The Environmental Case for Rooftop Solar Energy

Protecting California's Climate and Land

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Cover photo: Solar on affordable, multi-family housing in Tulare County. Credit: Spectrum Energy Development.

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Executive summary

California has long been a global leader in environmental protection. California's pioneering actions to reduce air pollution, safeguard natural areas, and protect vulnerable species have set a high standard for the United States and beyond.

Today, California faces its biggest environmental challenge: climate change. Over the next several decades, California will need to repower its economy with clean, renewable energy – and do so with as little impact as possible on wildlife and wild places.

Rooftop solar power is a key tool in the fight against climate change. Solar energy on homes, schools, farms and other buildings can be deployed at the speed and scale required to meet the climate crisis, and it can do so while contributing to a resilient, ecologically vibrant future for California.

Installing more rooftop solar can increase renewable electricity generation while protecting the state's open spaces and helping to make communities more resilient to global warming-related disruptions to the power grid. **To accelerate the transition to a 100% clean energy system while protecting our environment, California should adopt policies that continue the growth of solar power on homes, businesses, schools, farms and other buildings.**

Rooftop solar is critical to helping California meet its climate goals. California has set out to achieve net-zero greenhouse gas emissions by 2045 and also to obtain 100% of retail electricity sales from renewable and zero-carbon sources by 2045.[1]

- State officials assume that California will nearly quadruple its current rooftop solar capacity – from 10.5 gigawatts to 39 gigawatts (GW) – as it seeks to reach its 2045 climate and clean energy goals.[2] This is in addition to even larger amounts of utility-scale solar.[3]
- California has extensive potential for generating more electricity from rooftop solar installations (see Figure ES-1). A 2016 analysis by the National Renewable Energy Laboratory found that the state has the technical potential to meet more than three quarters of its electricity demand with rooftop solar energy.[4]

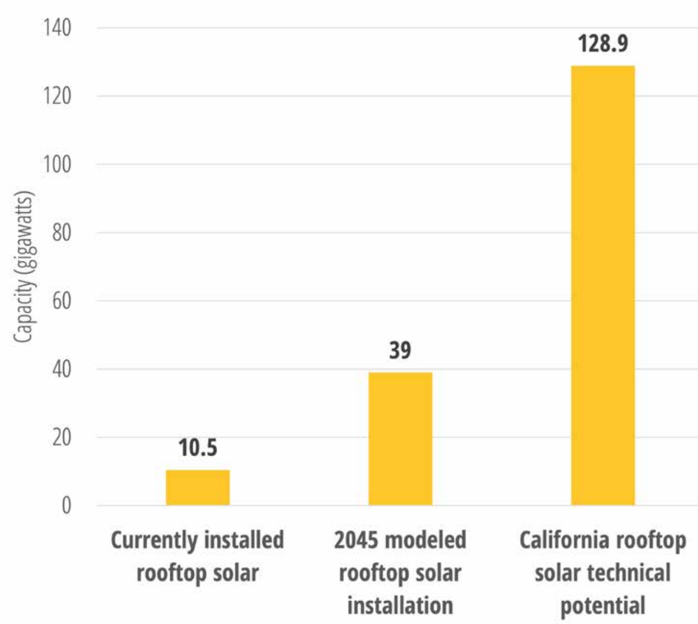


Figure ES-1. Rooftop solar has plenty of room to grow in California[5]

Rooftop solar can be installed more quickly than any other electricity generating source, enabling California to respond at the speed and scale necessary to address the climate crisis.

- A residential rooftop solar project is typically installed within three months of inception, and commercial rooftop installations typically take between two and four months.[6]
- Avoiding climate emissions today can help limit the extent of warming that the state and the rest of the world will experience.[7] Pollution reductions today provide greater benefit than the same emission reductions a year or 10 years in the future.

Rooftop solar energy does not change existing land uses and can help California protect agricultural land, fragile habitats and natural areas. These places are disrupted by utility-scale solar projects, which California will need to meet its climate and clean energy goals. However, by tapping rooftop solar opportunities, California can reduce the total amount of utility-scale solar needed and help to protect natural areas. State regulators calculate an additional 28.5 GW of rooftop solar will be built by 2045.[8] By using this amount of rooftop solar instead of utility-scale solar, California can maintain existing land uses on more than 148,000 acres of land – an area about half the size of the City of Los Angeles.[9]

- In October 2020, Governor Gavin Newsom issued an executive order committing California to protecting 30% of its natural land and water areas by 2030, up from the 22% that is protected currently.[10] Rooftop solar can help minimize conflicts between the state's conservation and clean energy goals.
- Rooftop solar is built on already developed land. By reducing the need for utility-scale facilities, it can reduce the impacts of electricity generation on the natural environment that California is seeking to protect.
- An additional land conservation benefit of rooftop solar is that it produces electricity close to where it is consumed. As a result, it reduces the need for new transmission infrastructure, which can damage or destroy farmland and ecosystems.

Climate change will have disruptive effects on California, even if we move quickly to curb emissions. Rooftop solar energy and batteries can help California communities be more resilient to climate-related disruptions to the electricity grid. When paired with energy storage, solar on homes, businesses, schools and other locations can help buildings or communities keep the power on during emergencies.

- Californians have experienced numerous climate-related blackouts in recent years, both during pre-emptive power shut-offs intended to prevent transmission lines from sparking fires in drought-stressed forests and during unprecedented heat waves when electricity demand outstripped supply.
- If a rooftop solar system is connected to battery storage, the energy the solar panels generate can be used to power a home even when the rest of the grid loses power.[11] This can keep food cold, operate well-water pumps, and provide cooling and lighting.

To ensure the installation of enough solar on homes, businesses, schools, farms and other buildings to meet its climate and clean energy goals, California needs a range of policies supporting rooftop solar generation, including:

- As California updates its net energy metering policy, which allows the owners of rooftop solar panels to be compensated for the electricity they provide to the power grid, it should **ensure that the revised policy provides sufficient support to allow the undiminished growth of rooftop solar**. Slower growth of distributed solar creates a risk that the state will not meet its climate and clean energy targets.
- California should seek to **accelerate solar energy adoption on affordable and rental housing**, including by allowing financing through utility bills and ensuring solar owners who pay reduced rates are fully compensated for the power they provide to the grid.
- In addition, cities and counties should establish online automated **permitting systems for small onsite solar projects**, using systems like SolarAPP+ developed by the National Renewable Energy Laboratory.

Introduction

Californians have a deep appreciation for the beauty of the natural world. And its fragility.

