Solar Homes

The Next Step for Clean Energy

ENVIRONMENT AMERICA RESEARCH & POLICY CENTER

FRONTIER GROUP

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Layout: Alec Meltzer/meltzerdesign.net
Cover photo: Rooftop solar panels atop homes in Austin, Texas. Credit: Roschetzky Photography via Shutterstock.

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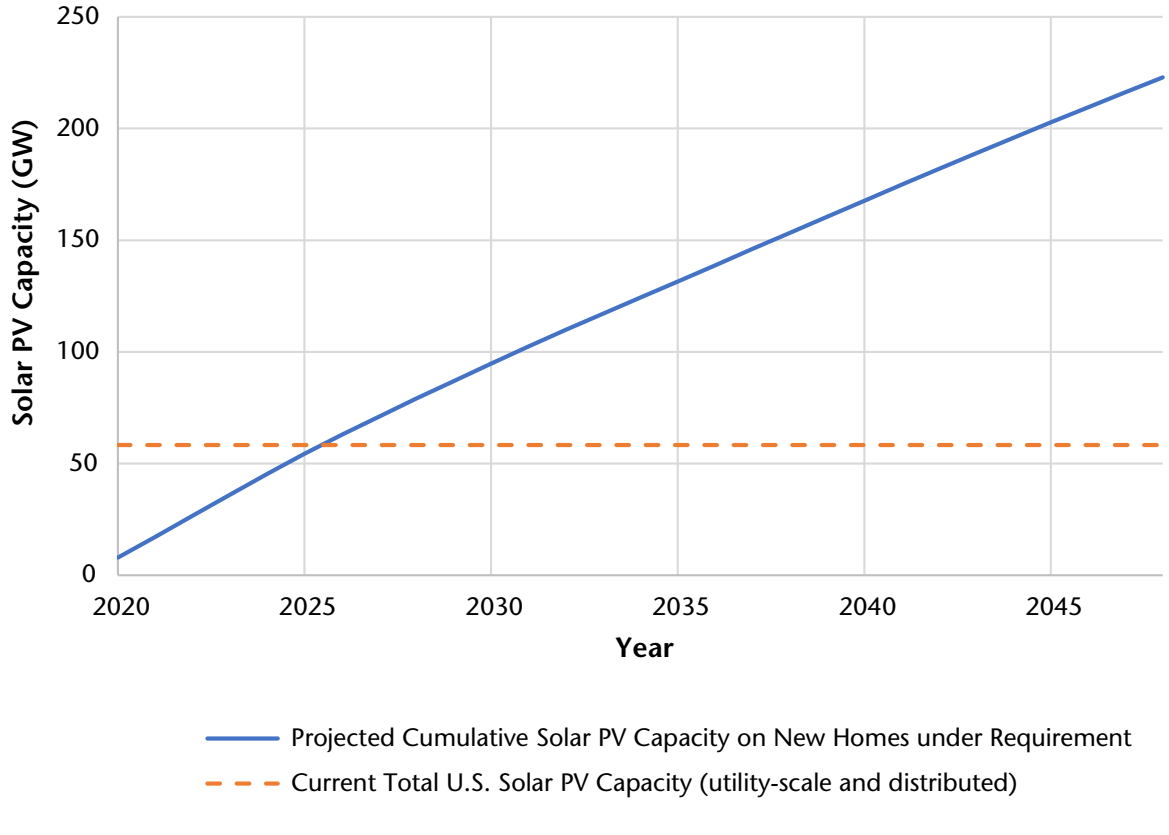
Executive Summary

America has a bold opportunity to speed the transition to a clean energy future by requiring solar power on new homes. Rooftop solar panels save homeowners money – even more so when they are installed during construction.[1] Including this common-sense technology on all new homes would help the nation to build an electric grid that's cleaner, more beneficial for consumers, and more resilient.

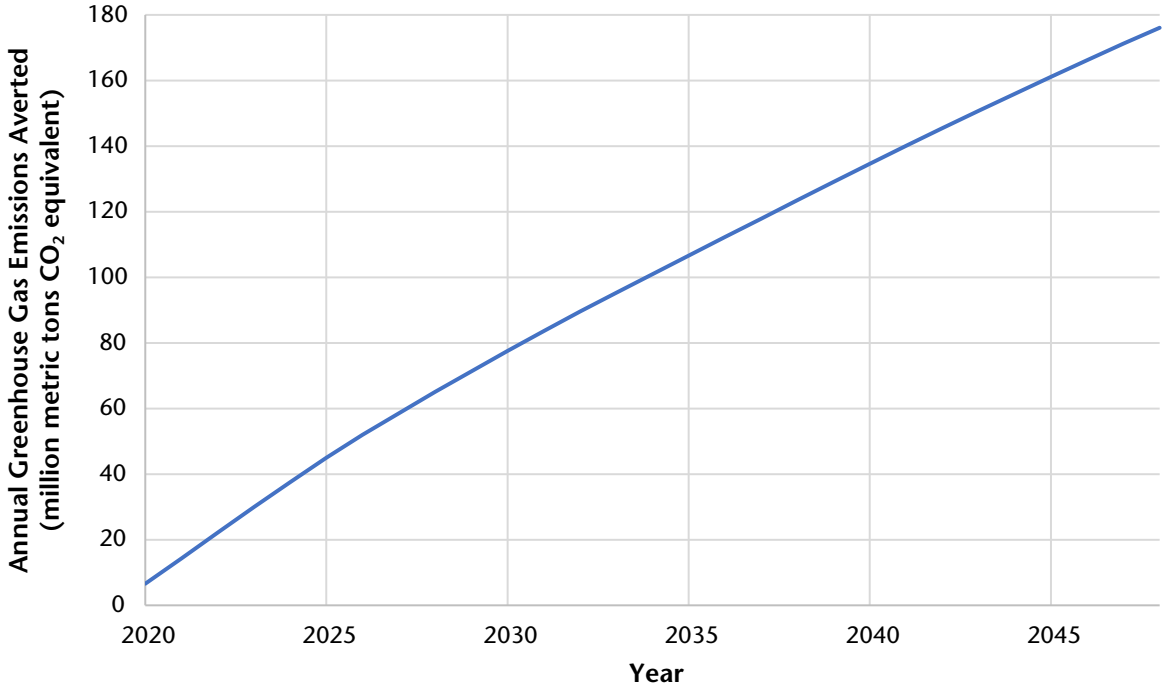
Installing solar panels on all new homes would accelerate the growth of solar energy capacity. **Installing solar panels on all new homes built from 2020 to 2026 would result in more solar energy capacity than the entire U.S. currently has installed. By 2045, installations on new homes would total 203 GW - 3.5 times as much solar capacity as the nation currently has installed**. (Details on sources and methods for estimates can be found in the Methodology).

