Solar on Superstores

Big roofs, big potential for renewable energy

ENVIRONMENT NEVADA RESEARCH & POLICY CENTER

FRONTIER GROUP

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Cover photo: Solar panels on the roof of the Baltimore, MD, IKEA. Photo credit: IKEA

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Executive summary

Solar electricity generation capacity has increased about 40-fold between 2010 and 2021, making solar energy the fastest growing form of electricity generation in the U.S.[1] That growth is due to solar energy's low and rapidly dropping price, the immensity of America's solar resources, and public policies that make solar power a viable and economically attractive option for individuals and businesses.[2]

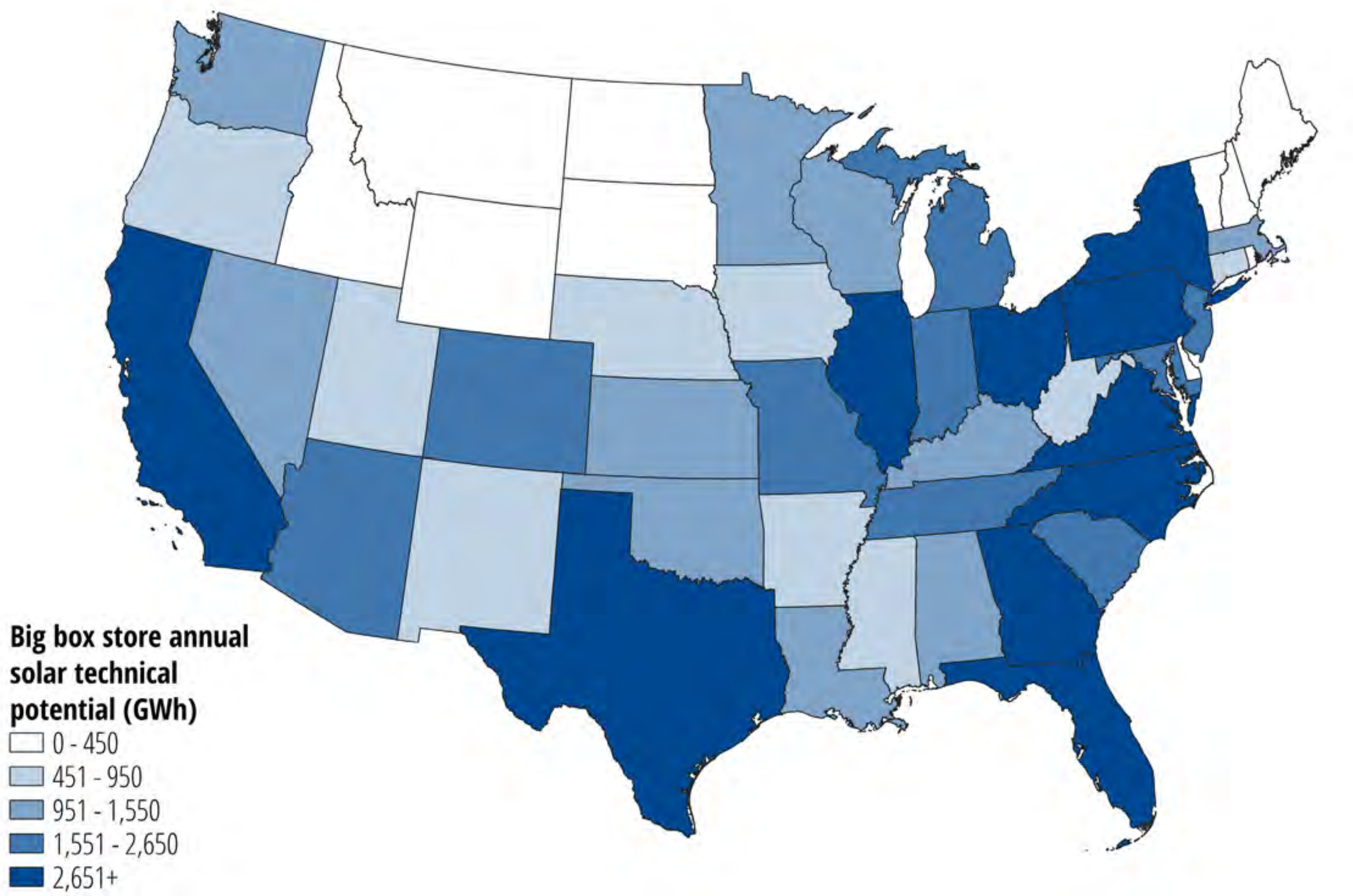

Figure ES-1. Big box store solar PV technical generation potential, by state

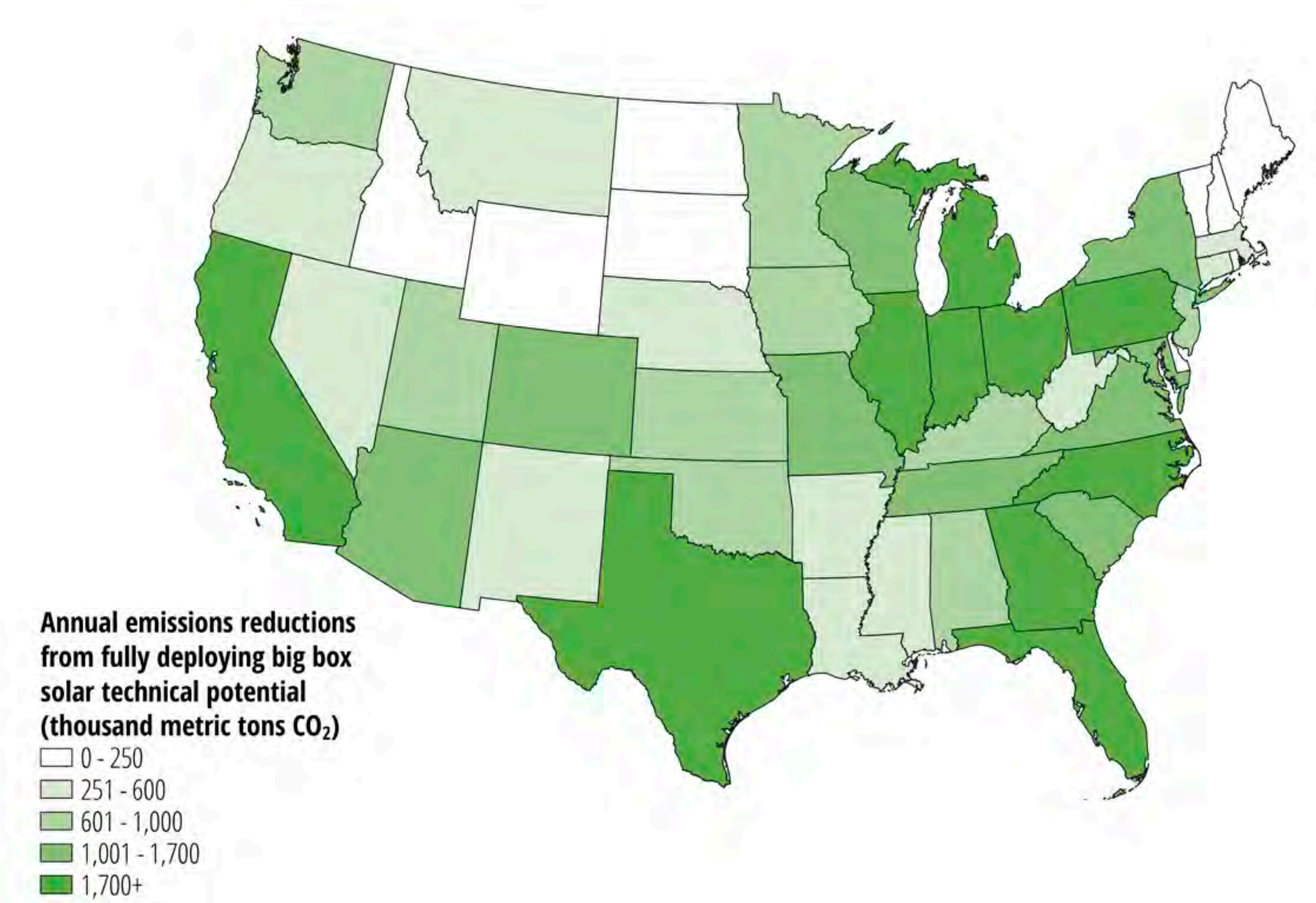

Figure ES-2. Annual carbon dioxide emissions averted by maximizing technical potential of big box rooftop solar, by state

America has only just begun to tap its solar resources. The United States has the technical potential to produce 78 times as much electricity as it used in 2020 just with solar photovoltaic (PV) energy.[3] To accelerate the transition to a future of 100% clean and renewable energy, America must take advantage of untapped solar energy opportunities, including on the rooftops of "big box" superstores.

The flat, open, sunny roofs of giant grocery stores, retail stores and shopping malls are perfect locations for solar panels.[4] The United States has more than 100,000 big box retail stores, supercenters, large grocery stores and malls, with almost 7.2 billion cumulative square feet of rooftop space.[5]

The rooftops of America's big box stores and shopping centers have the potential to generate 84.4 terawatt-hours (TWh) of solar electricity each year, equivalent to the amount of electricity that would power almost 8 million average U.S. homes, or more than 30,400 typical Walmart stores. California, Florida, Texas, Ohio and Illinois have the largest big box store solar generation potential. (See Appendix for state breakdowns.)

Putting solar panels on the nation's superstores would be good for businesses, good for electricity customers, good for the grid and good for the environment.

- Generating the full 84.4 TWh of clean solar power potential from America's superstores would **reduce global warming pollution by more than 52 million metric tons of CO_2 annually – equivalent to taking over 11.3 million passenger vehicles off the road**.[6]

- Texas, California, Florida, Illinois and Ohio have the largest emissions reduction potential. (See Appendix for state breakdowns.)
- Big box stores and shopping centers could **replace half of their annual electricity use** by fully building out their rooftop solar potential.