It is that appreciation that has led California to be a global leader in environmental protection. Time and again, when our air, water or wild places have been threatened, California has innovated. And California has led.

From establishing protections for birds in 1909 to enacting the nation's most comprehensive state-level endangered species act, California has pioneered the use of new tools to protect wildlife and wild spaces.[12] The state's strong coastal protections and our more than 15,000 parks and protected areas are further testament to our willingness to preserve our natural areas for our children and grandchildren to enjoy.[13]

At the same time, Californians also know that our efforts to preserve what is unique and special about our state – as well as our own health and well-being – are threatened by the existential challenge of climate change. That's why California has also been a global leader on climate and clean energy policies. In 2002, California adopted the nation's first statewide greenhouse gas emission reduction goal.[14] More recently, California adopted a requirement to get 100% of the state's electricity from clean sources by 2045.[15]

Eliminating carbon pollution in California will not be easy. Doing so while preserving our state's wild and special places will be even more challenging.

Rooftop solar energy provides a solution. By generating power on already developed land, close to where it is used, rooftop solar is a powerful tool to meet the climate challenge, protect our natural environment, and build resilience against the threats of the 21st century.

Generations of Californians have seen the promise of solar energy and developed innovative technologies and tools to foster its growth. ARCO built the world's largest solar facility in California in 1979.[16] In the mid-2000s, the state set a target of putting solar panels on a million rooftops within a decade – a goal we have now met.[17] Today, more than 20% of California's 2019 in-state electricity generation comes from customer-sited or utility-scale solar power.[18]

Now, however, the future of rooftop solar energy is at stake, as the California Public Utilities Commission (CPUC) considers changes to the key policy that compensates the owners of solar panels for the clean electricity they supply to the grid.

Californians have always looked to the future. As the CPUC and other decision-makers consider the future of solar policy in California, it is critical that they understand the unique role that rooftop solar can play in building a cleaner, healthier, and more resilient state – now and in the decades to come.

Rooftop solar is critical to achieving California's climate and clean energy goals

California has adopted some of the strongest climate protection and clean energy policies in the country. Rooftop solar energy is a critical component of achieving California's goals because it has the potential to provide large amounts of clean electricity, quickly.

California has established strong climate and clean energy goals

California faces numerous threats from climate change: sea level rise, coastal erosion and flooding; losses in snowpack and water supply; damage to forests and higher risk of wildfires; declining agricultural productivity; worsened public health; and destruction of natural spaces and ecosystems.[19] But the state is not sitting idly by.

California has strong goals to reduce greenhouse gas emissions and to increase the use of renewable energy. California has committed to cutting its emissions to 40% below 1990 levels by 2030 and to achieving net-zero greenhouse gas emissions by 2045 and net-negative emissions afterwards.[20] A separate clean energy standard adopted in 2018 requires that 60% of the state's retail electricity sales come from renewable sources by 2030 and 100% from renewable and zero-carbon sources by 2045.[21]

California is making notable progress on those climate and clean energy goals. For instance, in 2017, emissions from power generation were already more than 40% below 1990 levels.[22] This was driven in part by the growth of renewable power generation. Renewable energy capacity has more than tripled in the last decade and renewables supplied 36% of retail electricity sales in 2019, exceeding the state goal of 33% by 2020.[23] California's strong energy efficiency policies also helped by

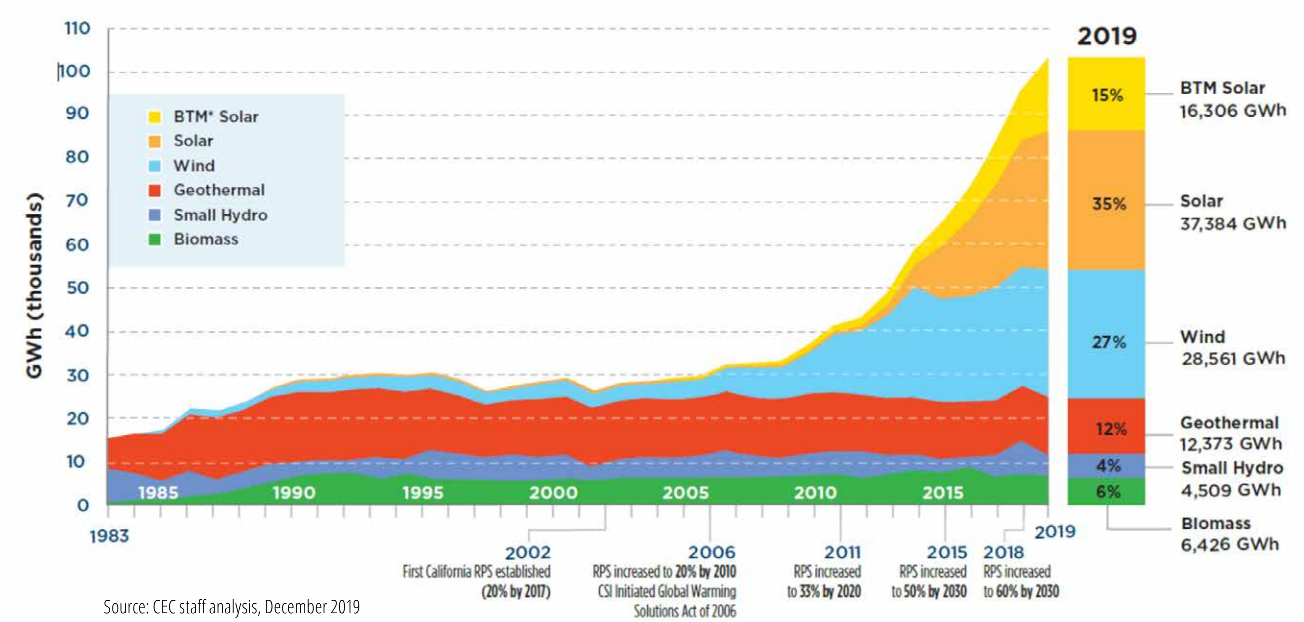


Figure 1. Renewable energy generation has increased rapidly in California[25]

reducing total electricity consumption even as the state's population has increased over the past decade.[24]

Rooftop solar is helping California to meet its goals

Rooftop solar power has played a critical role in the state's progress toward its climate and clean energy goals, thanks to a number of policies that have supported local clean energy generation.

Distributed solar – photovoltaic panels mounted on or near homes, schools, commercial buildings and farms – is California's third-largest renewable energy source, representing 15% of renewable electricity generation and 7.5% of total in-state electricity generation in 2019.[26] (See Figures 1 and 2.) And distributed solar has grown quickly: the capacity of rooftop solar in California has doubled every two to three years since 2006.[27] (See Figure 3.)

