

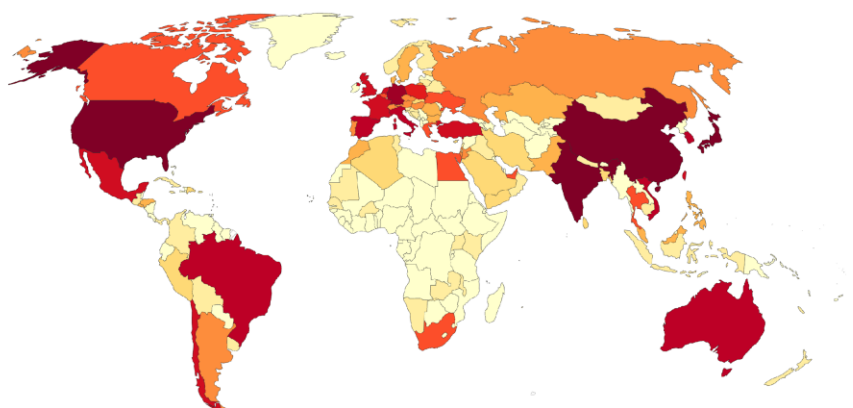
A Solar Powered Future:

Residential Adoption on a Global Scale

In 2022, solar energy became the fastest-growing source of electricity for the 18th year in a row, growing by 24% compared to 2021¹. The share of solar energy in the global energy mix has steadily increased due to falling costs, technological advancements, and supportive policies. Many countries have continued investing in solar energy infrastructure and implementing renewable energy targets to further accelerate the adoption of solar power. This paper will analyze the residential solar adoption rates by countries and states and explore the factors that contribute to them.

Solar power generation, 2022

Electricity generation from solar, measured in terawatt-hours (TWh) per year.



Source: Our World in Data based on BP Statistical Review of World Energy; Ember

OurWorldInData.org/renewable-energy • CC BY

The analysis that follows will focus on the growth and market dynamics of the residential solar segment.²

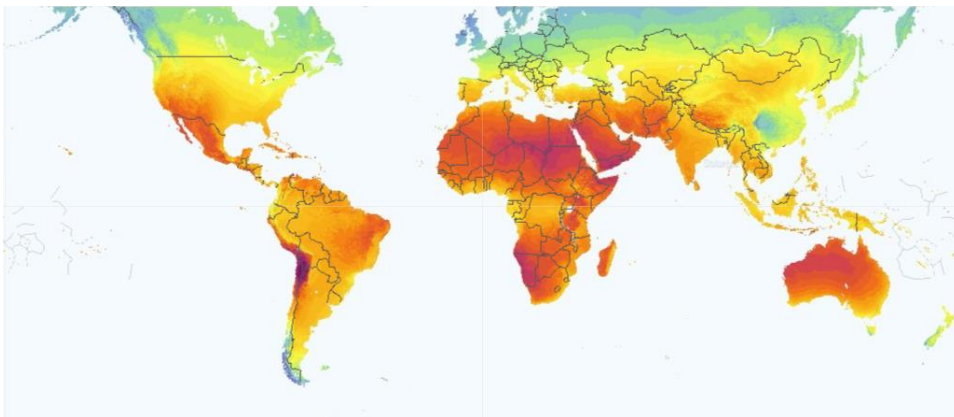
¹ <https://www.cnn.com/2023/04/12/world/wind-solar-renewables-record-climate-intl/index.html>

² <https://ourworldindata.org/grapher/solar-energy-consumption>

Drivers of Residential Solar Adoption

The growth of residential solar adoption is driven by a diverse set of factors, and the combination of those factors varies from place to place. Some of the most frequently cited factors driving residential solar adoption—which include the decisions around purchasing, installing, or analyzing solar technology—are:

- **The cost of electricity:** Rising rate-payer costs drive demand for solar.
- **Grid stability:** The inability of a country or region to reliably generate sufficient electricity to maintain a stable supply of electricity creates demand for resilience.
- **Local irradiance:** Regions with abundant sunlight generally provide more favorable conditions for solar development. The [graphic](#) below shows the direct horizontal irradiance (read: the amount of sunlight that hits the surface of the Earth) around the globe.