- Producing electricity on rooftops, close to where the electricity will be used, **reduces energy losses that happen during electricity transmission and distribution** – losses that made up 6% of gross electricity generation in 2020.[7] Solar power also **makes the grid more resilient to outages and disruptions**.

Many big box retail stores are already reaping the benefits of installing solar power on their rooftops.

- According to the Solar Energy Industries Association, the four companies with the most solar installed as of 2019 – Apple, Amazon, Walmart and Target – had solar installations totaling almost 1.4 gigawatts of capacity in that year.[8] That's more than 11% of the total commercial solar capacity installed in the U.S. as of 2019.[9]
- Walmart's solar installations have already saved the company over $1 million, and the company's installations in California were expected to provide between 20%-30% of each location's electricity needs.[10]

To combat climate change, help their communities, increase resilience and reduce energy expenses, **businesses should set ambitious goals to install solar generation capacity on their facilities and invest the time and resources needed to meet those goals**. They should, additionally:

- Investigate, catalog and report climate impact and energy use throughout their businesses;
- Set strong, detailed and comprehensive environmental goals; and
- Use their political influence to advocate for positive policy change.

Officials at all levels of government should implement solar-friendly policies that help to accelerate adoption of solar energy by America's businesses. These include:

- Extending and expanding the federal investment tax credit for solar power, as well as other tax incentives and credits;
- Ensuring that businesses that generate solar electricity are adequately compensated for the benefits they deliver to the environment, public health and consumers through programs like net metering, feed-in tariffs and value-of-solar payments;
- Enabling and enacting financing tools like third-party and Commercial Property Assessed Clean Energy (C-PACE) financing of solar installations to help remove financial barriers to solar adoption;
- Supporting community solar power programs to allow businesses to go solar in partnership with their communities; and
- Streamlining solar permitting and interconnection processes to make going solar easier and faster.

Introduction

Big retailers have a big impact on the environment. From the manufacturing and transportation of the goods they sell to the energy used to power warehouses, offices and stores, a significant share of the world's greenhouse gas emissions and pollution can be traced back to the globe-spanning supply chains that bring everything from dish soap to diapers onto the shelves of our local shopping centers.