Figure ES-1: Projected Cumulative Residential Solar Photovoltaic (PV) Capacity Added in U.S. under a Solar Homes Requirement.*



** See Methodology for sources and details on how projections were calculated.*

Figure ES-2: Projected Annual Greenhouse Gas Emissions Averted under a Solar Homes Requirement.*



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Adding solar energy to new homes would offset the use of fossil fuel-powered energy sources and cut 2017 carbon dioxide emissions from U.S. electricity generation by more than 9 percent annually by 2045. **A solar homes requirement would cut an estimated 161 million metric tons of CO_2 equivalent during 2045 – equivalent to taking more than 34 million of today's cars off of the road.**

A solar homes requirement would add the most capacity in the fastest growing states and help to reduce increasing demand on the electric grid in those states. Texas would add the most capacity to new homes with over 24 GW by 2045, followed by Florida, North Carolina, Georgia and Arizona.

A solar homes requirement would also significantly reduce states' carbon dioxide emissions. North Carolina, for example, could reduce annual CO_2 emissions from energy use by the equivalent of 9 percent of 2015 levels by 2045. By 2045, Nevada and Arizona could reduce annual CO_2 emissions from energy use by 8 percent of 2015 levels; Florida, South Carolina and Colorado by 7 percent; and Utah, Idaho and Georgia by 6 percent.

Requiring solar panels on new homes could transform the market and lower solar energy costs.

- Requiring solar panels on all new homes could lead to technological developments, market maturation and increased partnerships between home builders and solar companies.[2] A 2018 National Renewable Energy Laboratory (NREL) study found that these advancements could collectively **reduce the price of solar systems by 59 percent**.[3]

Installing solar panels during construction is a key part of a transition to low-carbon and zero-carbon homes. A solar homes requirement meshes

Table ES-1: The Top 10 States for New Residential Solar PV Capacity under a Solar Homes Requirement.*

State	Q2 2018 Total Solar PV Capacity (MW)[4]	Projected Added Residential Solar PV Capacity by 2045 under a Solar Homes Requirement (MW)	% Reduction in 2015 CO2 Emissions by 2045**
Texas	2,624	24,719	3.2%
Florida	1,943	24,423	7.3%
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Georgia	1,556	9,665	6.0%
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Tennessee	238	5,396	5.2%
California	22,777	5,200	0.8%

** See Appendix for full list of states. See Methodology for sources and details on how projections were calculated.*

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well with key energy policies such as strong building and appliance efficiency standards, electric vehicle policies, and policies to encourage home energy storage – helping to create a clean energy system.

- **Energy efficient design and appliances:** Increasing the energy efficiency of homes and appliances can significantly reduce electricity consumption – allowing solar power to meet a greater percentage of homes' energy needs.[5]
- **Electric homes and vehicles:** If homes adopt electric heating, hot water systems and vehicles, on-site solar panels can power them at least in part with clean, renewable energy.[6]
- **Battery storage:** Home battery systems can store excess solar power for use later when solar energy production is low. This saves homeowners money and also helps reduce both demand on and discharges to the grid, helping the grid operate more smoothly.[7]

Distributed solar energy reduces air pollution, improves public health, and makes the electric grid more resilient.

- **Switching to solar energy reduces air pollution, improving public health**. By offsetting the burning of coal and gas for electricity, solar panels improve air quality in our communities. From 2007 to 2015, wind and solar energy were estimated to prevent 3,000 to 12,700 premature deaths in the U.S. by improving air quality.[8]
- **Distributed solar energy makes the electric grid more resilient.** Distributed solar energy, when coupled with energy storage, can keep the power on during outages. This helps minimize impacts for those affected by disasters.[9]

Starting in 2020, the state of California will require new single-family homes, and multi-family homes up to three stories, to install solar photovoltaic (PV) systems.[10] Homes that cannot effectively accommodate solar panels due to shading from adjacent structures, such as buildings and trees, are exempt from the requirement.[11]

This requirement is part of the California Energy Commission's 2019 Building Energy Efficiency Standards, which also ramp up energy efficiency requirements for buildings. The new standards are expected to reduce greenhouse gas emissions from 2020 to 2023 equivalent to taking 115,000 cars off the road.[12] Under the new standards homeowners are expected to save $19,000 over 30 years.[13]

To take advantage of these benefits, state and local governments across the country should require all new homes to install solar PV systems. To support this policy and maximize its benefits, governments should also:

- **Set strong energy efficiency standards for homes.** Improving energy efficiency in homes is one of the most important steps to make a renewable energy system work.[14] The average single-family home in the U.S. would need over 9 kW of solar panels to meet its electricity usage versus the average home solar system size installed during 2017 of 7.4 kW. By eliminating energy waste through high-efficiency lighting and electric appliances, and by improving the energy-efficiency of attics, walls, windows and doors, rooftop solar panels can better meet homes' energy needs.
- **Accelerate home electrification and adoption of electric vehicles.** Transitioning home heating and hot water systems, and other appliances that currently run on gas and oil, to solar hot water or electricity can maximize the benefits of residential solar energy. The same is true of switching from gasoline-powered to electric vehicles, which are often recharged at home. All-electric homes can meet much or all of their energy needs with rooftop solar panels – benefiting homeowners financially and helping to transition to a 100 percent clean, renewable energy system.[15]
- **Support energy storage.** Residential batteries allow homeowners to store excess solar energy, powering homes when solar energy production is low and during peak electricity demand times. This saves homeowners money, which can make solar energy attractive even in a state that doesn't have pro-solar policies like net metering in place. Reducing demand during peak demand times can reduce electricity costs for all utility customers and reduce the need for "peaker" power generators that only operate during these times and tend to be the costliest and most polluting.[16]

Introduction

Imagine if every time you turned on your washing machine, air conditioner, lamp or stove, it were powered by sunlight. If every time you washed your clothes or cooked breakfast, you did so with the knowledge that it wouldn't trigger a coal-fired power plant to spew pollution into the air, or encourage fracking for natural gas, or contribute to the environmental and public health damage caused by our dependence on fossil fuels.

