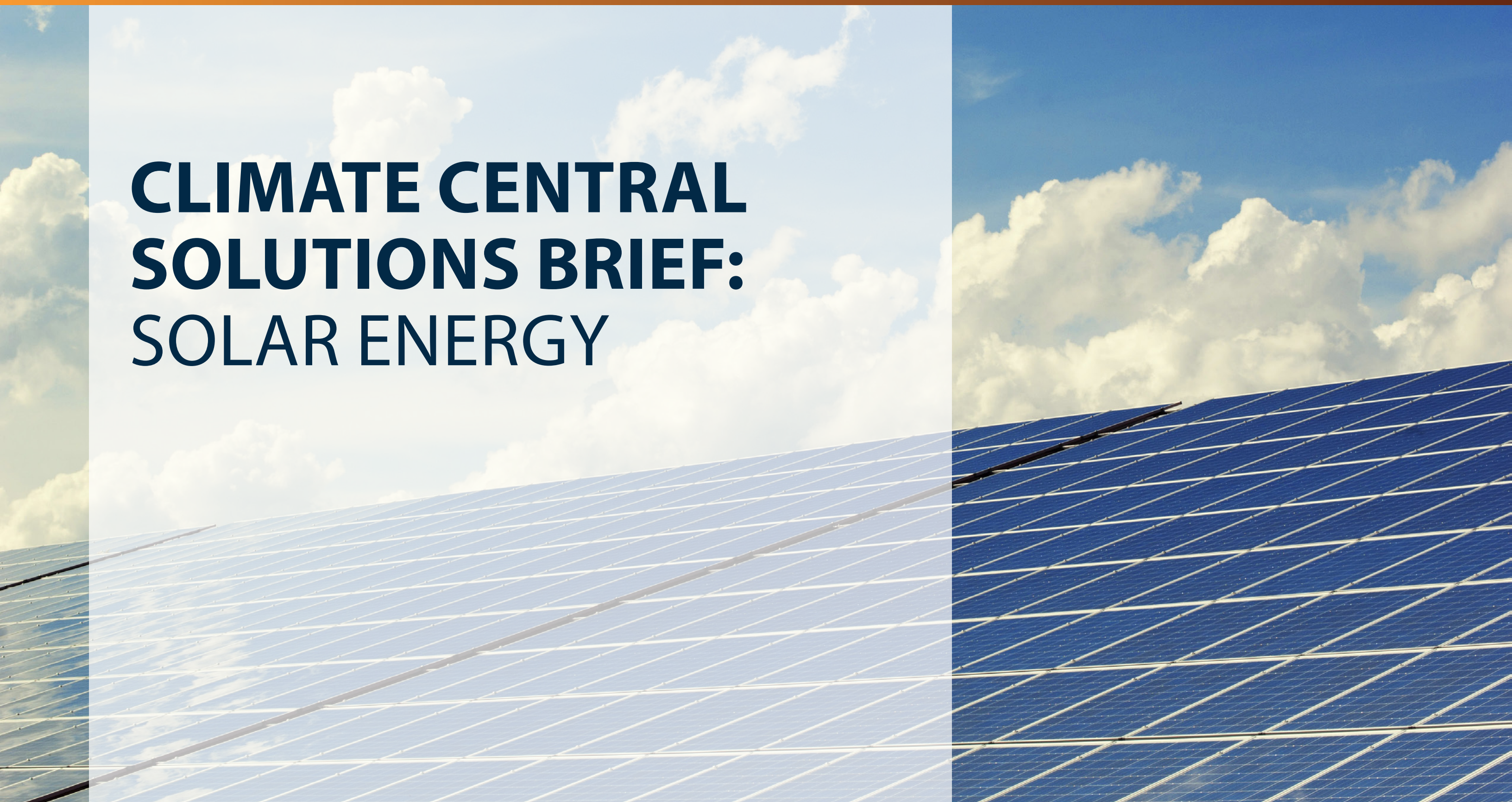
CLIMATE CENTRAL SOLUTIONS BRIEF: SOLAR ENERGY



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Research brief by
Climate Central

CLIMATE CENTRAL

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Part of the *Getting to Net Zero Series*

INTRODUCTION

Solar power has expanded dramatically in recent years, becoming the leading technology installed for new power generation globally. In 2019, it accounted for 45% of global capacity added according to the International Energy Agency (IEA). Solar power became the cheapest source of electricity in many parts of the world in 2020, outcompeting fossil fuels like coal and natural gas. As utilities, corporations, and city, state, and national governments begin to embrace "net zero" emissions targets, rapidly reducing greenhouse gases (GHG) that keep global warming below 2°C, solar energy will play a key role in achieving this goal.