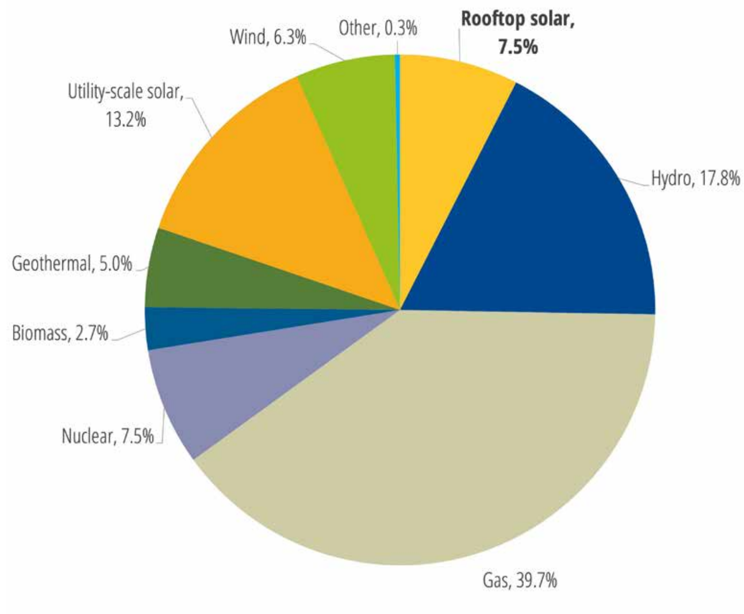


Figure 2. California's 2019 in-state electricity generation by energy source[28]

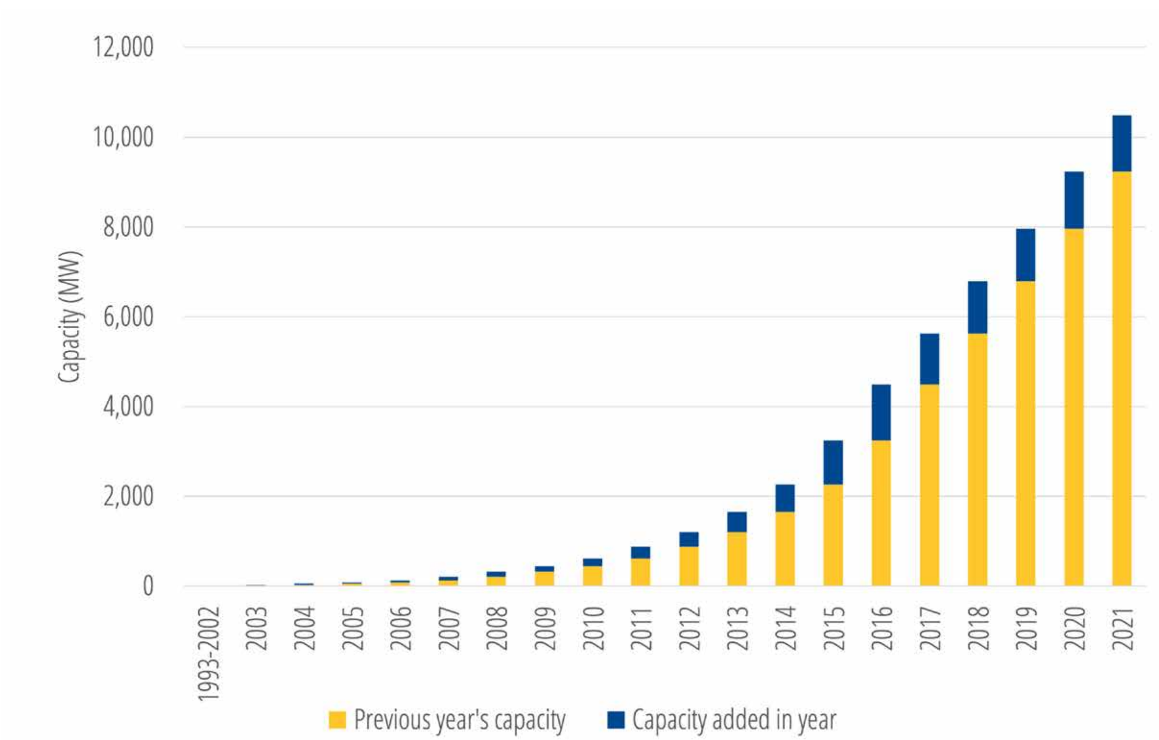


Figure 3. Rooftop solar capacity in California has grown rapidly[29]

California has adopted strong policies to promote the growth of rooftop solar energy.

- California first adopted a provision in 1995 that required electric utilities to compensate utility customers for power generated on-site and sent back to the utility.[30]
- In 2006, California adopted the Million Solar Roofs Initiative, which set the goal of installing solar on one million homes and then developed the California Solar Initiative, a suite of incentives designed to install 3 gigawatts (GW) of solar by 2016.[31] To achieve these goals, the state created incentives and rebates for solar panel installation, expanding solar energy and lowering its cost.[32] California achieved its 3 GW goal in 2015 and the goal of a million roofs with solar panels in 2019.[33]
- California has created multiple programs to help install solar energy on low-income housing. For example, between 2007 and 2008, the CPUC earmarked more than $200 million for installing solar on owner-occupied, low-income homes and multi-family affordable housing.[34] More recently, in 2015 the state adopted the Solar on Multifamily Affordable Housing program to spend up to $100 million annually to install solar energy on low-income apartment buildings.[35]
- In 2019, California also adopted a new set of building codes that reaffirmed the state's commitment to rooftop solar. The codes require that most newly built smaller residential buildings install solar generation capacity on the site as part of construction.[36] Many newly built smaller buildings that are exempt from the solar installation requirement, including hotels and commercial buildings, are still required to prepare the building or lot for future solar capacity installation.[37] These requirements are a continuation of California's climate leadership and a strengthening of the state's commitment to rooftop solar.

More rooftop solar will be essential in the years to come

California has tapped only a fraction of its rooftop solar potential. Adding more rooftop solar generation capacity, especially if paired with onsite storage, will help California meet its overall climate goals.