- **Equipment costs:** The decline in the prices of photovoltaic (PV) system components and installation labor have a positive impact on the adoption of residential solar systems.
- **Regulatory structures:** Favorable regulations, such as net metering or government incentives, often drive the growth of residential solar installations.
- **Geopolitical drivers:** World events that create unexpected changes in the availability or price of energy can accelerate renewable energy deployment.
- **Social drivers:** Desires for lower carbon footprints, contributing to grid protection through energy storage, projecting financial savvy by generating savings and return on investment over time, and the like.

While not an inclusive list, these factors establish a useful framework for analyzing the drivers of growth, or limiters thereof, of residential solar adoption. Further, the importance of these factors and the combination in which they are present vary from region to region.

Residential Solar Adoption Around the World

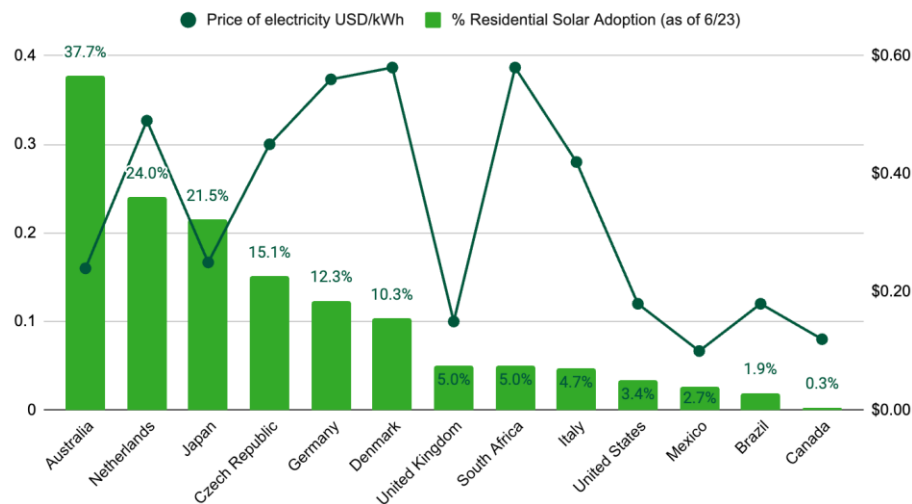
To calculate residential solar adoption rates, data about the number of residential solar installations in a jurisdiction is divided by the number of detached homes. Where the number of residential solar installations is unavailable, the total installed residential capacity, measured in megawatts, was divided by an average residential system size to arrive at a reasonable estimate of the number of residential installations.

The table below provides a top-line view of residential solar penetration on the country level and includes two of the most easily measured drivers of solar adoption, as described above.

Country	% Residential Solar Adoption (as of 06/23)	Number of installations	Number of houses	Price of electricity USD/kWh	Direct Normal Irradiation (kWh/m ² /day)	Industry Size (TWh)
Australia	37.7%	3,400,000	9,007,333	\$0.24	3.62-7.98	33.49
Netherlands	24.0%	1,920,000	8,005,452	\$0.49	2.32-2.78	17.67
Japan	21.5%	12,000,000	55,700,000	\$0.25	1.84-4.01	98.69
Czech Republic	15.1%	350,000	2,317,276	\$0.45	2.32-3.24	2.51
Germany	12.3%	2,650,000	21,552,600	\$0.56	2.72-3.32	58.98
Denmark	10.3%	283,333	2,748,569	\$0.58	2.38-3	1.99
South Africa	5.0%	330,500	6,600,000	\$0.15	4.19-8.5	6.21
UK	5.0%	1,200,000	23,900,000	\$0.42	1.24-2.79	13.91
United States	3.4%	3,000,000	87,804,068	\$0.18	1.46-7.80	204.29
Mexico	2.7%	94,893	3,480,000	\$0.10	3.37-8.06	13.39
Italy	4.7%	1,221,045	26,200,000	\$0.58	2.30-5.18	27.73
Brazil	1.9%	1,476,000	76,900,000	\$0.18	3.01-6.22	26.48
Canada	0.3%	43,000	14,100,000	\$0.12	1.59-5.05	5.56

National Trends

Residential Solar Adoption by Region Compared to Price of Electricity



This graph shows the relationship between the price of electricity (\$/kWh) and the rate of residential solar adoption as of 06/2023.