Now imagine it wasn't just you, but also your neighbors, and your entire town that had the experience of relying on electricity from renewable sources like the sun.

Today, the possibility of a 100 percent clean electricity system is closer than ever before – in part, due to the explosive growth of solar energy.

Over the last decade, the amount of solar power capacity in the United States has increased at an average annual rate of 54 percent.[17] Solar energy already saves homeowners money and the installed price of home solar power has dropped by more than 70 percent since 2010.[18] The U.S. currently has enough solar capacity installed to power 11 million American homes, a dramatic increase compared with just a few years ago.[19]

Rooftop solar panels are quickly becoming a common sight in our communities. Yet, every year in the United States, we build hundreds of thousands of buildings without solar panels that could accommodate them in ways that benefit their owners, the grid as a whole, and the environment.

Recognizing these benefits, the state of California has moved to require solar energy on new homes starting in 2020. The state's new solar homes requirement will introduce thousands of Californians to electricity that's cleaner, cheaper and more reliable. And these benefits will extend to all Californians through a healthier environment, more resilient electric grid, and reduced greenhouse gas emissions.

If such a policy were adopted in towns, cities and states across the country, the effect would be transformative - changing the way we utilize and think about energy and helping to transition our nation to a grid powered by 100 percent renewable energy. Together with improvements in energy efficiency, advances in energy storage systems, and the spread of electric appliances and cars, the widespread adoption of rooftop solar panels points to a brighter future – one in which the energy that powers our homes, transportation and lives runs on nothing but the sun.

Rooftop solar panels atop homes in Boulder, CO. Credit: Dennis Schroeder via National Renewable Energy Laboratory, CC BY-NC-ND 2.0.

Residential Solar Energy Benefits Public Health, the Environment and Consumers

Residential solar energy benefits everyone, not just homeowners with solar panels on their roofs. Replacing fossil fuel-burning energy sources with solar energy helps to reduce pollution, improve public health, and cut dangerous greenhouse gas emissions. Additionally, distributed solar photovoltaic (PV) energy can lower rates for all electric utility customers and can help make the electric grid operate more smoothly and be more resilient to disasters, especially when paired with energy storage.

Solar Energy Reduces Carbon Pollution

In order to avoid the worst impacts of climate change, the world needs to keep global temperature rise below 2 degrees Celsius above pre-industrial levels, meaning that the U.S. must reduce climate pollution by at least 80 percent relative to 1990 levels by 2050.[20] Many scientists believe that preventing the most dangerous impacts of global warming will actually require keeping temperature rise below 1.5 degrees Celsius.[21] This would mean that the U.S. will have to become a net-zero emitter of greenhouse gases by 2050.[22] The electricity generation sector, which is powered primarily by fossil fuels, is the nation's second largest emitter of greenhouse gases, pumping out about 28 percent of U.S. emissions.[23]

Fortunately, America is on the way to a new energy future. Renewable sources of energy now provide nearly one-fifth of the electricity consumed in the United States, double their share only 10 years ago.[24] This trend is expected to continue as renewable energy technologies develop and their prices continue to drop. In fact, solar energy is already cheaper than coal and gas in some cases.[25] This is good news for our climate because the lifecycle greenhouse gas emissions from solar energy are 96 percent lower than electricity from coal-fired power plants and 91 percent less than electricity from gas-fired power plants.[26]

Solar energy will be a key player in the transition to a clean energy system. There are already over 58 gigawatts (GW) of solar energy capacity installed in the United States, producing enough energy to power 11 million homes and offset more than 74 million metric tons of CO_2 annually – the equivalent of taking 15.8 million cars off the road.[27] But, this is only the beginning of solar energy's potential. In the last decade, the amount of solar energy installed in the United States has grown by an average of 59 percent per year, and growth is forecasted to continue.[28]

Switching to Solar Energy Reduces Air Pollution, Improving Public Health

Replacing coal- and gas-fired power plants with solar energy not only reduces greenhouse gas emissions, but also chemical and particle emissions that harm our health. Coal-fired electricity generation emits thousands of tons of small particles ($PM_{2.5}$), smog-causing nitrous oxides (NO_x), and volatile organic compounds (VOCs) into the air each year.[29]

Air pollution from power plants is estimated to cause between 7,500 and 52,000 deaths in the U.S. annually.[30] By offsetting electricity generated from fossil fuels, solar energy helps reduce air pollution. From 2007 to 2015, wind and solar energy were estimated to prevent 3,000 to 12,700 premature deaths in the U.S. by preventing air pollution.[31]

Air pollution aggravates asthma, chronic bronchitis and other respiratory diseases.[32] Small particle pollution has even been linked to heart attack and stroke.[33] Several studies have demonstrated a clear correlation between higher pollution levels and emergency room visits, part of the reason why coal production has been estimated to lead to health damages totaling $74.6 billion a year.[34]

Requiring solar energy on new homes would offset electricity generated by fossil fuels and reduce this dangerous pollution.

Residential Solar Energy Saves Consumers Money

Rooftop solar panels save homeowners money. In states with pro-solar policies, homeowners with solar energy can save between $10,000 to $30,000 over a 20-year period.[35] Installing solar panels during construction lowers solar energy's cost and leads to additional savings.[36]

Installing solar PV panels on a home in the Dover Air Force Base in Delaware. Credit: *Roland Balik, U.S. Air Force.*

Beyond simply saving homeowners money, solar energy offers another financial benefit in the form of price stability. By installing solar panels, particularly when paired with batteries, consumers are protecting themselves from the unpredictable swings and spikes in utility electricity costs.[37] On average, the price of electricity bought from U.S. utilities rises by 2.2 percent each year.[38] Purchasing solar energy gives a homeowner stability in their energy bill – an important benefit for many consumers.