California has enormous distributed solar potential. According to 2016 analysis by the National Renewable Energy Laboratory, the residential, commercial and industrial roofs in California have the technical potential to produce 194 terawatt-hours of electricity each year.[38] That is more than 77% of California's total 2019 electricity usage, and more than twice as much electricity as was used in all California homes in 2019.[39]

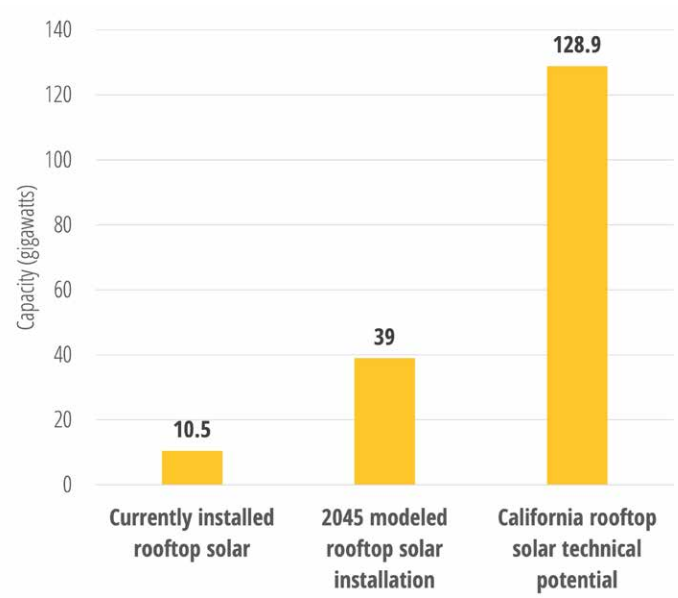


Figure 4. Rooftop solar has plenty of room to grow in California[40]

California will need to tap that potential to meet its goals of getting 100% of its retail electricity sales from renewable and zero-carbon sources and achieving net-zero greenhouse gas emissions by 2045. The California Energy Commission (CEC), California Public Utilities Commission (CPUC) and California Air Resources

Board (CARB) have jointly modeled several pathways by which California might achieve its clean energy goals. In every permutation of the state's future electricity system, they assume the state will have installed 39 gigawatts (GW) of distributed solar by 2045.[41] Currently, California has installed 10.5 GW of behind-the-meter solar capacity, so 39 GW would be a near-quadrupling of rooftop solar capacity.[42]

Expanding rooftop solar is a critical part of how California will achieve its clean energy goals. In every scenario modeled for 2045 – including with extensive electrification of transportation and buildings, increased use of hydrogen, and greater use of biofuels – rooftop solar capacity grows and is one of the largest sources of energy for the state.[43]

In addition, rooftop solar may help to reduce a problem created by a potential loophole in California's clean energy goal that could allow some dirty energy generation to continue in 2045 and later. California's 2045 clean energy mandate calls for the state to "supply 100 percent of retail sales and electricity procured to serve all state agencies by 2045" with renewable and zero-carbon sources.[44] If electricity is generated at a distance from where it is consumed, some energy is lost during transmission.[45] The CEC, CPUC and CARB have interpreted SB100's clean energy requirement as limited to retail sales, and not including electricity lost during transmission and distribution.[46] As a result, though all power sold to customers in 2045 may be from clean sources, the power lost during transport may come from polluting sources. This is reflected in many of the scenarios modeled by the CEC, CPUC and CARB, in which a significant amount of gas capacity continues, bringing with it all of the damages from extraction, transportation and combustion of gas.[47] Rooftop solar reduces the amount of transmission needed, which reduces the amount of fossil fuel-powered generation that might be retained. [48]

Rooftop solar can provide immediate pollution reductions

Not only will additional rooftop solar be an important part of California's efforts to meet its 100% clean energy goals, but it can also provide immediate progress toward the state's climate goals. Rooftop solar can be installed more quickly than utility-scale energy sources, helping California reduce emissions faster and offer greater climate protection.

While California has established its climate goals in terms of its annual emissions in 2030 and 2045, what matters for the atmosphere is the cumulative amount of pollution released: the state's "carbon budget." Reducing carbon emissions now by expediting the deployment of clean energy can both reduce overall warming and allow greater "margin for error" in the state's future carbon emission reduction efforts.[49] Immediate emission reductions will also reduce the risk that the climate will pass a tipping point, beyond which controlling global warming would be more difficult.

California's emission reduction goals apply to all sources of pollution, but reductions will be easier to achieve in some sectors in others. By moving quickly to cut emissions from electricity, while also trying to address the harder problem of cutting pollution from transportation and buildings, California can ensure it stays within its carbon budget and meets its 2030 goals.

Rooftop solar is an important tool for rapid climate pollution reductions. In a joint agency report on potential pathways for California to meet its emissions goals, CEC, CPUC and CARB assume that there will be a total of more than 23 GW of rooftop solar installed by 2030, about 2.5 times as much as is currently installed.[50] Keeping to that timeline will require rapid, widespread installation of new clean energy capacity, which is one of the strengths of rooftop solar.

Both residential and commercial rooftop solar projects can be installed within a matter of months, providing immediate emission reductions as utility-scale renewable energy projects are being built. Installing a residential rooftop solar system – including site evaluation, permitting and installation – takes about three months on average, though it can happen in as little as a few weeks.[51] Commercial rooftop installations follow the same process and typically take between two and four months.[52] As a result, a rooftop solar installation can begin providing clean electricity and displacing sources that produce climate pollution within months.

Utility-scale electricity sources generally require more time before they begin producing power. (See discussion of siting and transmission delays for utility-scale solar in the next section, on page 12.) Multiple steps in the construction of utility-scale solar installations lengthen their timeline to completion, including acquiring land and building additional transmission capacity.[53] Completing a utility-scale solar project takes six years, according to one estimate by the Solar Energy Industries Association.[54] Similarly, a utility-scale wind farm can take four to seven years to complete.[55]

While large amounts of utility-scale solar will be essential for achieving California's clean energy future, rooftop solar is a critical tool for California to ensure it adds new clean energy sources quickly. Distributed solar can begin producing clean electricity more quickly than any other source, helping to more immediately put the state on a path to a stable climate.