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At 37.7%, **Australia** has the highest residential solar adoption rate of the countries studied herein. "The Australian continent has the highest solar radiation per square meter of any continent and consequently some of the best solar energy resources in the world."⁴ The large and sunny country has consistently set impressive solar goals in order to decrease reliance on other sources of energy.⁵ At the time these data were collected, 3.4 million residential systems were installed in Australia, with an average of 300,000 being added annually.⁶ The Australian government offers many different incentives to drive solar adoption, including Small-Scale Technology Certificates (STCs) and Feed-in Tariffs (FiT), which are frequently incremental to state-level incentives.⁷

³<https://www.energy.gov.au/households/solar-pv-and-batteries>

⁴<https://www.ga.gov.au/scientific-topics/energy/resources/other-renewable-energy-resources/solar-energy>

⁵<https://www.energy.gov.au/households/solar-pv-and-batteries>

⁶<https://www.abc.net.au/news/2023-03-01/rooftop-solar-to-overtake-coal-as-australias-main-power-source/102033740>

⁷<https://instylesolar.com/solar-guides/full-list-australian-solar-rebates-incentives>

The Netherlands, one of the most mature solar markets in Europe, has a 24.0% residential solar attach rate, which has grown substantially in the last several years⁸. The high cost of electricity (\$0.49/kWh) is probably the most significant contributor to the impressive installation numbers. The Dutch government also offers a feed-in tariff (FiT) for solar energy, and it will be interesting to see what happens when that rate is adjusted at the end of 2023.⁹

Japan's solar industry has transitioned from a focus on ground-mounted utility solar to more commercial and residential rooftop installations. As the third highest adopter of residential solar (21.5%), Japan is making great strides towards the renewable energy goals set by the Ministry of Energy for 2030.¹⁰ The Japanese government offers a modest feed-in tariff (FiT) for solar energy, and the policy excludes systems connected to the grid before January 17, 2022.¹¹

The Czech Republic is using solar energy to boost economic growth and social welfare, and currently has 15.1% residential solar adoption.¹² The country is taking part in the EU energy objective of using, "at least 40% renewable energy sources in the EU's overall energy mix by 2030... With the government's objective to increase renewable energy sources, electricity production is expected to grow, driving the market."¹³ The government offers a Feed-in Tariff (FiT) for owners of solarized homes.

Germany has a 12.3% residential solar adoption rate, which can likely be attributed in no small part to the high electricity rates consumers pay there.¹⁴ "The main driver in the increased adoption by homeowners has been the rise in energy prices, The German Solar Industry Association (BSW) said, and consumers' desire for long-term stability and predictability."¹⁵ German consumers pay \$.557/kWh for grid-provided electricity, and the country has one of the longest histories with solar as an aggressive early adopter of photovoltaic technology.

⁸<https://www.pv-magazine.com/2023/01/31/netherlands-posts-another-record-year-for-residential-pv-in-2022/>

⁹<https://www.pv-magazine.com/2020/04/01/netherlands-to-support-residential-pv-through-net-metering-for-the-entire-decade>

¹⁰<https://www.pv-magazine-australia.com/2023/03/22/pv-expo-2023-japanese-solars-struggle-for-space/>

¹¹<https://www.pv-magazine.com/2022/02/24/japan-unveils-2022-feed-in-tariff-levels-for-pv>

¹²<https://www.mordorintelligence.com/industry-reports/czech-republic-solar-energy-market>