Solar energy generation has been increasing steadily in the United States, but it still only supplied 1.7% of the country's total electricity in 2019. And despite the pandemic in 2020, the U.S. added a record 19 gigawatts of solar, including rooftop, for a total of 89 GW installed capacity. That's enough to power 16.4 million American homes, according to the Solar Energy Industries Association (SEIA). The next few decades hold the promise of even more growth. A number of recent reports forecast more installations, supported by falling costs and growing support for reducing our reliance on fossil fuels.

This brief will prepare reporters for covering the coming transformation of our energy systems, diving into projections of how much more solar capacity is needed to reach the carbon emission goals set out in the Paris Climate Agreement. We'll also take a look at solar technology, its costs, where solar panels work best and why, and the potential for co-benefits like job creation and cleaner air.

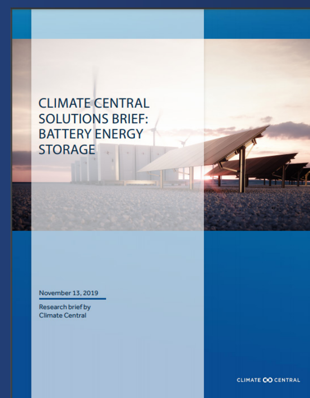
GETTING TO NET ZERO

In order to reach the target of the Paris Climate Agreement to limit global warming to 1.5°C, global greenhouse gas emissions need to be cut in half by 2030, and reach "net zero" by 2050. The term "net zero" simply means that any greenhouse gas emissions released are balanced by an equal amount being taken out of the atmosphere. This is the first of a series of climate solutions issue briefs exploring pathways to get to net zero, including carbon-free electricity, electrifying transportation and buildings, and transforming our agriculture and food production.

THE BASICS OF SOLAR ENERGY

There are three ways to harness energy directly from the sun: photovoltaics, solar thermal, and concentrating solar power. Most of us are familiar with photovoltaic energy (or PV), which is utilized in solar panels. When the sun shines onto a solar panel, it absorbs the light's energy and transfers it to negatively charged particles, or electrons. The electrons flow through the material as an electrical current. Solar thermal generally refers to a device in which sunlight is used for hot water heating or space heating or cooling. Concentrating solar power plants use mirrors to collect and concentrate the energy which drives steam turbines or engines that create electricity. This brief will focus mostly on PV energy systems.

As more solar energy is added to the electrical grid, two constraints have to be managed. Solar panels only produce electricity when the sun shines, with peak outputs occurring from late morning until midafternoon. But late afternoon is when demand for electricity typically begins ramping up, as people get home from work and begin turning on devices (or plugging in their electric car to charge). The second constraint is variability. Solar production levels can change rapidly depending on the hourly weather. One way to manage both of these challenges is coupling solar installations with battery storage (whose price has also fallen steeply in recent years) to help with peak electricity demand, cloudy weather, and the inefficiency of over-generation.