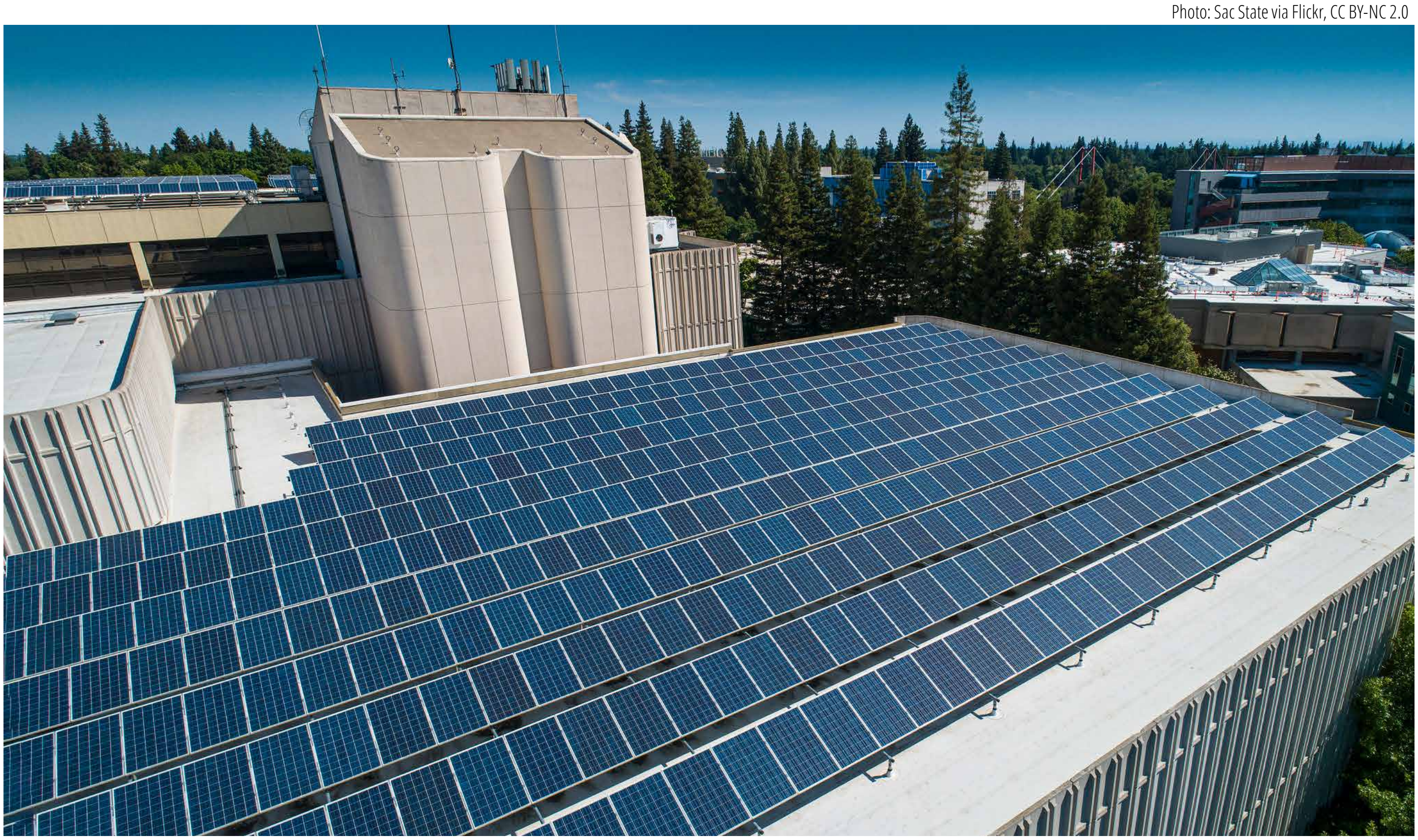
Thin-film solar installation on a Walmart store in Mountain View, California.

Rooftop solar has minimal land use impacts

Rooftop solar can help California meet its climate and environmental goals while minimizing any damage to the natural spaces, plants and wildlife the state is working to protect.

Unlike other forms of electricity generation, rooftop solar power has little impact on existing land uses. It typically doesn't disrupt habitat, affect farmland, or otherwise alter the natural landscape. Not only is solar generation capacity installed on already developed land, but it also produces electricity close to where it is consumed, reducing the need for long-distance transmission capacity that itself disrupts other land uses.[56] Rooftop solar, installed with or without batteries, therefore allows for renewable energy generation while conserving land.

As of 2011, California had developed 30,641 square miles of land – almost 20% of the total area of the



Solar panels on the California State University at Sacramento library.

Photo: sandy.redding via Flickr, CC BY-NC-SA 2.0

A Joshua tree in Hart's Place, California.

state – with homes, businesses, roads, mines, oil and gas wells, electricity generation facilities and other facilities.[57] Between 2001 and 2016, more than 465,000 acres of California's agricultural land was developed, mostly into urban space.[58] More than 330,000 acres of that was some of the state's most productive farmland.[59]

The state has a long history of protecting special natural areas as parks or with development limitations, but more recently has recognized that current measures may not be sufficient. In October 2020, Governor Gavin Newsom issued an executive order committing California to protecting 30% of its natural land and water areas by 2030, up from the 22% that is protected currently.[60] In their recent report on how the state may achieve its clean energy goals, CEC, CPUC and CARB list land conservation as a focus of the state's environmental vision and plan for achieving its environmental goals.[61]

However, the state's conservation goals can come into tension with the land requirements of clean energy projects that will be essential to meeting the state's climate goals. For example, even as California state officials granted endangered species protections to Joshua trees, they also gave exemptions to 15 separate solar projects that were ready to begin construction, allowing the projects to raze some of those trees.[62]

Meeting the climate challenge and transitioning off fossil fuels will result in some conflict with conservation goals. We will need to build utility-scale solar and wind facilities and connect them to the grid in order to generate enough energy to meet our needs. But not all routes to zero carbon emissions are equal, and we should take care to cut pollution while doing as little harm to our natural resources as possible. And rooftop solar helps to do that.

By making use of rooftop solar opportunities, California can reduce the scale of the conflict between the state's conservation and clean energy goals. Rooftop solar has essentially no land-use impacts since the panels can be mounted on existing homes, businesses, warehouses, religious institutions or other buildings (and can even be used to shade parking lots and other paved areas) and are connected into the existing electric grid.[63] By contrast, many forms of renewable electricity generation require development of large areas of farmland, desert or other undeveloped land that must be converted from its existing use for a utility-scale project. For example, several of California's desert solar projects, both under construction and operational, sit on over 4,000 acres of land.[64] Building more rooftop solar will reduce the amount of utility-scale solar that needs to be constructed.