¹³<https://www.pv-magazine.com/2021/07/21/south-africa-installed-1-3-gw-of-pv-last-year/>

¹⁴<https://www.pveurope.eu/financing/eupd-research-germany-huge-solar-potential-residential-rooftop-installations-still>

¹⁵<https://www.pv-tech.org/german-rooftop-solar-and-storage-soared-in-2022-as-homeowners-seek-independence-and-lower-prices>

With its bold goal for 100% renewable energy consumption by 2030, **Denmark** is relying on solar energy to play a key role.¹⁶ The country is currently at 10.3% residential solar adoption. Government incentives such as feed-in tariffs (FiT) and tax deductions are key drivers, likely offsetting the lower irradiance levels in the high latitudes.

South Africa has a more modest residential solar adoption rate of 5%.¹⁷ aims to deploy another 6GW of PV which will increase the (industry wide, not just residential) PV installed capacity from the current total electricity supply to 11% by 2030.” Individuals will be able to claim a rebate of up to 25% of the cost of new and unused solar panels, with a maximum of R15 000 per individual.¹⁸

Italy has just more than 25MW¹⁹ of residential solar capacity, giving that nation a 4.7% adoption rate. At \$.579/kWh, Italy has some of the highest electricity rates in Europe. The local solar industry is on pace for continued growth, but a maturing market likely means that growth will be more modest than in the past. The country has also had to rein in prior green building tax incentives due to the high cost charged to the Finance Ministry.²⁰

The United Kingdom has a residential solar adoption rate at 5%.²¹ The UK is expected to continue to increase solar capacity in line with its drive to reach net zero by 2050. In fact, the IEA also projects the UK’s solar capacity to nearly *triple* by 2030.”²² With around 1.2 million systems installed, six different solar grants are currently available for UK citizens, including ECO4, Home Upgrade Grant, SEG, Solar Together, VAT discount, and PPA Schemes.

The United States is the second largest energy consumer in the world, which underscores the importance of diversifying the energy mix.²³ The U.S. has a residential adoption rate of 3.4% and homeowners can take advantage of a variety of state and local incentives, as well as a

¹⁶<https://ens.dk/en/our-responsibilities/solar-energy/facts-about-solar-energy>

¹⁷<https://www.pv-magazine.com/2021/07/21/south-africa-installed-1-3-gw-of-pv-last-year>

¹⁸<https://www.treasury.gov.za/documents/national%20budget/2023/2023%20budget%20faqs%20-%20solar%20panel%20tax%20incentive.pdf>

¹⁹<https://www.pv-magazine.com/2023/03/01/italy-hits-25-gw-milestone>

²⁰<https://www.dailysabah.com/business/energy/italy-seeks-to-rein-in-out-of-control-cost-of-green-home-scheme>

²¹<https://www.theecoexperts.co.uk/solar-panels/popularity-of-solar-power>

²²<https://www.theecoexperts.co.uk/solar-panels/popularity-of-solar-power#link-do-we-expect-it-to-increase>

²³<https://www.sciencedirect.com/science/article/pii/S2090447921004470#s0020>

federal investment tax credit of 30% for installation costs.²⁴ Below you will see the country broken down into some of the top and bottom states.²⁵

Solar in **Mexico** is expected to continue to grow in the coming years, driven by popular residential net-metering and net-billing incentive programs.²⁶ With very favorable irradiance of 3.37-8.06 kWh/m²/day, solar is a productive and reliable renewable energy source in the country. With a 2.7% adoption rate, citizens of Mexico can "deduct 100% of their initial investment in a single fiscal year benefiting the taxpayer up to 30% savings on their purchase of a Solar system."²⁷

Brazil has tremendous solar potential based on its solar irradiation and the size of the population there.²⁸ While geographically large, Brazil only has a 1.9% residential solar adoption rate, with 1.46 million systems deployed. While the country has ample irradiance (3.01-6.22 kWh/m²/day), it also has rather low electricity prices (\$.175/kWh). Brazil offers net metering, feed-in tariffs, tax deductions, as well as local incentives to drive residential solar adoption.