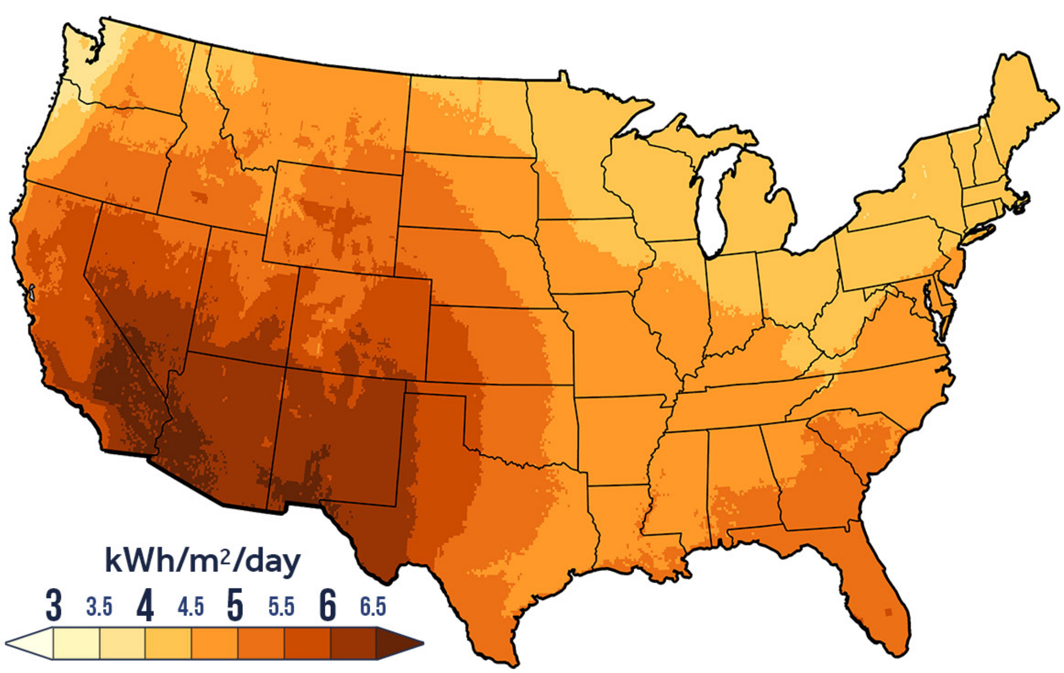
BATTERY STORAGE

Check out our Battery Storage Solutions Brief covering the rapid growth of battery storage capacity in the U.S. and how it can be used to reduce carbon emissions and make our power grid more resilient to extreme weather.

Can solar panels work anywhere there's sun? Basically, yes. While places with more sunny days will obviously produce more electricity from a given area of solar panels, the technology has advanced enough that they also work on cloudy days, just less effectively.

To find solar potential anywhere in the United States, the National Renewable Energy Lab's PVWatts performance estimation tool calculates the potential for a PV system's energy production incorporating weather and other factors. And check out Climate Central's WeatherPower tool which forecasts daily solar electricity generation by county, region, or state, and see how many homes or cell phones can be powered by the sun with the forecast weather conditions.