In recent years, pressure from shareholders and customers has led major retailers to pledge to cut emissions and make their business models environmentally friendly.[11] Some of the biggest companies in America – Amazon and Best Buy, Heineken and PepsiCo, Conde Nast, Netflix and Target, to name a few – have made such pledges in conjunction with organizations and initiatives that help companies craft and achieve such goals.[12] Others, like Walmart, have made independent pledges toward sustainability and the climate.[13]

Given the massive environmental impact of retailing, companies need to take advantage of every possible opportunity to reduce their environmental footprint. One of the best opportunities is right on the rooftops of their stores.

The rooftops and parking lots of "big box" retail stores are perfect locations to install solar energy systems. Solar power reduces the need to burn fossil fuels for electricity, which accounts for one-quarter of total U.S. greenhouse gas emissions.[14] Solar energy systems can also save businesses money, help reduce air pollution and improve the resilience of our electric grid.

Many companies, like IKEA and Target, are already installing solar power on their buildings.[15] But there is much more they can do. And given the scale and scope of the climate crisis, there is no time to waste.

This report reviews the immense potential to generate clean solar power on the rooftops of big box retail stores across America. To meet their climate goals and to show leadership in their communities, it is time for major retailers to take concrete steps to go solar.

The U.S. has vast solar energy potential — including on the roofs of big box stores

The promise and potential of renewable energy in general, and solar energy in particular, in the U.S. is enormous. All told, the U.S. has the technical potential to produce 78 times as much electricity as it consumed in 2020 with solar photovoltaic power alone, and 36 times its projected 2050 electricity consumption even if most of the economy were electrified.[16] In fact, every state in the country could produce at least as much electricity as it used in 2020 just with solar photovoltaics.[17]

For decades, that clean energy potential went largely untapped. Recently, however, falling prices, the increasing efficiency of solar panels, and supportive public policies in many states have led to a boom in solar energy installations.

Between 2011 and 2020, solar electricity generation increased more than 23-fold and, in 2020, solar energy accounted for 44% of all U.S. additions of new electricity generation capacity.[18] Solar energy is already among the cheapest forms of electricity generation, and is predicted to become even cheaper, with typical large non-residential distributed solar installations costing almost 60% less in 2019 than they did in 2011.[19]

The U.S. Department of Energy, in its *Solar Futures Study* series, found that solar power could serve as much as 45% of U.S. electricity demand in future scenarios in which the electric grid is decarbonized and many fossil fuel-powered systems – like cars and home heating systems – are replaced with electric alternatives.[20] The study further found that the U.S. could reach that level of solar energy installation without increasing costs for consumers, without disturbing natural land, while using far less water than the current electricity system, and while saving more than a trillion dollars overall.[21]

Commercial rooftops can produce a large amount of solar energy

The United States has more than 100,000 big box stores as defined in this report: retail stores, supercenters, large grocery stores and malls.[22] These stores are spread across the country and could host a significant amount of renewable energy generation capacity because their roofs are typically large and unobstructed, perfect for installing solar panels. (See Table 1.)

Big box retail stores operate a large amount of commercial real estate and each sell billions of dollars of products annually. According to the National Retail Federation, the five biggest retailers in the country – Walmart, Amazon, Kroger, Home Depot and Costco – had a collective 11,220 retail locations in the U.S. in 2020 and sold a combined $992 billion worth of goods in the U.S.[24] Other household names in the top 25 retailers in the U.S. by sales include Best Buy and Macy's.[25]

Solar potential on America's big box stores and shopping centers

The nation's commercial buildings, including superstores, currently host only a small fraction of their potential solar capacity. America's big box stores have almost 7.2 billion square feet of available rooftop space, and could host enough solar photovoltaic capacity to generate more than 84.4 terawatt-hours (TWh) of electricity each year.[26] **That's enough to power almost 8 million average U.S. homes, or more than 30,400 average Walmart stores.**[27] The solar energy generation potential of big box stores is equivalent to almost 65% of all the electricity generated by solar in the U.S. in 2020.[28] California, Florida, Texas, Ohio and Illinois have the largest big box solar generation potentials. (See Appendix for state breakdowns.)

TABLE 1. NUMBER AND AVERAGE SIZE OF BIG BOX STORES AND SHOPPING CENTERS BY REGION[23]

Region	Big box store rooftop area (million sq. ft.)	Big box buildings	Average big box store rooftop area (sq. ft.)
Midwest	1,729	22,086	78,287
Northeast	1,112	14,726	75,480
South	2,861	41,939	68,207
West	1,468	21,363	68,697
Total	**7,169**	**100,114**	**71,605**