Canada has an adoption rate of .3%, and this rather low figure can be attributed to a combination of lower irradiance (1.59-5.05 kWh/m²/day), depending on the region, as well as considerable amounts of snowfall and module soiling throughout the year.²⁹ Canada offers a 30% solar investment tax credit to help with installation costs.³⁰ Utility-scale solar has not gained traction in Canada, but the push for residential solar there is designed to decrease reliance on dirty energy.

Residential Solar Adoption in the United States

In the U.S., "the residential solar market experienced its 6th consecutive record year in 2022."³¹ Residential solar adoption, however, varies significantly from state to state, with some reaching

²⁴<https://news.energysage.com/solar-tax-credit-explained>

²⁵<https://pv-magazine-usa.com/2022/10/28/nearly-4-of-u-s-homes-have-solar-panels-installed>

²⁶https://www.solarfeeds.com/mag/solar-power-statistics-in-mexico-2021/#Residential_Solar_PV_Segment_Growth

²⁷<https://www.solarenergymexico.com/solar-incentives-mexico>

²⁸<https://ae-solar.com/brazil-solar-energy-market>

²⁹<https://renewablesassociation.ca/solar-energy>

³⁰<https://pv-magazine-usa.com/2023/03/30/canada-formalizes-six-year-30-federal-itc-credit-among-other-incentives>

³¹<https://www.seia.org/solar-industry-research-data>

as high as almost 20%, while others are nearly at zero.³² Beyond regional differences in irradiation, a lack of infrastructure are the primary causes of the disparity.

The table below shows the top ten and bottom five U.S. states using the number of houses, number of residential solar installations, and the calculated adoption percentage as of June 2023. The residential data was sourced from Wood Mackenzie, and the home from the U.S. census.

Rank	State	Residential Solar Adoption Rate: Single Detached Homes	Resi. data up to 2023 Mwdc	Number of Single Detached Homes 2021	Cost of electricity (USD)	Avg. Solar Radiation (kWh/m ² /day)
1	Hawaii	24.4%	596.13	296,149	\$0.43	5.27
2	California	15.2%	13,359.37	8,301,530	\$0.30	5.75
3	Arizona	11.1%	2,448.94	2,031,053	\$0.14	6.49
4	Nevada	10.6%	903.54	793,296	\$0.18	6.23
5	Massachusetts	8.2%	1,142.93	1,558,248	\$0.32	4.57
6	New Jersey	7.9%	1,475.00	2,027,880	\$0.17	4.67
7	Maryland	7.7%	912.16	1,321,828	\$0.16	4.82
8	Connecticut	7.6%	645.43	907,419	\$0.34	4.53
9	Utah	6.7%	522.19	799,053	\$0.11	5.51
10	Vermont	5.4%	113.08	226,665	\$0.21	4.28
46	Georgia	0.1%	75.78	3,013,266	\$0.13	5.26
47	Tennessee	0.1%	17.21	2,131,963	\$0.12	4.81
48	South Dakota	0%	1.14	275,249	\$0.12	5
49	North Dakota	0%	0.4	215,479	\$0.10	4.65
50	Alabama	0%	1.42	1,631,262	\$0.14	5.2

U.S. State-Level Analysis

Hawaii: With an adoption rate of 24.4%, Hawaii leads the nation in residential solar adoption, and the state also leads the nation in the cost of electricity at \$.43/kWh. Homeowners in the Aloha State can claim a 35% tax credit for the cost of solar installation, export excess power to the grid for credits, and gain tax exemptions for the value of their solar panels.³³

California: Despite having the highest total installed capacity (13,359.37 Mwdc) and the largest number of homes (8,301,530), California ranks second with an adoption rate of 15.2%.