Figure 1. Where Solar Energy Shines - Sunnier Places Have More Solar Potential

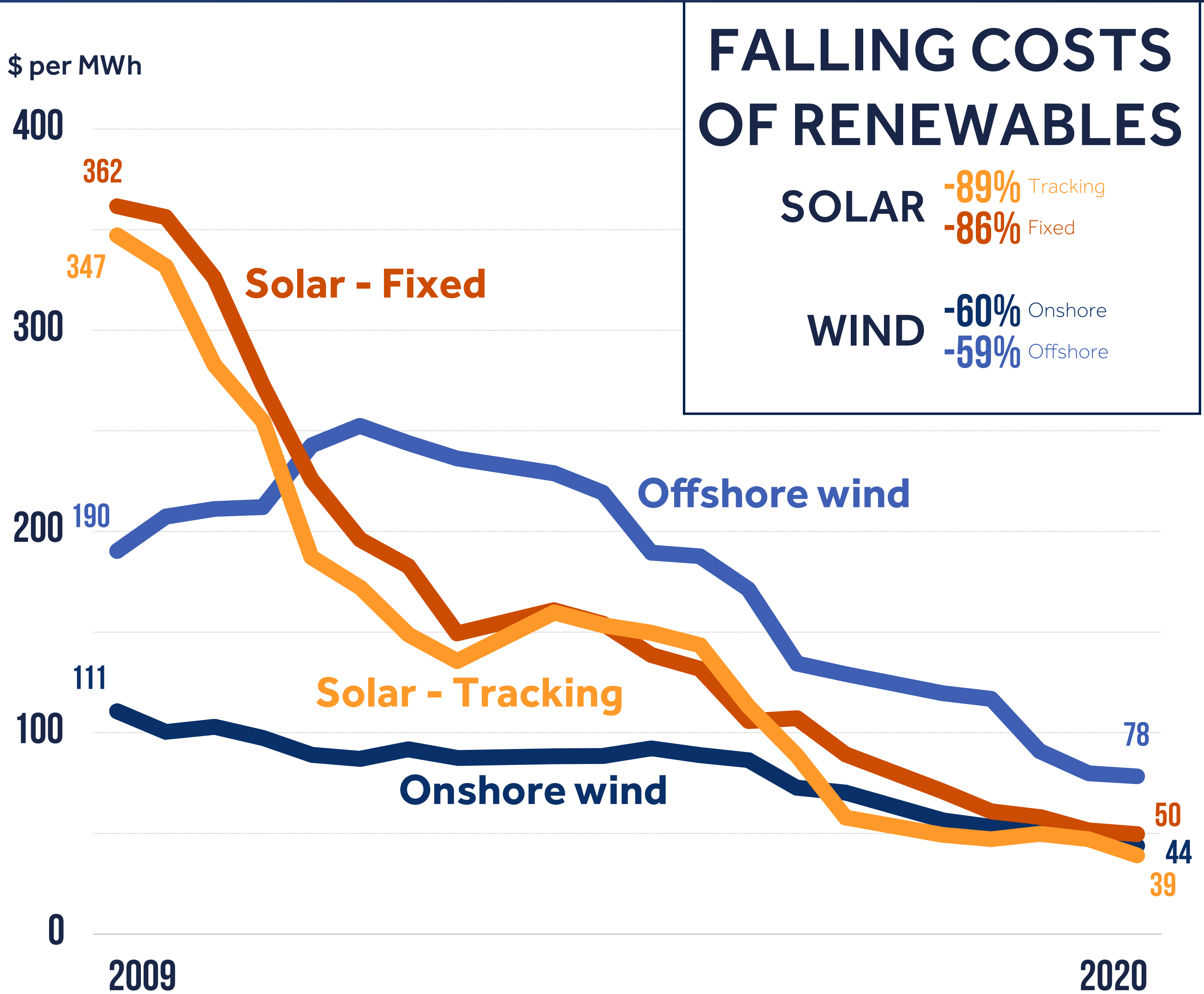


Source: National Renewable Energy Laboratory

WHAT'S BEHIND THE GROWTH IN SOLAR?

One of the biggest reasons behind solar's recent popularity and expansion across the nation is that solar costs have plummeted, dropping below coal and gas prices (See Figure 2 BNEF data).

Figure 2. BloombergNEF Levelized Cost of Energy



Government policies can also have a major impact on solar, with tax credits and states setting standards for utilities to purchase a percentage of their electricity from renewable sources.

Perhaps one of the most influential policies on solar was the SunShot Initiative, a Department of Energy initiative launched in 2011. The project aimed to reduce the total costs of solar energy by 75% to make it competitive with other forms of energy without subsidies by the end of the decade. And it worked, meeting the goal of utility-scale solar costing $0.06 per kilowatt-hour (approximately $1 per watt) three years early. Costs for residential and commercial solar are still higher than their target, despite prices falling about 60%. The federal Solar Investment Tax Credit, a 26% tax credit for solar systems on residential and commercial properties is also largely credited for helping in the financing of solar projects across the country.

SOLAR COMES IN ALL SHAPES AND SIZES

Rooftop Solar

Rooftop solar installations are constructed on the roofs of residences or small commercial buildings. They are generally designed to meet the needs of a single building with the intention of reducing dependence on the grid and/or lowering the owners' electricity bills. Many states allow net-metering, in which residential or commercial customers with PV systems can sell the excess electricity they aren't using back into the grid. At night or on cloudy days, net-metering enables customers to pull power from the grid, without battery backup.

In the U.S., rooftop solar costs fell to $2.84/Watt in 2020, down 23% from 2014, mostly due to decreasing hardware costs. Beyond the hardware, soft costs are tied to developing new solar energy projects, and can include permitting, zoning compliance, grid interconnections, financing and taxes, and labor and installation costs. Inconsistent building codes, permitting practices and uncertainty in permitting timelines can cause project delays and lead to increased project costs.