Residential solar energy can save all electric utility customers money – even those without solar panels on their rooftops – if policies are in place to maximize solar energy's benefits.[39] Solar panels help reduce demand on the grid, which can lower electricity rates for all customers. Reducing peak demand can also prevent the need for "peaker" power plants, which are only turned on when demand exceeds the capacity of the electric grid's main energy generators. These peaker plants tend to be the oldest, most polluting and most expensive to operate, so alleviating their use can lead to significant cost and emissions savings.[40]

By decreasing demand for electricity from the grid, residential solar energy can also reduce the need for new power plants, transmission lines and other infrastructure, leading to further savings. Additionally, since solar power is produced on-site, it reduces the amount of energy that is lost as heat during the transmission of electricity from power plants to homes. These energy savings can be significant, as 5 percent of all energy distributed in the U.S. is lost during transmission.[41]

Distributed Solar Energy Makes the Electric Grid More Resilient

When paired with energy storage systems like batteries, solar energy can reduce the impact of power outages – particularly when tied into microgrids. A couple of downed power lines can leave thousands of people without power and cause large human and economic consequences. After Hurricane Maria, for instance, the people of Puerto Rico lost more than 3.4 billion customer hours of electricity, which was central to the estimated $47.5 billion of forfeited economic revenue that resulted from the storm.[42]

Homes and buildings with enough solar energy and energy storage capacity installed may be able to keep their own lights on during and immediately after outages and even provide power to their neighbors if they are tied together through a "microgrid," which can operate independently of the larger electric grid.[43] While having a resilient power source in a blackout can be beneficial for personal and economic reasons, it can be life-saving for hospitals, police and fire stations.[44]

Requiring Solar Energy on New Homes Would Create a Wave of Clean, Renewable Energy

Requiring solar panels during new home construction just makes sense, and will unleash a surge of solar energy deployment. Installing solar energy when a home is first built reduces solar energy's costs and creates the potential for new business and technological innovations.[45] Moreover, knowing that solar panels will be installed in a home from the start allows the home to be designed to maximize solar energy production and use.[46]

California has already committed to achieving these benefits through its solar homes requirement. The Solar Energy Industries Association (SEIA) conservatively estimates that this will add an additional 800 MW of solar PV capacity in California from 2020 to 2023 – 200 MW per year on average.[47] This is more than a 23 percent increase from the 858 MW of residential solar energy deployed in 2017, mostly on existing homes.[48]

A Solar Homes Requirement Would Transform the Market and Lower Costs

Requiring solar energy on new homes would prompt builders to develop new ways to incorporate solar panels into their home building process. This would lead to benefits such as reduced costs, streamlined processes and technological innovations that would be felt throughout the solar energy market – not just by new homeowners.

If solar panels were required on all new homes, there would likely be increased integration between the home construction and solar installation industries, which could help drive down the "soft costs" associated with installing solar panels. Soft costs are all expenses other than the panels themselves, including marketing, permitting, inspection and installation. Currently, soft costs make up nearly two-thirds of rooftop solar energy's price tag, so reducing these costs would have a large impact on reducing solar energy's overall cost.[49]

Closer partnerships between solar energy companies and homebuilders would help to lessen design costs, for example by encouraging the creation of standardized models of home energy systems. Solar installers could also take advantage of the opportunity to install panels on multiple homes at the same time to reduce labor, permitting and even supply chain costs.[50]

Marketing is another soft cost that could be dramatically reduced through solar and home building partnerships. Right now, identifying and acquiring customers is one of the largest expenses for many rooftop solar installers, but partnerships with home builders could nearly eliminate this cost. Already there are several solar energy companies pioneering this method, leading to decreased costs and a more seamless experience for homeowners.[51]

A 2018 National Renewable Energy Laboratory (NREL) study found that installing solar panels during new home construction could lead to business integration, technological development, soft-cost-reduction and market maturation, where even small solar installers could purchase solar energy system components at wholesale prices. These developments could collectively reduce the price of solar systems by 59 percent.[52] And a Lawrence Berkeley National Laboratory study found that installing solar panels on new homes versus existing homes already yields significant cost savings in California.[53]

Requiring Solar Energy Supports the Transition to Low-Carbon and Zero-Carbon Homes

Including solar panels in home construction plans can help maximize their energy production and use – moving us closer to the day when all new homes produce as much energy as they consume.

Accounting for rooftop solar panels in home design can maximize how much energy they produce.[54] The angle of the roof, the direction it faces and the amount it is shaded can all be optimized for solar energy production. For instance, designing a segment of the roof with unshaded southern exposure can increase the production of solar panels by up to 17 percent.[55] Placing solar panels on multiple planes and directions can also increase production by maximizing exposure during the different times of day.[56]

A home with an electric heat pump, which efficiently provides both heating and cooling. Electric appliances such as this, as well as energy efficient design, home batteries and electric vehicles, allow solar panels to meet more of homes' energy needs. Credit: Lani Hudelson via Flickr, CC BY-ND 2.0.

By pairing solar energy with highly efficient construction, rooftop solar panels can meet a higher percentage of home energy needs.[57] As with solar energy, energy efficiency measures are most easily adopted during home planning and construction. Passive solar homes, for example, are designed to retain the sun's heat during the winter and limit sun exposure in the summer. Attics, walls, windows and doors that minimize the amount of heat that is transferred in and out of homes are critical to reduce energy loss and minimize the energy needed to heat and cool homes. Energy-efficient appliances and lighting can also reduce home energy usage. For example, solar water heating panels can also be installed on the roof to offset more than half of the water heating needs of the home.[58] All these energy-saving features can maximize the amount of energy supplied by solar energy and are most easily and cost-effectively adopted during new home construction.

The benefits of solar energy are magnified when builders and homeowners incorporate electric appliances during home construction. On average, heating and hot water systems consume 62 percent of the energy used in U.S. homes.[59] The majority of heating and hot water systems burn fossil fuels directly.[60] Choosing efficient electric home appliances over models powered by gas or oil can allow rooftop solar panels to meet much more of a home's energy needs, maximizing the benefits of the investment.

Home batteries also enable solar panels to meet more of homes' energy needs by storing excess solar energy for later use when production is low or electricity costs are high, saving homeowners money. These systems can also help the electric grid operate more smoothly. In addition, home batteries can help keep the lights on during power outages and, if integrated into microgrids, help make the electric grid more resilient. As with other clean energy equipment, energy storage systems are easier to install during construction.[61]

Knowing that solar panels will be installed also enables builders to ensure that homes' main circuit breakers have the right ratings to accommodate solar energy systems, and that the installed conduits from the inverters to the panels are placed so as to reduce losses from energy transmission.[62]

California's Solar Homes Requirement Leads the Way

As part of its 2019 Building Energy Efficiency Standards, California will require new single-family homes, and multi-family homes of up to three stories, to install solar PV panels starting in 2020.[63] These standards will help increase renewable energy production in California, maximize residential solar energy's benefits to the electric grid, cut greenhouse gas emissions, and save money.