³²<https://www.forbes.com/home-improvement/solar/best-worst-states-solar>

³³<https://energy.hawaii.gov/what-we-do/financial-assistance-and-grants/financing-and-incentives-for-renewable-energy-projects/state-of-hawaii-and-federal-incentives/>

The price of electricity varies around the state, with the average being \$.295/kWh; this is one of the higher costs analyzed above. California is making the most of its high level of solar radiation, of which it receives an average of 5.75 kWh/m²/day. Homeowners can claim a 26% tax credit for the cost of solar panel installation, participate in NEM3 Net metering, secure loans to finance the final cost of solar panel installation with no money down or receive a property tax exemption for the value of their panels.³⁴

Arizona: With an adoption rate of 11.1%, Arizona has a significant residential solar presence. The state has a total installed capacity of 2,448.94 Mwdc and 2,031,053 homes. The state also has the highest average solar radiation at 6.49 kWh/m²/day and homeowners can claim a 25% tax credit for the cost of solar panel installation, participate in net metering for credits, and receive tax exemption to help with solar installation costs.

Nevada: Nevada ranks fourth with an adoption rate of 10.6%. The state has a larger number of homes (793,296) and a higher installed capacity (903.54 Mwdc) compared to Hawaii. The state also has one of the higher average irradiances, at 6.23 kWh/m²/day. Homeowners can claim a 25% tax credit for the cost of solar panel installation, participate in net metering, leverage property tax exemptions, and secure PACE financing.

Massachusetts: Comes in at number five, with an adoption rate of 8.2%. Living in this East Coast state comes with high electricity costs at \$ 0.32/kWh. Homeowners can claim a 26% tax credit for the cost of solar panel installation, participate in net metering, benefit from property tax exemptions, and secure PACE financing.

New Jersey: Although it has a more modest solar adoption rate of 7.9%, New Jersey also has a comparatively smaller number of homes (2,027,880) and an installed capacity of 1,475.00 Mwdc. Homeowners can claim a 26% tax credit for the cost of solar panel installation, participate in net metering, benefit from property tax exemptions, and secure PACE financing.

³⁴<https://www.energysage.com/local-data/solar-rebates-incentives/ca/>

Maryland³⁵, **Connecticut**³⁶, **Utah**³⁷ & **Vermont**³⁸ have adoption rates ranging from 7.7% to 5.4% indicating a moderate level of residential solar adoption. They also have an average amount of solar radiation to take advantage of. Connecticut has a high electricity rate, at \$0.34/kWh, and residents stand to benefit from more added solar. All four states offer income tax credits ranging from 26%-30%, net metering, and property tax exemptions to assist with the upfront financial burden and drive residential solar adoption.

The U.S. states with the lowest solar adoption rates are **Georgia**³⁹ (46), **Tennessee**⁴⁰ (47), **South Dakota**⁴¹ (48), **North Dakota**⁴² (49), and **Alabama**⁴³ (50). These states have adoption rates of 0.1% or lower. Since neither solar radiation nor electricity rates differ drastically from their federal fraternal, residential solar represents a growth opportunity for enterprising entrepreneurs. Further, these five states have solar investment tax credit options, property tax exemptions, PACE financing, and net metering programs, as well as organizations like the Tennessee Valley Authority (TVA) which offers a rebate of up to \$1,000 for solar projects.⁴⁴

³⁵<https://energy.maryland.gov/pages/info/renewable/solar.aspx>

³⁶<https://portal.ct.gov/pura/electric/office-of-technical-and-regulatory-analysis/clean-energy-programs/residential-renewable-energy-solutions-program>