A number of things can affect the suitability of rooftop solar, including local climate and electricity consumption, which varies significantly across regions due to differences in demographics, sizes and types of homes. For example, Texas has some of the highest annual electricity consumption by household with its hot, humid and long summers, while Vermont residents have some of the lowest consumption with short and cooler summers. A report from NREL found that a number of states with below-average solar resources (such as Maine, New York, and Minnesota) have similar or even greater potential to offset their electricity sales from rooftop solar compared to states typically associated with solar abundance (Arizona and Texas). And nationally, the potential for rooftop solar on small buildings could meet 39% of total electricity sales nationwide (see Figure 3).

Figure 3. Estimated Rooftop PV Technical Potential for Small Buildings by State (NREL 2019)

	Annual generation potential % of total sales	Installed Capacity Potential (GW)
CA	43.6	76.8
VT	40.3	2.0
ME	40.0	4.2
NM	32.8	4.6
NH	32.4	3.2
AZ	31.6	15.0
RI	31.2	2.1
MI	30.6	28.3
FL	30.3	50.3
SD	29.5	2.9

Solar canopies over parking spaces are an emerging trend, at airports, stadiums, universities, and on the roofs of parking decks. They provide a clean energy source for the facilities and electric vehicle charging stations. Additionally, they provide shade to vehicles and shelter from precipitation. And there are a lot of parking lots out there: One study explored installing solar canopies at the parking lots of WalMart Supercenters across the country and estimated that 11.1 gigawatts of solar energy could be deployed, potentially powering more than 346,000 EV charging stations.

Community Solar

Community solar refers to local solar facilities shared by multiple community members. A number of local subscribers—residents, small businesses, churches, civic organizations, municipalities—can share equal access to the economic and environmental benefits of solar energy generation, whether or not the solar panel is installed directly on their roof or property or not. Community solar projects have the potential to make the benefits of solar energy more obtainable to the 40% of U.S. households who live in rental housing, including single residences and multi-family housing, and to the frontline communities who are facing disproportionate burdens from climate change. As of 2020, 20 states had policies enabling community solar, and there were over 1,100 MW of community solar capacity distributed across 811 projects in 39 states and Washington, D.C.

Utility Scale Solar

Utility-scale solar facilities are large solar installations that directly supply solar electricity into the grid. Usually these projects have generation capacity of at least one megawatt (MW) or greater. Utility-scale solar can be paired with energy storage to manage peak demand and keep continuity of service, provide backup power, and more. While essentially carbon-free, energy from utility scale solar isn't perfect. Because the panels convert only 20% of the sunlight they collect into usable electricity, they can require large areas for installation.

In utility-scale solar, the electricity is sold to wholesale utility buyers, not end-use consumers like in distributed generation. Utility-scale solar is often contracted by long-term power purchase agreements (PPA), which ensures stable pricing for many years.

Figure 4. Top 10 States in the Community Solar Market

MN	568 MW
MA	234
GA	97
CO	54
TX	51
FL	35
AZ	26
UT	20
OK	17
MO	17

Cumulative community solar capacity (MW) by year (NREL 2020)

NET ZERO AMERICA: WHAT THE FUTURE OF SOLAR COULD LOOK LIKE NEAR YOU

Net Zero America (NZA), a research initiative by scientists and engineers at Princeton University, was published in December 2020. The team modeled five pathways to show what energy-system transformations are required for the U.S. to get to net-zero emissions by 2050. In this section, we explore one of their scenarios, and what it means for solar capacity and jobs in the next few decades.

The Net Zero America "high electrification" (E+) scenario assumes nearly full electrification of transportation and buildings by 2050 and few other constraints on energy supply options. The researchers programmed their model to select the means and technologies that enable the country to reach net-zero emissions by 2050 with the least total energy-system cost. The assumption of full electrification by 2050, combined with the goal of minimizing costs, leads to a pathway with a large ramp up in solar and wind energy generation in the first decade (across 4 of the 5 NZA scenarios, the initial ramp up in solar and wind is similar). In other words, in order to have the energy we need to be net-zero in 2050, we need to grow solar and other renewables very quickly.

