ivanpah and Topaz, cover 5.6 and 9.5 square miles, respectively. Large solar developments may block wildlife travel routes and disrupt breeding populations.^{3,5,6} Concentrating solar plants create zones of superheated air as



high as 800° F that burn and kill passing birds, bats, and insects in flight. Steam-producing CSP tower plants require 1000 gal of water per 1000 MW hours of electricity produced, adding more demand to limited desert water supplies.⁵ Future expansion of commercial solar energy will require careful consideration of environmental tradeoffs.

When compared to other nations in the northern hemisphere, the U.S. has exceptionally high solar potential, which is not limited to the Southwest. Germany has lower daily solar potential than either the northeastern or northwestern U.S., yet it was the global leader in PV solar capacity in 2011 with 35.6% of the world's share of solar PV power production.⁷ Rooftop solar capacity in the U.S., though growing, is largely untapped.⁸ Rooftop solar potential is estimated at over 800 terawatt-hours (TWh, equivalent to 800 billion kilowatt-hours) of energy.⁴ Federal, state, and local subsidies have helped to increase rooftop solar applications by making PV solar more affordable for the average home or business owner. The current federal [solar tax credit](#) through 2023 allows up to 26% of photovoltaic system's cost if installed in 2022 and 22% for systems installed in 2023. Congress must renew the tax credit for 2024 to continue it beyond 2023.

How can I use this information?

This EnviroAtlas national map, Average Annual Daily Potential Solar Energy, estimates the average daily potential kilowatt hours of solar energy that could be captured per square meter within each 12-digit HUC. A companion map, Area of Solar Energy, gives the area of each 12-digit HUC in square kilometers. The two maps together illustrate the solar

energy potential recorded across a given area without taking into account land use, ownership, land cover, or aspect. The maps provide planners and the general public with a national and regional view of gross solar energy potential. Used together or independently, these maps can help inform discussions about the benefits and environmental tradeoffs of commercial and private solar applications.

The solar energy potential map may be overlaid and compared with other EnviroAtlas maps depicting land cover and habitat, such as protected areas, ecoregions, GAP ecological systems, and [connectivity](#). These data layers along with information on species distributions and habitat needs can help to assess the adequacy of reserves, remaining habitat core areas, and movement corridors for wildlife near large existing or proposed solar developments.

How were these data created?

The average daily potential watt hours of solar energy were estimated from maps produced by the National Renewable Energy Laboratory (NREL) for the U.S. Department of Energy (February 2009). The original data was from a 10km, satellite modeled dataset representing data from 1998–2005. The 10km data was converted to 30m grid cells, and zonal statistics were estimated for a final value of average kWh/m²/day for each 12-digit HUC. The insolation values represent the resource available to a flat plate collector, such as a photovoltaic panel, oriented due south at an angle from horizontal equal to the latitude of the collector location. For more information about the original dataset, refer to the National Renewable Energy Laboratory ([NREL](#)) website.

Selected Publications

1. Tsao, J., N. Lewis, and G. Crabtree. 2006. [Sandia Laboratory solar FAQs](#). Accessed July 2022.
2. Simons, G., and J. McCabe. 2005. [California solar resources in support of the 2005 integrated energy policy report](#). CEC-500-2005-072-D, California Energy Commission, Sacramento, California, 22 p.
3. Glicksman, R.L. 2011. [Solar energy development on the federal public lands: Environmental trade-offs on the road to a lower-carbon future](#). *San Diego Journal of Climate and Energy Law* 3:107–158.
4. Lopez, A., B. Roberts, D. Heimiller, N. Blair, and G. Porro. 2012. [U.S. renewable energy technical potentials: A GIS-based analysis](#). Technical Report NREL/TP-6A20-51946, National Renewable Energy Laboratory, Golden, Colorado.
5. Lieberman, E., J. Lyons, and D. Tucker. 2011. [Making renewable energy wildlife friendly](#). Defenders of Wildlife, Washington, D.C. 15 p.
6. Lovich, J.E., and J.R. Ennen. 2011. [Wildlife conservation and solar energy development in the desert Southwest, United States](#). *Bioscience* 61(12): 982–992.
7. Theel, S., and M. Greenberg. 2013. [Myths and facts about solar energy](#). Media Matters for America. Accessed July 2022.
8. Marcacci, S. 2014. [U.S. solar energy capacity grew an astounding 418% from 2010–2014](#). CleanTechnica. Accessed July 2022.

What are the limitations of these data?

The amount of solar energy striking the earth's surface varies by latitude, season, and time of day. This map represents an estimate of gross solar potential, which overestimates actual electricity generation capacity. A map of technical potential would omit areas where solar applications are unlikely, such as forested areas and northern aspects. The calculation of average annual daily potential is based on environmental factors and does not take into account the viability of installing solar systems.

How can I access these data?

EnviroAtlas data can be viewed in the interactive map, accessed through web services, or downloaded. The solar energy data used to create this map may be downloaded at the [NREL](#) website. NREL has also developed dynamic maps and [analysis tools](#) to help apply renewable energy data.

Where can I get more information?

A selection of resources related to the environmental benefits and possible effects of solar development is listed below. For additional information on how the data were created, access the [metadata](#) for the data layer from the dropdown menu on the interactive map layer list. To ask specific questions about this data layer, please contact the [EnviroAtlas Team](#).

Acknowledgments

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