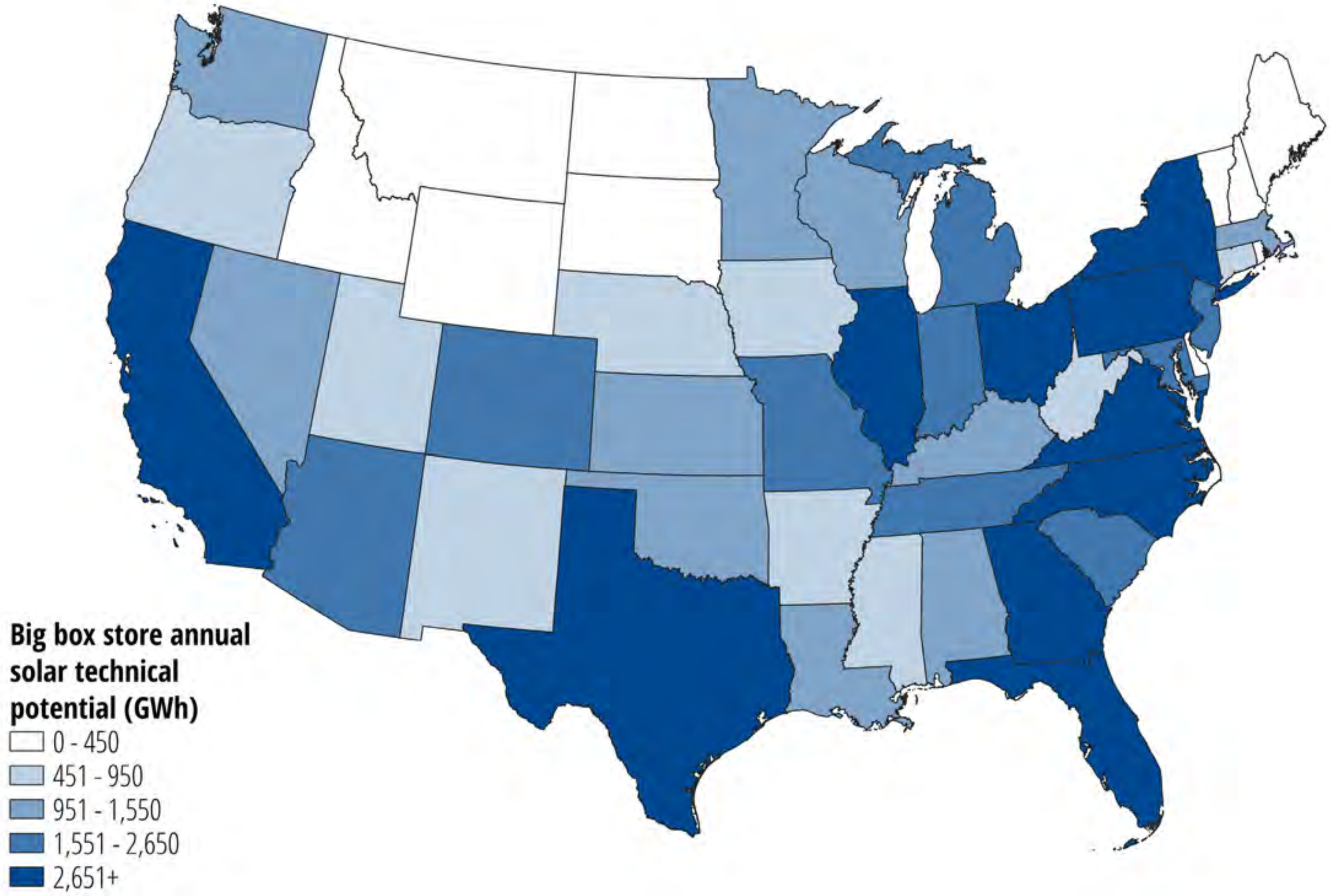

Figure 1. Big box store solar PV technical generation potential, by state

The big box retail stores, large grocery stores and malls considered in this report account for approximately 4.5% of all electricity use in the United States.[29] **Electricity produced by rooftop solar panels on big box stores could provide 50% of the annual electricity use of these buildings.**[30]

The biggest retailers in the country own or operate a huge amount of space. Just 10 of the top 25 highest revenue-generating chains in the U.S. operate almost 2.1 billion square feet of space, an area slightly smaller than Madison, Wisconsin, or about half the size of Birmingham, Alabama.[31] These 10 companies – Walmart, Target, Home Depot, Lowe's, Kroger, Albertson's, Macy's, Costco, TJX (the parent brand of TJ Maxx) and Publix – have the potential to generate almost 24 TWh of solar electricity on-site, which is more than 18% of all the solar electricity generated in the United States in 2020.[32]

These estimates of solar energy potential only include rooftop space on retail stores. Big box stores are often surrounded by parking lots and other areas that could host solar energy production. Solar panels are capable of providing shade in parking lots, some of which span several acres, while taking up no additional land and reducing vehicle fuel consumption for air conditioning use, as well as reducing the energy demand and electricity bills of the stores and potentially providing zero-emission electric vehicle charging.[44] Furthermore, many retailers and businesses own large distribution warehouses that, although not included in this analysis, are also ideal locations for solar panels. By taking advantage of these additional opportunities for solar power generation, big box stores and other retail outlets could produce even more solar energy than is estimated here.

TABLE 2. SOLAR CAPACITY POTENTIAL FOR 10 OF AMERICA'S TOP BIG BOX STORE CHAINS[33]

Company	Total U.S. square footage (sq. ft.)	Annual rooftop solar potential (GWh)	Number of U.S. households brand solar could power (thousands)
Walmart[34]	783,557,000	8,974.4	842.7
Target[35]	241,648,000	2,767.7	259.9
The Home Depot[36]	238,600,000	2,732.8	256.6
Lowe's Companies[37]	208,000,000	2,382.3	223.7
The Kroger Co.[38]	179,000,000	2,050.2	192.5
Albertsons Companies[39]	113,000,000	1,294.2	121.5
Macy's[40]	113,000,000	1,294.2	121.5
Costco Wholesale[41]	81,400,000	932.3	87.5
TJX Companies[42]	70,185,000	803.9	75.5
Publix Super Markets[43]	59,600,000	682.6	64.1

IKEA: Bringing solar to Maryland superstores

Solar parking canopy at IKEA Baltimore. Photo credit: IKEA

In February 2021, IKEA completed a 1.35-megawatt solar installation at its Baltimore, Maryland, location.[45] But the installation is not on the store's roof, which already had a 500-kilowatt solar energy system; instead, the solar panels are on top of raised canopies over the store's parking lot.[46]

The solar canopies provide many benefits – to IKEA, its customers and the community. The installation cut the Baltimore store's energy use by 84% and energy spending by 57% between September and December 2020.[47] Customers receive protection from rain and sun when they park their cars and, by shading the surface of the parking lot itself, the canopies prevent that surface from absorbing so much energy that it superheats the air above.[48] By shading the parked cars, the canopies reduce the energy those cars then need to use to reach a comfortable temperature, and the structures include charging stations for electric vehicles.[49] Finally, the Baltimore community gets a more efficient electric grid.[50]

The Baltimore IKEA solar parking canopies were partially funded by a grant from the Maryland Energy Administration, whose Solar Canopy Grant Program has helped build thousands of kilowatts of solar generation capacity around the state – enough to power over 2,000 Maryland homes.[51] In addition to the Baltimore solar canopies and solar canopies at six stores in California, one in Utah and one in Texas, IKEA is also installing a solar canopy at its College Park, Maryland, location.[52]

IKEA's solar installations are a small but meaningful step towards decarbonizing Maryland, where superstores are responsible for approximately 6% of the state's total electricity consumption.[53] Maryland's 1,801 big box stores boast nearly 140 million square feet of rooftop area, enough to generate 1,586 GWh of electricity annually, which could power nearly 149,000 U.S. homes or 572 Walmarts.[54] According to Jenn Keesson, IKEA U.S.' Country Sustainability Manager, "The IKEA vision is to create a better everyday life for [all] people," and that vision is threatened by climate change.[55] IKEA believes that, "no matter the size or scale," every piece of climate action – "[f]rom creating more sustainable stores through solar energy…to advocating for a net zero carbon economy" – is important.[56]

Going beyond rooftop solar installations presents big box stores and owners of shopping centers with even more opportunity to reduce their environmental impact and expenses while helping their customers and communities.