Any system-wide transformation can be expected to produce winners and losers, and transitioning to a net-zero economy will be no different. Opportunities for manufacturing, construction, and administrative and financial jobs in solar and wind will expand in a number of states, even as some areas and regions will see the shuttering of coal and other fossil-fuel businesses. Looking at the NZA solar industry projections, most states are predicted to have growth in utility-scale capacity (42 states) and in solar jobs (34 states) by 2030. In the E+ scenario, there are 495 new solar jobs per 10,000 people nationwide by 2030, suggesting that solar could become a significant industry and major employer by the next decade.

According to the NZA models, a number of states in the Southeast and Midwest could see major increases in capacity and in the number of solar jobs. The Southeast has abundant solar potential, and the Midwest has a lot of agricultural land suitable for large-scale solar installations. And agrivoltaics, a type of solar system that allows for crops to grow, offers hope for co-locating PVs and agriculture.

In densely populated states, such as New York and New Jersey, solar can be installed near urban centers and transmission lines, making it cost effective to deploy, although large, utility-scale installations could prove challenging to develop with so many neighbors and urbanized areas.

Figure 5. Potential for Solar Jobs under NZA High Electrification Scenario

Largest Total Number of Solar Jobs 2030 *(Thousands of Jobs)*	
TX	81
CA	78
FL	75
SC	59
VA	37
NC	34
GA	31
NJ	30
NY	27
IN	20

Largest Per Capita Number of Solar Jobs 2030 *(Jobs per 10,000 people)*	
SC	121
NE	77
NM	73
VA	44
FL	37
NJ	34
NC	34
ND	32
MO	32
DE	31

Change in Per Capita Solar Jobs 2020 - 2030 *(Additional jobs per 10,000 people)*	
SC	105
NE	74
NM	54
VA	35
FL	29
MO	28
IN	26
NC	26
AL	24
GA	22

Texas and California, largely due to their size and sun exposure, lead the nation in the total number of solar industry jobs in 2030 in the E+ scenario. Not unexpectedly, Florida, the Sunshine State, is expected to do well with total solar jobs and growth in these jobs, and some of the largest solar installations in the country are breaking ground there in 2021. South Carolina leads the ranking of solar industry jobs per 10,000 people, and has an additional 105 solar jobs per 10,000 residents by 2030 in the E+ scenario. Nebraska and North Dakota, two states that are perhaps not thought of first for sunbathing, see large increases in solar industry vocations. Solar jobs may not be restricted to sunny states. By 2050, the E+ scenarios shows over a half million solar manufacturing jobs nationwide, outpacing solar jobs in the construction sector.

ENERGY CONVERSIONS FOR YOU TO KNOW

A watt is a measure of power and there are 1,000 watts = 1 kilowatt [kW]

1 million watts = 1 megawatt [MW]