³⁷<https://hub.utahcleanenergy.org/solar-power/solar-incentives-in-utah>

³⁸<https://www.energysage.com/local-data/solar-rebates-incentives/vt/>

³⁹<https://www.energysage.com/local-data/solar-rebates-incentives/ga>

⁴⁰<https://www.energysage.com/local-data/solar-rebates-incentives/tn>

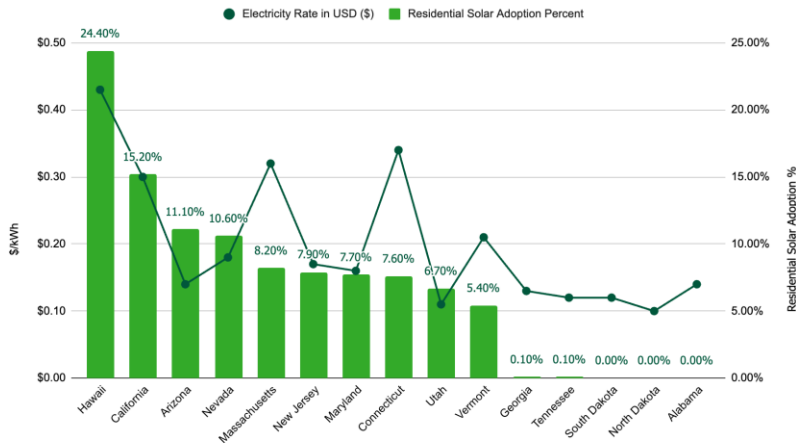
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⁴²<https://pv-magazine-usa.com/2023/02/17/50-states-of-solar-incentives-north-dakota>

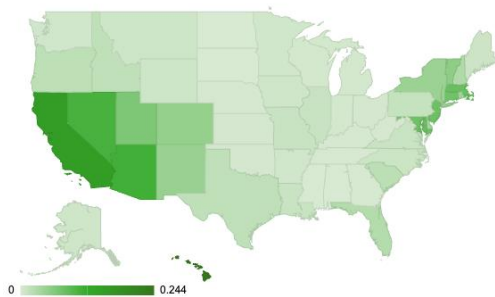
⁴³<https://pv-magazine-usa.com/2022/11/16/50-states-of-solar-incentives-alabama>

⁴⁴<https://www.tva.com/energy/valley-renewable-energy>

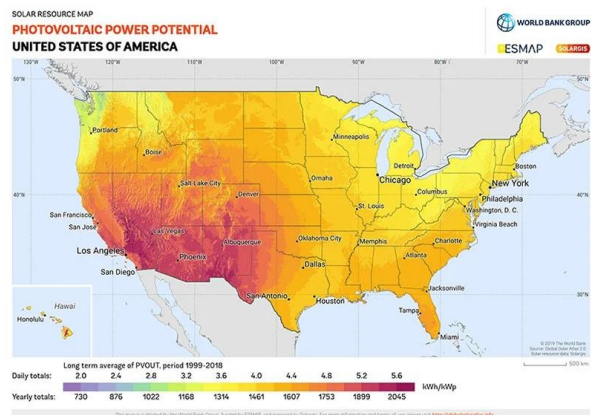
Residential Solar Adoption by State compared to Price of Electricity



The data cited herein are from 2023, and the ranking and adoption percentages will change over time as more households embrace solar energy and new policies and incentives are implemented. Already 54% of all new electric capacity added to the U.S. grid in the second quarter of 2023 came from solar. Solar’s increasing competitiveness against other technologies has allowed it to quickly increase its share of total U.S. electrical generation - from just 0.1% in 2010 to nearly 5% today,⁴⁵ and the landscape remains ripe with opportunities for further growth.



Shown: % adoption of residential solar (ranging from 0-24.4) across the United States.



Shown: PV output irradiance across the United States.

⁴⁵<https://www.seia.org/solar-industry-research-data>

The Future of Solar

The adoption of residential solar is steadily increasing, on a global scale, thanks to various influencing factors. The diminishing costs, advancements in technology, and supportive policies have played significant roles in propelling the growth of solar energy. Many countries have invested in solar infrastructure and established renewable energy targets to accelerate the implementation of residential solar power. The advantages of residential solar are numerous, including the option to add resilience with energy storage, reduced utility bills, benefits from net metering, government incentives, a lower carbon footprint, long-term financial savings, and financial returns through accumulated savings over time. In some combination, these benefits have propelled nations worldwide toward a future powered by solar energy.

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