The benefits of scaling up commercial rooftop solar power

Going solar is good for big box stores, good for local electric grids and good for consumers. A 2021 analysis of the value of solar energy published in *Renewable and Sustainable Energy Reviews* showed that the benefits that solar power brings to the electricity grid, to our communities and to the environment are worth more than the value of the compensation utilities give for solar power in many places.[57] Generating electricity with solar panels on the roofs of big box stores can reduce pollution that drives global warming, make our electric grid more resilient, cut consumer costs, reduce unhealthy air pollution, and cut costs and improve brand image for the businesses themselves.

Big box solar power brings widespread community benefits

Reducing global warming pollution

In 2019, the United States emitted over 6.5 billion metric tons of carbon dioxide-equivalent greenhouse gases.[58] Electricity generation accounted for 25.1% of those emissions, and fossil fuel combustion was responsible for 98.8% of all electricity generation emissions.[59]

Solar panels produce power without global warming pollution. Even when emissions from manufacturing, transportation and installation of solar panels are included, solar power produces 95% less greenhouse gas pollution per unit of electricity than a coal-fired power plant, and 91% less global warming pollution than a gas-fired power plant.[60] By replacing electricity generated by burning fossil fuels, solar power significantly reduces greenhouse gas emissions and improves air quality.

Fully building out the solar technical potential of big box stores to generate 84.4 TWh of electricity would reduce global warming pollution by more than 52 million metric tons of CO_2 annually – equivalent to taking over 11.3 million passenger vehicles off the road.[61] Texas, California, Florida, Illinois and Ohio have the largest emissions reduction potential. (See Appendix for state breakdowns.)

Some major U.S. businesses have committed to reducing or eliminating their emissions of greenhouse gases. Best Buy and Amazon are signatories to The Climate Pledge, meaning that they have committed to net-zero carbon emissions by 2040.[62] Target has set a goal of achieving net-zero emissions by 2040, Walmart aims to have zero emissions with no carbon offsets by the same year, and IKEA has committed to net-zero or net-negative emissions by 2030.[63]

And many U.S. businesses have already begun to make significant investments in solar energy. As of the first quarter of 2021, commercial solar capacity totaled over 14 gigawatts, an exponential increase in just the last decade.[64] According to the Solar Energy Industries Association, the four companies with the most solar capacity as of 2019 – Apple, Amazon, Walmart and Target – had rooftop and off-site installations totaling almost 1.4 gigawatts of capacity in that year.[65] Some particular standouts among retail superstores are:

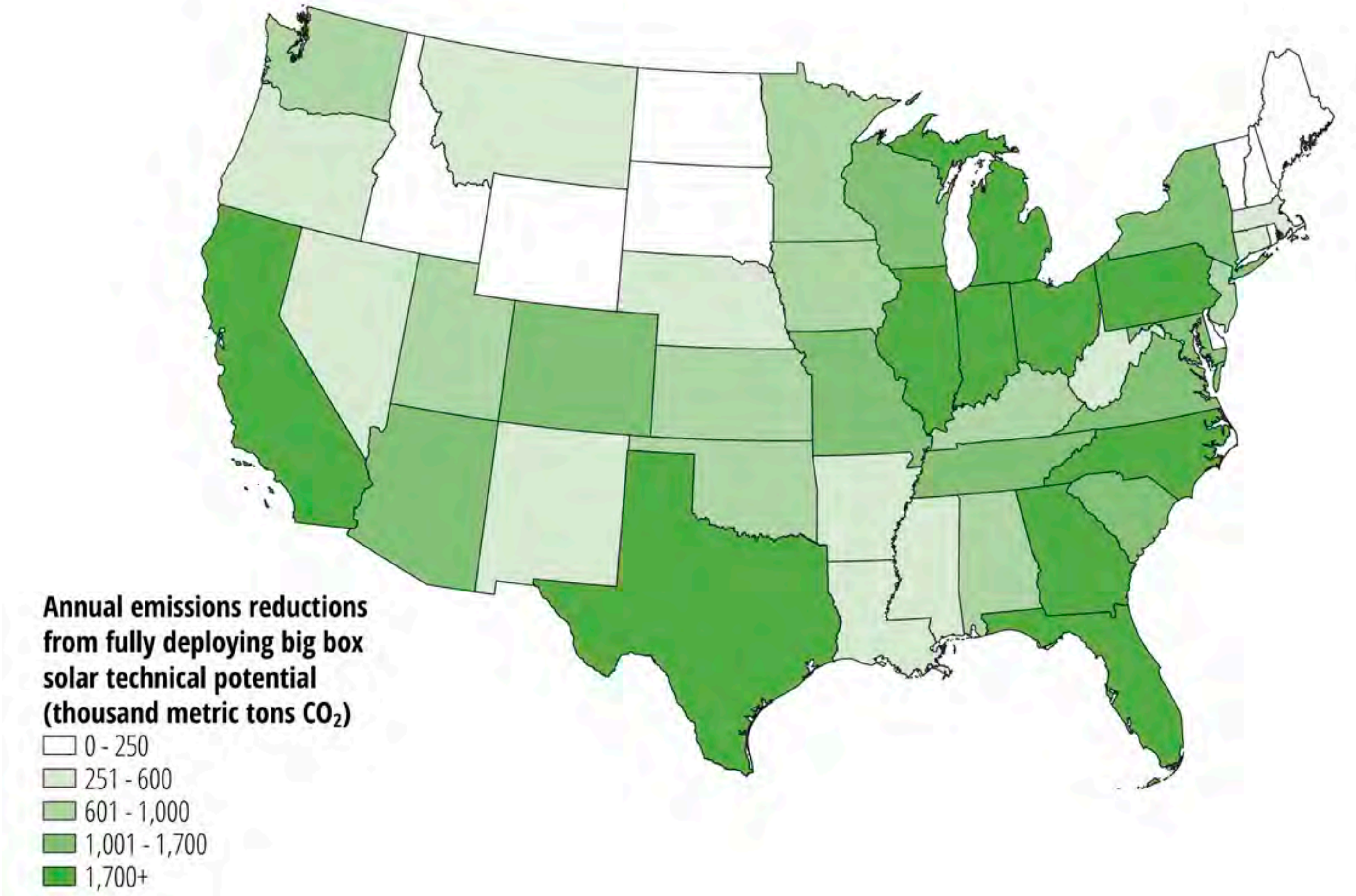

Figure 2. Annual greenhouse gas emissions averted, by state

- **Target**: Target had installed 259 megawatts of solar generation capacity on its stores and distribution centers as of the end of 2019, enough to power about 49,000 U.S. homes.[66]
- **Walmart**: Walmart had installed almost 194 megawatts of solar generation capacity on its U.S. facilities as of the end of the 2021 fiscal year, with additional capacity in off-site solar farms.[67]
- **IKEA**: IKEA has a total of 54 solar arrays, with installations on 90% of its U.S. locations.[68] Globally, IKEA sources 51% of its direct energy use from renewable sources.[69]

Creating a resilient electricity system

Rooftop solar energy can be a great tool to help communities keep critical infrastructure functioning during outages and blackouts, which are likely to become more common due to global warming-driven extreme weather.[70] Solar panels paired with batteries and smart inverters (which allow a building to separate itself from the larger grid) together, or just smart inverters by themselves, can continue to provide power even when the larger electricity grid has failed.[71] Solar panels can also serve as the power source for microgrids – interconnected systems from the size of single buildings to whole communities – and thus can help vulnerable areas or buildings that house critical infrastructure but can't generate their own electricity retain power during outages.[72]

Solar photovoltaic panels also use far less water than conventional electricity generation, helping conserve water in times of drought. Per unit of electricity, utility-scale solar farms use 97% less water than gas-fired power plants, and rooftop solar panels use even less because they don't require water for installation.[73] A recent study in the journal *Environmental Science & Technology* found that a future U.S. energy system that relies mainly on renewable sources of electricity would use far less water than either the current system or future systems that rely on coal or nuclear energy.[74]

Because solar PV panels do not rely on water for electricity production, communities that generate a significant amount of electricity from solar panels are less susceptible to electricity disruption during droughts. In 2021, severe drought in California put immense pressure on the power grid due to a combination of low hydroelectricity production and increased electricity demand for cooling.[75] However, renewables – including solar – helped to pick up the slack.[76] Climate change will only increase the risk of drought, and solar power – which produces the most energy during the day when cooling needs are highest – can be a great tool to meet electricity needs.[77]

Cutting consumer costs

Scaling up U.S. rooftop solar electricity generation would deliver important benefits to Americans. In addition to reducing losses from transmission and distribution, distributed solar can help avoid the need for expensive investment in transmission infrastructure.

According to the U.S. Energy Information Administration, over 6% of gross electricity generated in 2020 was lost in transmission and distribution and nearly 5% more was used to run power plants themselves.[78] Distributed solar energy on commercial rooftops avoids these losses by generating electricity at or near the location where it is used.[79] Additionally, by generating energy right where it is used, distributed solar generation can help eliminate the need for expensive new transmission capacity.[80] The costs of wasted energy and new infrastructure are passed on to consumers, so cutting those costs helps save Americans money.

Reducing air pollution

Installing solar panels on commercial rooftops can improve air quality by reducing our reliance on polluting fossil fuels for electricity. In 2020, the United States generated 60% of its electricity from fossil fuels.[81] Burning fossil fuels for electricity doesn't just release greenhouse gases that drive global warming; it also releases air pollutants that threaten public health.[82]

Fossil fuel-fired power plants were responsible for 11% of U.S. nitrogen oxide emissions and 50% of U.S. sulfur dioxide emissions in 2017.[83] Sulfur dioxide contributes to the formation of acid rain, and forms small particles in the air that can penetrate deep into the lungs and trigger respiratory diseases such as bronchitis and emphysema.[84] Particulate pollution has been linked to increased rates of hospital admissions and premature death, as well as damage to the respiratory and cardiovascular systems, mental health and cognitive effects, reduced fertility, increased cancer risk and increased risk of infectious diseases.[85] A study of the effects of particulate pollution on mortality found that it causes around 100,000 premature deaths in the U.S. each year.[86] Nitrogen oxides contribute to the formation of ozone "smog." Ozone has been linked to respiratory damage, worsened mental health, worse pregnancy outcomes, increased cancer risk and increased risk of infectious disease and premature death.[87]

Generating more of our electricity from clean, renewable sources like solar energy allows us to rely less on air- and climate-polluting fossil fuel power plants, which protects the health of Americans.