Under the solar PV requirement, the solar panels must have enough capacity to generate at least the amount of electricity used by the home over the course of a year.[64] This will be calculated based on the square footage of the home, the number of dwelling units, and the climate zone.[65] The average required size across California's 16 climate zones and standard home sizes is expected to be 3.38 kW.[66]

Home builders can offset some or all of the required solar PV capacity by providing access to community solar systems or by adding additional energy efficiency features in the home.[67] Homes with less than 80 contiguous square feet of unshaded roof area due to shading from other permanent structures, such as adjacent buildings and trees, are exempt from the requirement.[68]

This requirement is expected to increase the number of new homes in California built with solar panels from about 15,000 up to around 80,000 each year.[69] The Solar Energy Industries Association (SEIA) conservatively estimates that this will add an additional 800 MW of solar PV capacity in California from 2020 to 2023 – 200 MW per year on average.[70] This is over a 23 percent increase

from the 858 MW of residential solar energy deployed in 2017, which was mostly on existing homes.[71]

This requirement is part of the state's 2019 Building Energy Efficiency Standards, which are updated every three years and aim to reduce building energy use, improve indoor and outdoor environmental quality, and ensure that builders use the most energy-efficient building practices while being cost-effective for homeowners over a 30-year period.[72]

California's robust energy efficiency requirements make it easier to power homes with solar energy. California's 2019 Building Energy Efficiency Standards update the thermal envelope standards that limit how much heat is transferred in and out of buildings.[73] This will reduce home energy consumption and make it easier to power homes with solar energy. The 2019 standards also update ventilation requirements for residential and nonresidential buildings to reduce indoor air pollution, and efficient lighting requirements for nonresidential buildings.[74]

The solar energy and efficiency requirements of California's 2019 standards are projected to cut household energy use by 50 percent. From 2020 to 2023, the standards are expected to cut greenhouse gas emissions equivalent to taking 115,000 cars off the road.[75] This will help California meet its goal of reducing greenhouse gas emissions to 40 percent below 1990 levels and obtaining 60 percent of its electricity from renewable energy sources by 2030 – and 100 percent from clean sources by 2045.[76]

The new building efficiency standards are also projected to save homeowners money. The standards are expected to collectively add about $9,500 to the cost of constructing a home, but save homeowners an average of $19,000 in energy and maintenance costs over 30 years.[77] Overall, the policy has been projected to put $1.7 billion back in the pockets of Californians by 2050.[78]

The standards were also designed to maximize benefits to the electric grid.[79] The standards encourage homes to install "appropriately sized" solar energy systems that meet, but do not greatly exceed their energy needs, reducing the amount of excess solar energy discharged to the grid. The standards also encourage the adoption of residential energy storage systems such as batteries by allowing them to count toward the energy efficiency requirements.[80] These systems can store excess solar energy on-site for later use, helping to support the stability of the electric grid.

A Solar Homes Requirement Would Lead to a Dramatic Jump in Solar Energy Capacity

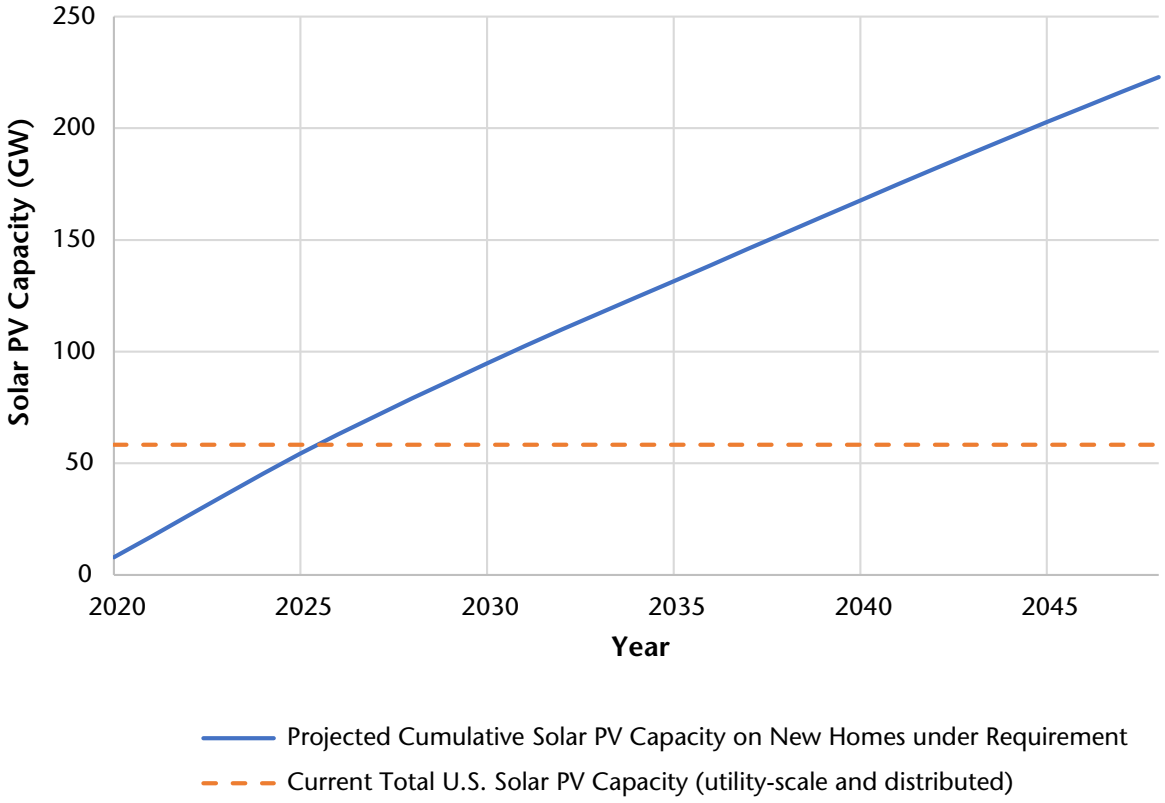
Residential solar energy will be a key part of our nation's transition to a more sustainable energy system. Requiring solar PV systems on new homes would rapidly increase solar energy capacity across the country – reducing harmful greenhouse gas emissions, limiting air pollution and making the electric grid more effective and resilient.