Going big on rooftop solar could help California protect hundreds of thousands of acres of land. According to modeling by CEC, CPUC and CARB, California will need to add a minimum of 28.5 GW of rooftop solar by 2045.[66] By using rooftop solar instead of utility-scale solar for a portion of its clean energy, California can maintain existing land uses on more than 148,000 acres of land – an area about half the size of the City of Los Angeles.[67] Each 1 GW of rooftop solar instead of utility-scale solar potentially avoids the conversion of almost 5,200 acres of land, an area slightly smaller than the city of Monterey.[68]

Based on where recently built utility-scale solar facilities have been sited, using rooftop solar can enable protection of agricultural land and desert areas. A recent utility-scale solar project, the Blythe Solar Power Project, which came online in 2016, was built on the Palo Verde Mesa in the Sonoran Desert, an area with plant species that grow nowhere else in the state.[69] The facility occupies more than 4,000 acres of desert that is home to sensitive species, including the threatened desert tortoise and Harwood's woollystar, a wildflower that grows in fewer than 20 locations around the world.[70] Another solar project, the CalSun Solar Project in Alameda County, will sit on nearly 90 acres of agricultural land.[71]

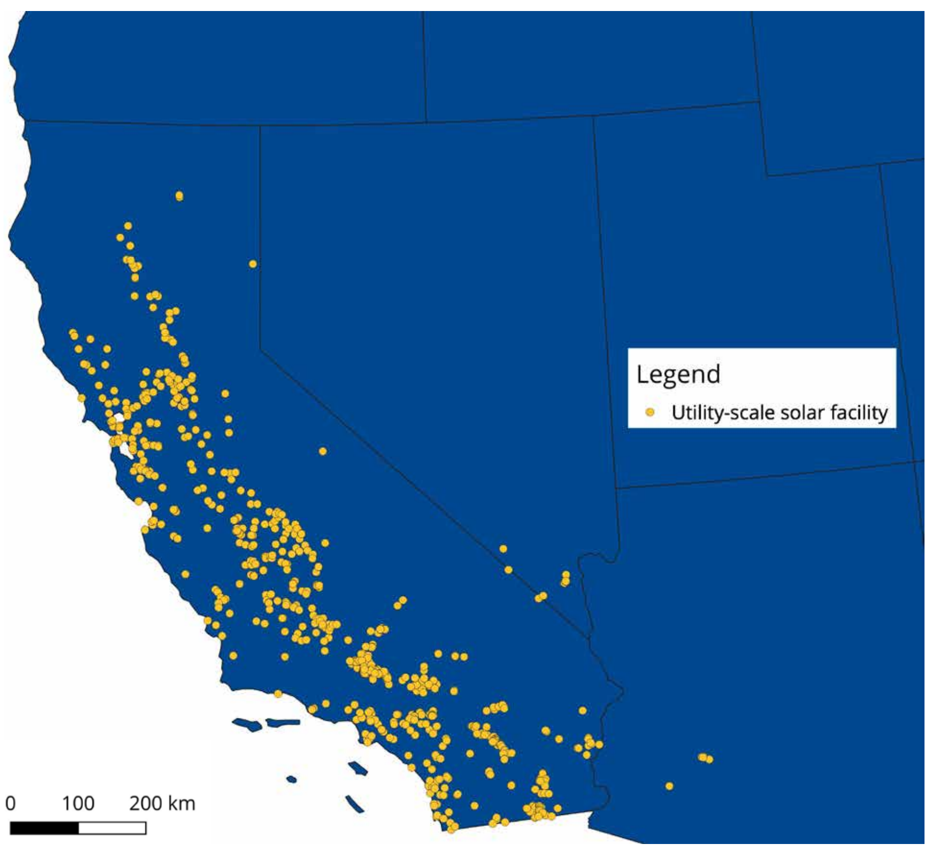


Figure 5. Utility-scale solar facilities supplying power to California are numerous[65]

Photo: Dana Wilson/BLM via Flickr

A California desert tortoise.

While the value of California's agricultural land is obvious, the importance of its desert land is less apparent but no less significant. The Mojave, the Colorado and the Great Basin deserts are home to many species endemic to California, including the endangered bighorn sheep and threatened desert tortoise.[72] The beauty of the desert landscapes draws visitors and inspires artists. Because of the ecological value of California's deserts, siting new energy projects there can be difficult: almost 100 projects proposed for the Southern California desert have been denied, often for environmental reasons.[73] Building more rooftop solar will limit how much desert area the state needs to develop to meet its clean energy and climate goals.

Caution is required to minimize the potential ecological harm from utility-scale projects, which helps to ensure that such projects are built with as little impact as possible on fragile ecosystems. But the deliberative planning process also contributes to their lengthy construction timeline. Even if successful, the level of care needed to ensure utility-scale projects cause no harm means that rooftop solar is a more surefire approach to achieving short-term climate goals.

Rooftop solar also does not require repurposing land for new electricity transmission infrastructure, reducing the harm such infrastructure can do. That harm includes fragmenting habitats, cutting through farmland and damaging natural landscapes. When electricity generation happens at a distance from consumption, however, it must be transported using high-capacity transmission lines to the system of smaller wires – the distribution network – that connect to homes and businesses.[74]

The more utility-scale generation facilities that are built, the more transmission capacity that will be needed. A 2017 report by the California Natural Resources Agency (CNRA) stated that there may be sufficient existing transmission capacity to deliver some new renewable

Sunset in the Mojave Desert.

energy into the grid, but predicted the scale of new additions would necessitate new transmission capacity by 2030.[75] Additionally, the report clarified that the excess transmission capacity in California's system is not located where it will likely be needed to transport electricity from high-value renewable energy facilities to where the power will be used; in other words, the state will need to build more transmission capacity.[76] (Adding transmission capacity is costly. See text box on page 17.)

Transmission infrastructure can have a significant footprint and impact on the land it uses both during and after construction. During construction, transmission lines impact wildlife by removing habitat and causing disturbances with the presence of machines and humans.[77] Completed transmission lines require a strip of land up to 150 feet wide, which has to be cleared of trees and other vegetation that could interfere with the lines or towers or prevent access for maintenance.[78] Those corridors can create barriers for some species by dividing their habitats.[79] And the maintenance of the lines and corridors can harm wildlife and the environment. Maintenance requires people and machines to move through the space and may involve herbicides for vegetation management.[80] Additionally, the transmission equipment itself, once built, can leak potent greenhouse gases, an issue that California utilities and regulators are in the process of addressing.[81]

These effects are evident in the projects described by CNRA. One project in the Lugo-Eldorado transmission corridor in Southern California would cross critical habitat for the desert tortoise and bighorn sheep, while also intersecting or abutting several Desert Wildlife Management Areas and several areas with particular cultural, scenic and natural value.[82] Another project in the Imperial Valley would run through tribal land and National Forest wilderness.[83] A third project, in the Midway-Devers area, would cross farmland, wilderness area and preserved habitat of the fringe-toed lizard.[84]