1 MW equals roughly 3.125 million photovoltaic (PV) panels

1 billion watts in 1 gigawatt (GW) 1 GW powers roughly 300,000 homes

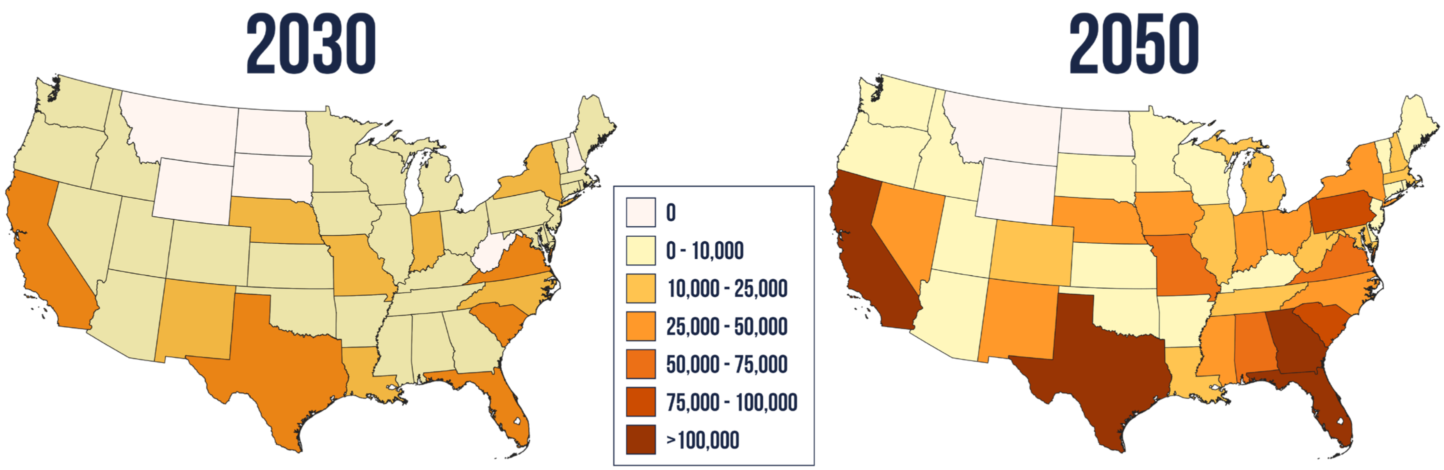
1 Terawatt = 1,000 GW (Energy.gov)

A kilowatt hour (kWh) is a measure of energy being used over time.

1 kWh is the amount of energy you would use if a 1,000-watt hair dryer ran for an hour

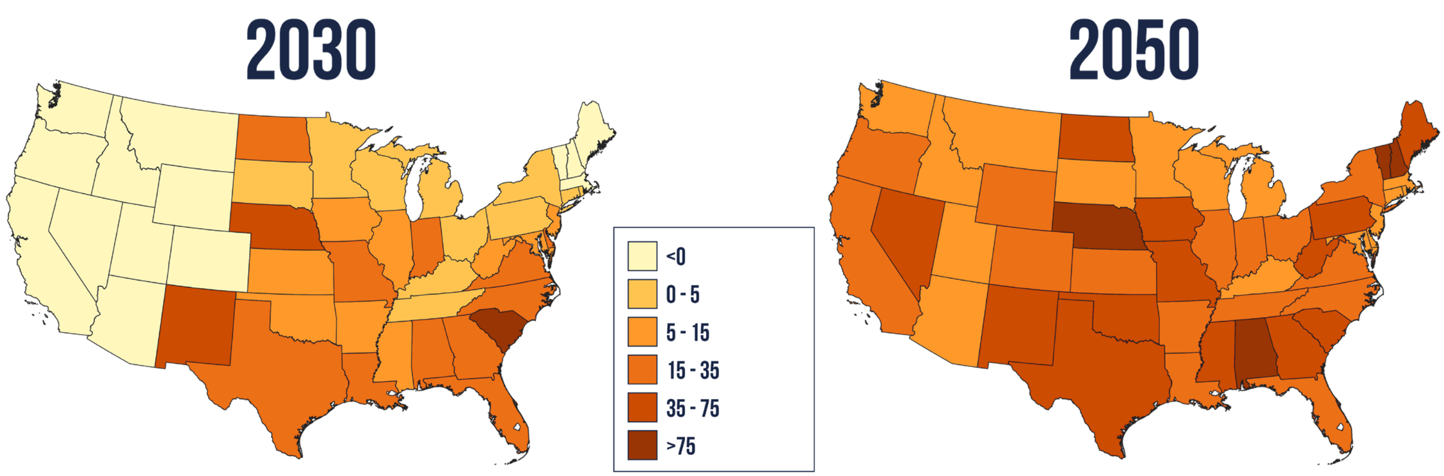
MODELING A PATHWAY TO NET ZERO: SOLAR

Figure 6. Potential Utility Scale Solar Total Capacity 2030 and 2050, MW



Source: Net-Zero America, High Electrification Model (E+)

Figure 7. Potential Change in Solar Jobs per 10,000 people 2030 and 2050



Source: Net-Zero America, High Electrification Model (E+)

EXPANDING THE BENEFITS OF SOLAR POWER TO EVERYONE

Solar energy has a number of social and economic benefits. Besides reducing greenhouse gas emissions, solar electricity generation can reduce air pollutants, depending on how much electricity is generated for the grid and the types of fossil fuel generation displaced. And if equitable policies to deploy solar energy are put into place, disadvantaged communities could see significant co-benefits such as reduced energy bills and good jobs.