Requiring solar PV systems on new homes would greatly increase U.S. solar energy capacity. Installing solar panels on all new homes built from 2020 to 2026 would result in more solar power capacity than the entire U.S. currently has installed. By 2045, installations on new homes would total 203 GW - 3.5 times as much solar energy capacity as the nation currently has installed. (Details on sources and methods for estimates can be found in the Methodology.)

A solar homes requirement would add the most capacity in the fastest growing states and help to reduce increasing demand on the electric grid in those states. Texas would add the most capacity to new homes with over 24 GW by 2045, followed by Florida, North Carolina, Georgia and Arizona.

A solar homes requirement would help reduce U.S. greenhouse gas emissions – which account for over 14 percent of the global total – by reducing electricity generated by fossil fuel-burning sources.[81] By 2045, a solar homes requirement could cut over 9 percent of 2017 U.S. CO_2 emissions from the electric-

Figure 1: Projected Cumulative Residential Solar Photovoltaic (PV) Capacity Added in U.S. under a Solar Homes Requirement.*



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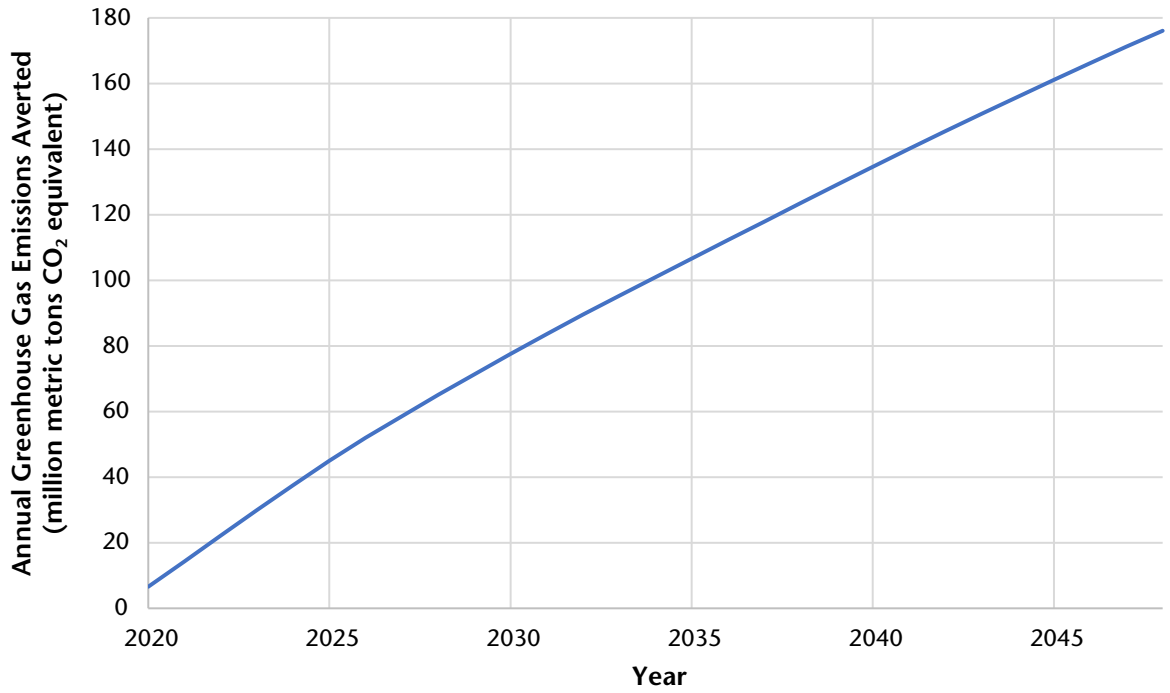
ity-generation sector annually. In total, such a policy could cut 161 million metric tons of CO_2 equivalent during 2045 – equivalent to taking over 34 million of today's cars off of the road.

A solar homes requirement would also significantly reduce states' carbon dioxide emissions. North Carolina, for example, could reduce annual CO_2 emissions from energy use by the equivalent of 9 percent of 2015 levels by 2045. By 2045, Nevada and Arizona could reduce annual CO_2 emissions from energy use by 8 percent of 2015 levels; Florida, South Carolina and Colorado by 7 percent; and Utah, Idaho and Georgia by 6 percent.

Requiring solar energy on new homes is just one of many options to expand solar power in the U.S. There are plenty of untapped existing home and business roofs and spaces for solar power installations. The U.S. has the technical potential to install over 1,000 GW of solar power capacity on rooftops alone versus the 58 GW currently installed across the country on both roofs and in large-scale utility installations.[82]

A solar homes requirement would have benefits beyond expanding solar capacity and reducing emissions, too. The cost reductions and technical and business developments that would arise from such a requirement would be felt throughout the industry. If a solar homes requirement also encouraged home energy storage and electrification, as California's standards do, those sectors would benefit as well.

Figure 2: Projected Annual Greenhouse Gas Emissions Averted under a Solar Homes Requirement.*



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Policy Recommendations

Requiring solar panels on new homes could add 3.5 times as much solar PV capacity as is currently installed in the U.S. by 2045, and cut emissions equivalent to taking 34 million of today's cars off the road that year. Not only would this help tackle the mounting crisis of climate change, but it would reduce air pollution, improve public health, reduce costs for all, and create a more smoothly operating and resilient electric grid.

State and local governments should:

- **Require solar energy adoption during new home construction.** Requiring solar energy on new homes would create a surge of clean, renewable energy deployment and transform the market. California is the first state to adopt a solar homes requirement, but several cities and towns across the country, including South Miami, FL, and Lancaster, CA, have previously adopted such policies.[84] Governments could also allow solar PV panels to count toward home energy efficiency requirements.

  Those jurisdictions that are not ready to require solar panels in new construction can at least mandate that every new home and building be "solar ready," enabling a solar energy system to be easily installed in the future.[85]

- **Set goals for solar energy deployment**. Governments should set overall goals for new solar energy generation as part of strong renewable energy requirements for their jurisdictions.