New transmission capacity also takes a long time to build. That means new utility-scale renewable generation that requires new transmission capacity will have to wait to provide clean power to Californians until the lines are built and power can flow. The Transmission Agency of Northern California suggests that 13 years is a conservative estimate for the average time from planning to completing construction of a transmission project and that as permitting, approval and land acquisition processes are constrained, it could take even longer.[85] California has many projects planned, but the vast majority of them are repairs or upgrades to existing lines or substations, with very few new transmission lines proposed.[86]

To be clear, new transmission infrastructure is necessary to make the California electric system more reliable and efficient, and to integrate more renewable energy generation facilities. It is, however, slow to complete, has impacts on the environment, and is expensive. Likewise, utility-scale renewable electricity generation is essential to transition to 100% renewable energy, but it also has downsides, including the amount of land required. Rooftop solar can help reduce and delay the costs and the need for new transmission infrastructure and can take the place of new utility-scale facilities, helping to protect the environment.[87]

New transmission capacity is expensive

New transmission infrastructure will be critical to achieving California's clean energy and climate goals. New transmission infrastructure enables more clean energy use by delivering clean energy from areas of high production to areas of demand.[88]

However, transmission capacity is very expensive to construct. Thus, for the sake of conservation and for minimizing costs for ratepayers, who pay for new transmission infrastructure through their utility bills, the state should seek to minimize how much transmission capacity it needs to add. [89] Rooftop solar can help.

Completed projects and some that are underway have high price tags. For example, the 117-mile Sunrise Powerlink in Southern California, which began operating in 2012, cost $1.9 billion to build.[90] The 732-mile TransWest Express project, which will run from Wyoming to Nevada and connect into the California grid, is fully permitted and slated to cost $3 billion.[91]

Future projects will be similarly expensive. A 2017 report by the California Natural Resources Agency examined several proposed transmission projects that would address likely needs given current loads and probable future demands from new generation. The cheapest project in the analysis was an upgrade of an existing line, and yet had expected costs of more than half a billion dollars. Other projects had price tags in the realm of $2 billion.[92]

Transitioning to renewable energy will reduce water use

California has struggled with drought for decades, and water conservation is important for all activities in the state, including electricity generation. In contrast to existing gas facilities, solar energy (and other forms of renewable energy) uses less water. Switching to wind and solar energy can help California generate clean electricity while placing less demand on the state's limited water supply.[93]

Gas plants rely on water for cooling and to produce steam that drives electricity-generating turbines. A study of water use in electricity production found that, nationally, a typical natural gas plant consumes 0.056 gallons of water per kilowatt-hour (kWh) of electricity.[94] This means a 500 MW gas plant operating at 90% capacity would consume 245 million gallons of water annually.

Solar, wind, wave and tidal energy facilities, on the other hand, consume far less water to produce power. For example, utility-scale wind farms consumed 0.003 gallons of water per kWh of electricity produced in 2014, or just 5% of the consumption rate of gas plants.[95] Solar photovoltaic plants consumed just 0.0018 gallons of water per kWh of electricity produced on average in 2014 – or just 3% of the rate of water consumption of a gas plant.[96]

The biggest single source of water use for utility-scale solar facilities – which isn't captured in the above statistics regarding water use per kWh of electricity – is during construction, when water is used to help prepare the ground for installation. One project proposed for construction in the California Desert, the Palen Solar Project, estimated a total use up to 570,000,000 gallons (equivalent to 864 Olympic swimming pools) of water during construction.[97] Rooftop solar uses almost no water, since it is only required for panel cleaning, not for cooling or installation.[98]

Rooftop solar can boost California's resilience to climate change impacts

Installing solar energy on homes, businesses, schools and farms can improve the resilience of California communities to climate-related disruptions to the electricity grid, especially when paired with energy storage. Rooftop solar can help provide power when centralized electricity production is not available because of emergencies or planned blackouts.

Climate change has led to interruptions in California's electricity supply. Failures in California's transmission system have sparked devastating wildfires in forests and scrubland left parched by climate change and mismanaged by federal and state agencies.[99] To avoid more fires, utilities have pre-emptively turned off power, creating huge planned blackouts.[100] In October 2019, for instance, 2.5 million Californians lost power for multiple days during an effort to prevent electrical equipment from sparking wildfires.[101] Additionally, unprecedented heat waves – an expected consequence of climate change – have caused electricity demand for cooling to exceed supply, triggering rolling blackouts.[102]

California would benefit from an electricity system that allowed more homes, schools and community centers to retain power for essential uses during emergencies. Installing solar energy now could help pave the way for a future in which that is possible.

If a rooftop solar system is connected to a battery storage system, the energy the solar panels generate can be used to power a home even when the rest of the grid loses power.[103] By pairing rooftop solar with a battery (or with a special inverter), homes and businesses can "island" themselves: they can separate from the electric grid to run on their own power. This can keep freezers and refrigerators running so that food doesn't spoil, operate pumps and maintain access to well water, and provide some access to cooling and lighting when the power grid goes down. Rooftop solar paired with a battery can provide power around the clock, if generation and storage are sufficiently large, while rooftop solar alone can provide power for immediate use during the day.

Islanding a building or a group of buildings with onsite solar and batteries creates what is known as a microgrid: subsections of the electric grid that can be isolated from each other and the larger grid in the case of a disruption and can retain power with local distributed generation and storage.[104] Microgrids help to maintain power for as many consumers as possible during power interruptions on the larger grid. Furthermore, after a blackout, microgrids can play the part of a battery in a combustion engine, helping larger generators come online to restore power to the rest of the grid more quickly.[105]

The value of rooftop solar and batteries has already been demonstrated in California. Borrego Springs, in San Diego County, is an isolated community with a single, vulnerable transmission line providing electricity.[106] A microgrid pilot project coordinated between the U.S. Department of Energy, San Diego Gas & Electric and the California Energy Commission installed distributed solar generation, storage and the technology needed to island the town.[107] The microgrid has provided power through planned and weather-related blackouts on the grid, and has even shown the capability to help with restarting the larger grid after a blackout.[108] Separately, batteries coupled with solar panels helped provide power to the California grid during the state's power shortage in August 2020, reducing the scale of blackouts.[109]

Finally, rooftop solar can reduce the risks to, and posed by, transmission infrastructure. Transmission infrastructure is vulnerable to overload and damage from high wind, storms and other natural events.[110] Damaged transmission infrastructure can spark fires, and overloaded infrastructure can cause blackouts.[111] Persistent underinvestment by utilities has exacerbated this problem, and wildfire mitigation is expected to drive utility-rate increases in the near future.[112] By reducing the need for new transmission infrastructure, rooftop solar helps to reduce the number of points of vulnerability and the number of lines that could spark fires, protecting Californians and their bank accounts.