When solar energy displaces coal-powered plants, air pollution is reduced, particularly on the most polluted days and within communities that relied on coal-generation plants, or that were downwind of these plants. Solar energy also produces far lower levels of harmful pollutants including fine particulate matter (PM2.5), sulfur dioxide (SO2), and nitrogen oxides (NOx). Analysis from NREL shows that achieving the SunShot-level solar deployment targets—14% of U.S. electricity demand met by solar in 2030 and 27% in 2050—could decrease cumulative power-sector emissions of PM2.5 by 8%, SO2 by 9%, and NOx by 11% by 2050. These pollutant reductions could save the U.S. $167 billion from lower future health and environmental damages, while also preventing 25,000–59,000 premature deaths.

The residential solar energy boom in recent years has largely benefited white and wealthier homeowners who could afford up-front installation costs or have the means to take advantage of state and local programs that offered incentives. A 2019 study found that even when controlling for income, communities of color have installed fewer rooftop solar facilities than predominantly white communities—potentially missing out on savings over time. In the U.S., low-Income, Black, Hispanic, and Native American households spend more of their household income on energy bills, with energy burdens that are 20-45% higher than white, middle-class households.

In 2014, the National Housing Trust launched NHT Renewable, a company that works to place solar systems on top of affordable housing across the country. They've partnered with housing owners and operators to put up 5 MW of solar across 50 buildings, serving over 600 families. GRID Alternatives, a non-profit based in Washington, D.C., aims to build community-powered solutions to advance economic and environmental justice through renewable energy. Since 2004, they've installed over 14,000 PV systems, preventing 1.2 million tons of carbon emissions and saving more than $400 million on energy costs for their clients. GRID Alternatives has created a workforce development program to train community members on solar installation and a national tribal program to help finance and implement solar power projects that meet community needs.

There are a number of reports outlining best practices for making the deployment of solar power and other renewables more equitable:

Institute for Policy Studies: How States Can Boost Renewables, with Justice for All
Clean Energy States Alliance: Solar with Justice
The Solar Foundation: Solar Industry Diversity Study
NAACP: Just Energy Policies

GLOSSARY

Capacity - The maximum output of electricity that a generator can produce under ideal conditions, typically determined as a result of performance tests. Capacity is generally measured in megawatts or kilowatts. (Energy.gov)

Clean Energy Standard (CES) - A policy designed to increase the share of electricity produced by clean energy sources (or through electricity savings from energy efficiency). Typically, a CES sets a target for electricity sales for a state or region. For example, In California, SB100 requires that 50% of electricity sales must be met through clean electricity sources, including solar, wind, geothermal, and biomass.

Community Solar - Community or shared solar is broadly defined as a project where multiple participants own or lease shares in a mid-sized solar facility, (usually between 500 kilowatts and 5 megawatts) and receive credits that have the potential to lower their monthly utility bills based on how much power the facility delivers to the grid.

Distributed Generation - Electricity produced at or near the point where it is used. Distributed solar energy can be located on rooftops or ground-mounted, and is typically connected to the local utility distribution grid. (SEIA)

Generation - The amount of electricity that is actually produced over a specific period of time, measured in watt-hours). To understand the unit of megawatt-hours (MWh), consider a solar installation with a capacity of 2 megawatts that is running the first hour at full capacity (solar noon) and second hour at two-thirds capacity (past the peak hour). Megawatt hours for this scenario = (2*1) + [(2/3)2*1] = 3.33 MWh. (Energy.gov)

Net Metering - Net metering allows residential and commercial customers who generate their own electricity from solar power to sell the electricity they aren't using back into the grid at the same price per kWh that they pay for electricity they use from the grid when the solar power is insufficient to meet their need for electricity. (SEIA)

Utility Scale - Utility-scale solar facility is one which generates solar power and feeds it into the grid, supplying a utility with energy. Virtually every utility-scale solar facility has a power purchase Agreement (PPA) with a utility, guaranteeing a market for its energy for a fixed term of time.