- **Set strong energy efficiency standards for homes.** Single-family homes in some U.S. states would need up to 15 kW of solar energy capacity on average to meet current electricity consumption needs.[86] Solar systems of that size are not practical to install on many roofs. Cutting down residential energy consumption is therefore crucial to enable rooftop solar panels to meet home energy needs and strong energy efficiency requirements are one of the most effective ways to do this. States should adopt the most recent International Energy Conservation Code for buildings.[87]

  The United States has already greatly reduced energy consumption due to efficiency improvements. In 2014, efficiency improvements saved 58 quadrillion Btu of energy, almost 60 percent of total energy consumption that year.[88] Further energy efficiency improvements could reduce electricity demand by another 40 to 60 percent by 2050.[89]

  Governments should also set ambitious energy efficiency standards for appliances.[90]

- **Encourage electrification of homes and vehicles.** Electrification of home heating and hot water systems, as well as appliances that run on gas and oil, can maximize the benefits of residential solar energy. The same is true of switching from gasoline-powered to electric vehicles, which are often recharged at home.

  All-electric homes can meet much of their energy needs with rooftop solar panels. This benefits homeowners financially, reduces emissions that harm public health and the climate, and reduces both demand on and discharges to the electric grid, helping it operate more smoothly.[91]

Governments and utilities should encourage the adoption of electric home heating systems and appliances by offering rebates and tax incentives for builders and consumers.[92] Governments should also make sure that building codes and electric rate designs are friendly to electric home systems – see NREL's report "Electrification of Buildings and Industry in the United States" for specific policy approaches.[93]

- **Encourage the adoption of home energy storage systems.** Home energy storage systems, such as batteries, allow homeowners to store excess power from their solar panels onsite instead of discharging it to the electric grid. Home batteries can also power homes when solar production is low, thus reducing demand on the grid. This is particularly helpful when demand on the electric grid is highest.[94] Home batteries also help solar energy save homeowners money, which can make solar energy more attractive in states without pro-solar policies such as net metering.

  Governments should consider policies such as "time-of-use" pricing, which offers customers lower prices when demand is lowest to reduce demand at peak times when rates are highest – regulators should reference "Guidance for Utilities Commissions on Time of Use Rates" for best practices.[95]

- **Ensure pro-solar electricity policies.** Governments should ensure that electricity rates and other components of electric bills, such as fixed charges and utility charges, are fair for all customers, so that both those with and those without rooftop solar panels can share in the financial benefits of expanding distributed solar energy. The Regulatory Assistance Project has helpful tools for decision makers to set fair regulations.[96]

- **Promote solar PV adoption and energy efficiency improvements in existing homes.** Solar PV adoption and energy efficiency improvements are a great investment for existing homes as well – providing the same benefits to consumers, public health, the environment and the electric grid. Governments should also encourage solar energy adoption and energy efficiency improvements in existing homes.

- **Incorporate appropriate exemptions and alternatives**. There will be some homes that will not be able to effectively incorporate rooftop solar energy, such as those with too much shading from adjacent trees or buildings. Governments should include exceptions for such homes.

  Governments should also allow builders to offset some or all of the solar PV capacity requirement by giving homeowners access to community solar systems, and ensure that the bill savings to the homeowner from the community solar option would be comparable to the savings from a home system.

Rooftop solar panels at the Dover Family Housing Community. Credit: Roland Balik via United States Air Force, CC BY 1.0.

Methodology

California's 2019 building efficiency standards will require all new multi-family residential buildings of three stories or less and all single-family homes to be built with solar PV systems installed starting in 2020.[97] The solar PV systems must be sized to meet each home's projected electricity consumption, which will be calculated based of the number on units in the building, its square footage, and the climate zone where it is built. This is because larger homes consume more energy than smaller homes, and homes in different regions of California consume more or less energy. For example, homes in the southern interior of California tend to consume more energy because they have higher air conditioning needs. Homes with less than 80 contiguous square feet of unshaded roof area due to shading from other permanent structures, such as adjacent buildings and trees, are exempt from the requirement.[98]

For this report, we calculate the solar energy capacity and greenhouse gas emission reductions that would result from 2020 to 2045 if a similar policy were adopted in each state; Washington, D.C.; and the United States as a whole. Comparable data to calculate the average solar capacity factor in Alaska and Hawaii were unavailable, so those states are excluded from the analysis of greenhouse gas emissions reduction.

For this analysis, we first estimate the number of new homes that will be built and will fall under this requirement. Projections for housing starts, or the number of new homes that undergo construction, come from Moody's Analytics for both single-family homes and units in multi-family homes.[99] We assume that all housing units are started and completed in the same year. We assume that 44 percent of the multi-family housing starts are in buildings of three stories or less. This assumption is based on the U.S. Census Bureau finding that 200,000 out of 358,000 – or 56 percent – of multi-family units completed in 2017 were in buildings with four or more floors, thus 44 percent were in buildings of three floors or fewer.[100] We also assume that 83 percent of all housing starts will be suitable for solar panels based on the National Renewable Energy Laboratory's (NREL) finding that approximately 83 percent of small building rooftops in the U.S. are suitable for solar energy.[101]

California's requirement dictates that solar PV systems must be sized to meet homes' projected electricity needs.[102] Because California has a mild climate and strong energy efficiency standards, its homes consume less energy than the national average. We calculate that single-family homes in the U.S. would require over 9 kW solar PV systems on average to meet current electricity consumption. This was based on the Energy Information Administration's (EIA) 2015 Residential Energy Consumption Survey and NREL's assessment of the amount of solar energy that can be produced by solar panels in each state.[103] Homes in some states would need up to 15 kW of solar PV capacity on average to meet their electricity needs.

For the sake of conservatism, and accounting for the current status of technology, we assume that single-family homes would be required to install 7.4 kW solar systems. In 2017, 7.4 kW was the average solar PV system size installed on single-family homes in the U.S. This is based on the Solar Energy Industries Association's (SEIA) finding that approximately 300,000 residential solar PV systems were installed in the U.S. during 2017 with a combined capacity of 2,227 MW.[104] Only single-family homes are included in SEIA's residential category.[105]

Because California has already adopted a solar homes requirement, we use SEIA's estimate based on the specifics of that requirement for California. SEIA estimates that an additional 800 MW of solar PV capacity will be added in California from 2020 to 2023 under the requirement, or 200 MW per year on average.[106] This figure does not include the solar energy that would have been installed on new homes if the policy were not enacted and is therefore, comparatively lower than our estimates for other states. We used the same methodology used for other states when including California in national projections.