Big box stores directly benefit from hosting solar panels

Big box stores consume a lot of electricity for lighting, temperature control, refrigeration, water heating and to run equipment – most of which is currently generated using fossil fuels. On average, each of the nation's retail superstores, large grocery stores and malls consumes 1,664 megawatt-hours of electricity annually, and – using the national average price for commercial electricity – big box stores nationwide spend approximately $17.89 billion per year on electricity.[88] Electricity produced by rooftop panels could provide 50% of the annual electricity use of these buildings, reducing total electricity consumption of big box stores by 84.4 terawatt-hours.[89]

Some big retail brands are already saving money on their electricity bills and contributing to a cleaner and more secure electricity grid by adopting solar energy. In 2019, Target reached its 500th solar installation on stores and distribution centers, each of which provides between 15%-40% of a location's electricity needs.[90] Walmart's solar installations have already saved the company over $1 million, and each installation provides between 20%-30% of the location's electricity needs.[91]

Installing solar on big box stores also delivers some unique benefits:

- Because big box stores generally use most of their energy during the day, when the sun is shining, they benefit from instantaneous use of the free electricity solar panels generate.[92]
- Solar panels paired with energy storage can also reduce demand charges, which often account for between 30%-70% of commercial customers' bills.[93] Demand charges, which are calculated from peak load times rather than monthly energy use, can be reduced by smart battery installations that supply energy at moments of high energy use.[94]
- Solar panels can indirectly lower business cooling and heating costs by shading roofs during the day and providing insulation at night.[95]

Finally, by taking visible and meaningful action to reduce emissions and fight global warming, brands can attract more loyalty and increase preference for their products. Surveys consistently show that the majority of consumers consider the sustainability of products and brands when making purchasing decisions.[96] Nielson found that 73% of global consumers are willing to change their buying habits to reduce their environmental impact, Deloitte found that nearly a quarter of consumers say they will switch to buying companies' products specifically because of shared values on environmental issues, and a 2019 survey commissioned by Enel Green Power found that about half of Americans are willing to pay extra to make a more sustainable purchase.[97]

Walmart: The nation's largest retailer could also lead on the environment

Walmart is the nation's largest retailer, with sustainability goals to match its scale, but it has work to do to meet its ambitions and its potential as an environmental leader in the U.S. and around the world.[98] Among its other goals, Walmart has set out to have zero emissions by 2040 and to be powered by 100% renewable energy by 2035.[99]

Walmart installed its first on-site solar panel in 2007, and by the end of fiscal year 2021 had almost 194 megawatts of solar capacity on the rooftops of its U.S. facilities.[100] Each installation provides 20% to 30% of the site's electricity needs.[101] Among organizations participating in the Environmental Protection Agency's Green Power Partnership program to increase the development and use of renewable electricity, Walmart ranks fourth overall and first among retail brands for total amount of renewable energy used, consuming 2,700 gigawatt-hours of renewable energy in the U.S. per year.[102] That accounts for 14% of Walmart's total U.S. electricity use, while Walmart reports that in 2020 it sourced 36% of its global electricity use from renewable sources.[103]

In 2012, Walmart set a goal of procuring 7,000 gigawatt-hours of renewable electricity by 2020, and in 2014 added the goal of doubling the number of its on-site U.S. and Puerto Rico solar installations by the same year.[104] Walmart did procure 7,000 gigawatt-hours of renewable energy globally in fiscal year 2021 but fell about 25% short of its solar installation goal, with only 419 projects completed and another 41 under development at the end of fiscal year 2021.[105]

Solar panels on a Walmart in Caguas, Puerto Rico. Credit: Walmart via Flickr, CC-BY 2.0

Walmart is involved in renewable energy projects around the world, many of which are not rooftop solar installations, and reports having developed more than 2.3 gigawatts of renewable energy capacity in total.[106] In terms of U.S. *rooftop* solar capacity, however, Walmart is not at the forefront: competitors like Target, which had 259 megawatts of rooftop solar at the end of 2019, and IKEA, which has solar installed at 90% of its U.S. locations, are leading the way.[107] With 5,253 stores in the U.S. alone, and many more distribution centers and stores worldwide, Walmart can add to its large solar portfolio and make a huge impact by redoubling its rooftop solar efforts.[108]

Recommendations

America's superstores are perfectly suited to generating clean, renewable solar electricity. Their wide, flat roofs receive lots of sunlight, and they can make use of that electricity directly or serve as sources of emission-free energy for the surrounding community.

In order to reduce their environmental impacts, help their communities and save money, **big box retailers should set ambitious goals to install solar generation capacity on their facilities and invest the time and resources needed to meet those goals**. Almost any large retail building, warehouse or distribution facility is capable of supporting a solar installation, and most parking lots could be covered by a solar canopy. Big box brands should install solar on as many of their buildings and parking areas as possible, as quickly as possible.

Big retailers can also increase their climate and social impact in a number of ways. Specifically, they can:

- Investigate, catalog and report climate impact and energy use throughout their businesses – including by adopting the protocols of some globally recognized standards – which would allow stakeholders, governments and the public to keep track of companies' efforts in reducing their environmental impact.[109]

- Set strong, detailed and comprehensive environmental goals that include building out solar generation capacity while also improving energy efficiency, reducing emissions, electrifying equipment and vehicles, and increasing the use of recycled materials.

- Use their political influence to advocate for positive policy change – including policies that support distributed solar installation and adoption specifically, and the broader decarbonization effort more generally.

Policy makers can enact changes that help businesses go solar. **Officials at all levels of government must implement solar-friendly policies that help to accelerate America's commercial solar energy adoption.** These should include:

- *Extending and expanding the federal solar investment tax credit and adding or extending state-level solar energy tax credits* – Solar tax credits help lower the cost of, and remove financial barriers to, commercial solar installations.[110] The federal investment tax credit, which takes 26% of what a company or individual spends on solar installation off of their taxes, is an important incentive that goes a long way toward removing financial barriers to solar.[111] These credits should be extended for at least 10 years to encourage future solar adoption, and should be expanded and improved to make them easier to use by more people – including by allowing them to be monetized as refunds or direct payments.[112] Some states offer similar tax credits, which give further incentive to go solar.[113] Other potentially important incentives include property tax exemptions, which exclude the value of solar equipment from the assessed property value on which business owners – and homeowners – must pay taxes; and sales tax exemptions for solar equipment.[114]

- *Adopting and preserving strong solar compensation policies* – These policies ensure that businesses are appropriately compensated for the electricity that they export to the grid and make solar power an affordable business investment for big box stores.