Policy recommendations

California has established ambitious but necessary clean energy and climate goals. Meeting those goals and achieving the level of climate protection that they offer will require extensive and equitable growth of clean energy in the state. Solar energy on homes, businesses, schools, farms and other locations will help California achieve those goals on the timeline required, with a minimum of disruption to the state's natural lands, and in ways that will help California communities to better withstand the impacts of climate change.

To meet its climate and clean energy goals, California needs policies that support rooftop energy generation. Without distributed solar energy, the state risks its ability to achieve its climate and clean energy targets.

Ensure that compensation for rooftop solar recognizes the full value provided to the environment and the grid

Net energy metering (NEM) is one of the tools California uses to encourage installation of renewable energy on homes and businesses.[113] NEM allows the owners of distributed energy resources, such as rooftop solar panels, to be compensated for the electricity they provide to the power grid. Complementary policies help tenants benefit from rooftop solar, too. California NEM policy has helped spur the growth of residential and commercial rooftop solar installations.

California first instituted net metering in 1995 with Senate Bill 656, which required every electric utility in the state to develop a standard contract to compensate utility customers for power generated on-site and sent back to the utility.[114] California has modified and updated its NEM policy multiple times over the decades to ensure the growth of clean energy. As a result, NEM has played a critical role in helping grow solar energy production in the state.

California is now undertaking the next revision to its NEM policy. The revised policy should **provide sufficient support to allow rooftop solar to continue to grow**, as is needed for the state to reach its carbon reduction and clean energy goals.

- California's new policy should take into account the full benefits of rooftop solar, including the climate, land conservation and community resilience benefits laid out in this report, as well as the reduction in the need for new transmission and distribution lines. California should also recognize the long-term benefits of immediate installation of distributed solar by calculating the climate benefits delivered over the lifetime of the panels.
- California should **ensure equitable access to rooftop solar energy**, including for renters and in low-income communities, which will help the state maximize the amount of rooftop solar energy installed. Customers who qualify for the California Alternate Rates for Energy (CARE) program and

who install solar panels should receive compensation from the utility for excess power at non-CARE rates. Maintaining virtual NEM, which allows tenants to benefit financially from solar installed on multifamily buildings, will allow more landlords to install solar power. In addition, NEM credits should be transferred to incoming tenants instead of defaulting to the utility.

- Fees levied only on solar customers will discourage growth in solar energy and energy storage and are not compatible with meeting the state's clean energy goals.
- Utilities must honor commitments they made to customers who installed solar panels in past years regarding how much they would be paid for solar energy they supply to the grid. Retroactively changing those agreements would undermine consumer faith in the value of solar energy and would slow installation of additional capacity.
- As California revises its NEM policy, it should provide clear, long-term rules. Abrupt changes to NEM policy have the potential to interrupt the state's momentum on adding customer-sited solar and storage capacity.

Adopt other policies that are supportive of consumer-sited solar and storage

California should adopt other policies that support the continued and equitable growth of consumer-sited solar energy and battery storage.

- Cities and counties should **establish online automated permitting systems** for small onsite solar projects. The National Renewable Energy Lab has developed SolarAPP+, a free online permitting software that helps local governments process permits more easily. The state could support adoption of automated permitting by providing funds for technical backup for governments that implement the software.
- California should provide **support for the installation of solar energy on community buildings**, such as schools, libraries and community centers. Especially if coupled with battery storage, these sites can produce clean energy and improve local resilience.
- The state should adopt policies that **enable the creation of virtual power plants**. The California Independent System Operator and the CPUC can adopt a policy that would make it possible for utility customers to sell the energy stored in consumer-sited batteries to the broader grid. This would increase the ability of consumer-sited solar energy and battery systems to provide power to the grid at times of high demand.
- The state should require utilities to **allow customers to finance their solar energy and/or storage system through zero or low-interest loans that get repaid through their utility bill**. Coupled with adequate consumer protections, this would benefit lower-income customers who have less access to conventional lending streams.

Methodology

To calculate the amount of land that could be kept in its current use by installing rooftop solar rather than utility-scale solar, we began by calculating the average area per megawatt (MW) of utility-scale solar facilities in California. Solar facilities and their acreage were drawn from Janet Wilson, "Solar surges in the California desert. So why are environmentalists upset?," *Desert Sun*, 3 January 2020, archived at http://web.archive.org/web/20201021155421/https://www.desertsun.com/story/news/environment/2020/01/03/solar-surges-california-desert-environment-trump/2665799001/. The calculated average acreage per megawatt was 7.4 acres per MW of capacity. This estimate is comparable to modeling done by E3 for The Nature Conservancy, which put the land requirements for utility-scale solar in the U.S. Southwest at more than 7.7 acres per MW of capacity.[115]

We then calculated how much electricity a MW of utility-scale solar would produce, using a utility-scale solar capacity factor for California from Fred Mayes and Chris Namovicz, "Southwestern states have better solar resources and higher solar PV capacity factors," *U.S. Energy Information Administration*, 12 June 2019, archived at http://web.archive.org/web/20210320151745/https://www.eia.gov/todayinenergy/detail.php?id=39832.

Utility-scale solar facilities have a higher average capacity factor – meaning they produce more electricity per megawatt of capacity – than rooftop solar installations. We estimated how much more rooftop solar would need to be installed to produce an equivalent amount of electricity to that produced by one MW of utility-scale solar by multiplying the capacity of rooftop solar by its capacity factor, and then dividing by the capacity factor of utility-scale solar. California rooftop solar average capacity factor is the average of the Los Angeles and Daggett, CA, capacity factors listed in the "Constant Cost" scenario of: National Renewable Energy Laboratory, *Annual Technology Baseline: Electricity, Residential PV Systems*, accessed 26 May 2021, archived at https://web.archive.org/web/20210424163718/https://atb.nrel.gov/electricity/2019/index.html?t=sr.

Using this data, we calculated that 148,000 acres of land would be conserved by installing the rooftop solar capacity assumed in the SB 100 Joint Agency Report modeling rather than building utility-scale solar to generate an equal amount of electricity. We also calculated that installing a generic 1 GW of rooftop solar rather than utility-scale solar would conserve 5,200 acres of land.

Notes

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