For multi-family homes of three stories or less, we assume a required solar PV capacity of 4.1 kW per housing unit. This is based on the calculation that multi-family housing units in buildings of two to four units consume 55 percent as much electricity as single-family homes in the U.S. on average, based on EIA 2015 Residential Energy Consumption Survey data.[107] We use apartments in building of two to four units (TYPEHUQ = 4) as a proxy for multi-family homes of three stories or less. And we use single-family detached house (TYPEHUQ = 2) and single-family attached house (TYPEHUQ = 3) for single-family homes. We calculated the weighted average annual electricity use of both single-family and multi-family homes using total site electricity usage (kWh) and final sample weight (NWEIGHT), or the number of homes represented by each survey response. Based on this analysis, U.S. single-family homes used 12,252 kWh of electricity during 2015 on average and units in multi-family homes of 2-4 stories used 6,727 kWh – or 55 percent as much.

The solar capacity that would be added if all new, suitable homes install solar PV systems is calculated by multiplying the projected number of suitable housing starts by the assumed required panel sizes.

The solar energy that would be produced by this added capacity is calculated by multiplying the cumulative added capacity by the average capacity factor for each state. The capacity factor is calculated based on data listed in Table 3 of the NREL report *Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment*.[108] The installed solar capacity potential of each state is converted from GW to kW and the annual generation potential of each state is converted from TWh per year to kWh per year. The annual generation potential of each state is then divided by 8,760 (the number of hours in a year) and its installed capacity potential to arrive at the capacity factor.

The greenhouse gas emissions that would be averted by producing that amount of solar energy were calculated based on the non-baseload carbon intensity of the electric grid in each state, per NREL methodology for calculating solar energy greenhouse gas offsets. This data is based on the Environmental Protection Agency's (EPA) Emissions & Generation Resource Integrated Database (eGRID).[109] To calculate CO_2 equivalent, CO_2 emissions are added to the CO_2 equivalent of CH_4 and N_2O emissions. CO_2 equivalent emissions are calculated by multiplying CH_4 and N_2O emissions by the 100-year global warming potentials used in the fifth International Panel on Climate Change (IPCC) Assessment – 34 times for CH_4 and 298 times for N_2O.[110] eGrid data were unavailable for Washington, D.C., so we estimate the carbon intensity of D.C.'s grid as the overall carbon intensity of the PJM electric region, which D.C. falls within. We assume that the carbon intensity of the electric grid in all states will decrease by 0.2 percent each year per an NREL methodology.[111]

Comparisons to car emissions are based on the EPA Greenhouse Gas Equivalencies Calculator estimate that passenger vehicles – all two-axle, four-tire vehicles – emit 4.67 metric tons of CO_2 equivalent per year.[112] Comparisons to current U.S. GHG emissions are based on the EPA finding that the U.S. emitted 6.87 billion metric tons of CO_2 equivalent in 2014 and the EIA finding that the U.S. electric power sector emitted 1.744 billion metric tons of CO_2 in 2017.[113] Total U.S. solar PV capacity as of the second quarter of 2018 is 58.3 GW.[114] Current state solar capacities are based on SEIA 2018 Quarter 2 data.[115] States' current energy-related CO_2 emissions come from the Energy Information Administration's 2015 data.[116]

Appendix

States' current solar PV capacities, and projected solar PV capacities and reductions in CO_2 emissions by 2045 under a solar homes requirement. See Methodology for sources and details on how projections were calculated.

State	Q2 2018 Total Solar PV Capacity (MW)	Projected Added Residential Solar PV Capacity by 2045 under a Solar Homes Requirement (MW)	% Reduction in Energy Sector CO2 Emissions by 2045*
Alabama	251	2,558	1.5%
Alaska	2	248	N/A
Arizona	3,613	7,601	8.1%
Arkansas	141	1,339	1.8%
California	22,777	5,200	0.8%
Colorado	1,055	5,904	6.9%
Connecticut	498	776	1.1%
Delaware	121	898	3.6%
District of Columbia	53	174	3.0%
Florida	1,943	24,423	7.3%
Georgia	1,556	9,665	6.0%
Hawaii	849	625	N/A
Idaho	414	2,402	6.1%
Illinois	98	3,558	1.6%
Indiana	317	3,706	2.0%
Iowa	71	1,817	2.3%
Kansas	16	1,597	3.2%
Kentucky	41	2,213	1.7%
Louisiana	92	2,994	0.9%
Maine	42	598	1.2%
Maryland	967	2,577	4.3%
Massachusetts	2,226	2,356	1.9%
Michigan	118	4,187	2.3%
Minnesota	901	3,683	3.0%

State	Q2 2018 Total Solar PV Capacity (MW)	Projected Added Residential Solar PV Capacity by 2045 under a Solar Homes Requirement (MW)	% Reduction in Energy Sector CO2 Emissions by 2045*
Mississippi	228	1,444	1.3%
Missouri	168	2,736	2.3%
Montana	54	554	2.0%
Nebraska	21	1,338	3.1%
Nevada	2,658	4,111	8.4%
New Hampshire	76	647	2.0%
New Jersey	2,526	2,516	1.2%
New Mexico	753	1,179	2.9%
New York	1,463	3,555	1.2%
North Carolina	4,491	13,160	9.0%
North Dakota	0	437	0.8%
Ohio	182	4,633	2.1%
Oklahoma	48	2,076	1.9%
Oregon	477	2,797	3.9%
Pennsylvania	386	4,847	1.7%
Rhode Island	65	255	1.0%
South Carolina	591	6,113	7.2%
South Dakota	1	736	4.4%
Tennessee	238	5,396	5.2%
Texas	2,624	24,719	3.2%
Utah	1,627	4,094	6.4%
Vermont	227	285	0.9%
Virginia	635	4,996	3.0%
Washington	133	5,959	4.9%
West Virginia	7	545	0.6%
Wisconsin	56	3,030	2.7%
Wyoming	2	351	0.8%

** Excludes net-emissions from agriculture, land use and forestry.*

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