Strong net metering policies encourage solar adoption, and the lack of such policies deters solar installation.[115] Alternatives to net metering include feed-in tariffs and value-of-solar payments, which, if they account for all the benefits of solar energy, can also help ensure solar owners receive fair compensation.[116] As policy makers ensure that solar owners are fairly compensated for the power they produce, they should also ensure that they are not burdened by solar-specific charges and fees, which can discourage solar adoption.[117]

- *Enabling third-party sales of electricity* – Although businesses that purchase their own solar panels can enjoy the full financial benefits of reduced energy costs, third-party financing options – like power-purchase agreements (PPAs) and solar leases – are a great alternative for businesses to tap the potential of solar energy.[118] These arrangements allow companies to either lease the panels from a third party at a fixed cost and enjoy the energy benefits, or pay a fixed price for the electricity the panels produce without paying for the panels.[119] PPAs and leases are also good tools for companies that do not own their buildings: by removing the up-front investment cost of solar, these tools can be useful in getting property owners and tenants to work together.[120] States should allow companies that install solar panels to sell electricity directly to customers without subjecting them to regulation as public utilities.

- *Adopting financing programs like Commercial PACE* – Financing options that provide businesses with low up-front costs and long-term repayment options are important for the commercial solar industry. For example, Commercial Property Assessed Clean Energy (C-PACE) financing programs allow local governments to pay the up-front cost of commercial solar projects, with the expenses repaid by the businesses via their property taxes.[121] By 2017, C-PACE programs had delivered nearly half a billion dollars to almost 1,100 renewable energy projects around the country.[122] New Jersey became the 38th state with a C-PACE program in August 2021.[123]

- *Allowing and encouraging community solar programs* – Community solar programs allow people who may not be able to install solar panels themselves to invest in a solar installation on another property and share credit for the electricity produced by the solar panels and sent back to the electric grid.[124] Partnerships between businesses and local governments to establish community solar projects at the local level can be a creative source of financing for solar projects on commercial rooftops.[125]

- *Streamlining solar permitting and instituting affordable permitting fees* – The "soft costs" associated with solar power – costs such as those associated with installing the system, completing paperwork, and paying taxes and permitting fees – typically make up more than half of the total cost of an installed commercial solar energy system.[126] Local governments should work to reduce these costs and streamline the permitting process. Tools like the National Renewable Energy Laboratory's SolarAPP+ tool, which automates permitting and approval for residential solar systems, could be adopted to free up staff time from reviewing residential installation applications so that more time could be used to review commercial installation applications, which are typically more complicated.[127]

Methodology

This analysis relied on National Renewable Energy Laboratory data *2019 City and County Commercial Building Inventories*, available through the Open Energy Data Initiative (OEDI).[128] The inventories in that dataset "provide modeled data on commercial building type, vintage, and area for each U.S. city and county."[129] Each record contains modeled data on a subset of buildings within a specific city or county with fields including building use, building area, number of stories, and the number of buildings of that type in that location.

Building subsets were considered "big box stores" if they had 25,000 square feet or more of rentable building area, 15 or fewer stories, and an Energy Information Administration Commercial Building Energy Consumption Survey (CBECS) building type of "Retail store," "Other retail," "Grocery store/food market" or "Enclosed mall."[130]

In calculating rooftop area for big box buildings, records were only considered for building subsets in which the "yearbuilt_mean" was before 2019 or blank and in which "bldg_count" was not blank. The resulting dataset after applying these conditions matched the summary calculations for fully constructed buildings contained in the original dataset.

Total rooftop area for each building subset was then calculated as the total building area (specifically, "rentable building area") for all the buildings in that subset divided by number of building stories per building. Entries that had a blank in the number of stories field were assumed to have one story.

For each building inventory record, average building area was calculated as the total area for the building subset divided by the number of buildings in that subset.

To calculate the solar generation potential of big box stores in each state, the National Renewable Energy Laboratory's (NREL) 2016 report *Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment* – which presents the results of a study of rooftop solar potential broken down by building size and by state – was used.[131] Alaska and Hawaii are not included in that study, and so are excluded from our analysis except in comparisons to total U.S. energy usage. The 2016 NREL report presents the area of building rooftops suitable for solar deployment and the technical generation potential for rooftop solar on medium and large buildings broken down by state. Dividing the technical generation potential by the usable rooftop area produced an estimate of the amount of electricity that could be produced per square foot of usable rooftop area in each state. Multiplying this figure by the area of big box store rooftops in each state and an estimate of the proportion of large building roofs suitable for hosting solar panels (66% according to the same 2016 NREL report) resulted in the estimate of big box store rooftop solar generation technical potential for each state.[132] This technical potential was then adjusted to account for increasing solar panel efficiency since the 2016 study was published. The authors of the 2016 report wrote "[F]or this analysis we assumed a module power density of 160 W/m^2, corresponding to a module efficiency of approximately 16%. If a power density of 200 W/m^2 were assumed instead, corresponding to a module efficiency of approximately 20%, each of the technical potential estimates would increase about 25% above the values stated in this report."[133] According to the Lawrence Berkeley National Laboratory's 2021 *Tracking the Sun* summary data tables, available for download at https://emp.lbl.gov/tracking-the-sun, the median module efficiency for large non-residential solar modules in 2020 was 19.5%.[134] The calculated big box store rooftop solar technical generation potentials for each state were multiplied by the ratio of 2020 module efficiency to the efficiency assumed in the 2016 NREL report to produce the final estimates of rooftop generation potential.

This resulting estimate of big box generation potential by state and region formed the basis for other energy equivalents. Those were calculated as follows:

- Share of total electricity sales by state were calculated as the ratio of big box rooftop solar generation potential to 2020 electricity retail sales, the data for which were downloaded from the Energy Information Administration's *Electricity Data Browser*.[135]
- Equivalent in households was based on average electricity consumption of an American household (residential utility customer) in 2019 of 10,649 kilowatt-hours.[136]
- Equivalent in Walmart stores assumes annual electricity consumption of 2.772 gigawatt-hours per store. This estimate is based on an average Walmart retail area of 180,000 square feet, based on reporting from *Business Insider*, and a U.S. average electricity use per square foot for "Retail store" of 15.4 kilowatt-hours, from the U.S. Energy Information Administration's 2012 *Commercial Buildings Energy Consumption Survey* (CBECS).[137] As the assumed Walmart area only includes shopping area, the assumed average Walmart electricity consumption is likely an underestimate, as it does not account for non-shopping building space.
- Global warming pollution reduction potential was calculated by multiplying big box PV potential by each state's non-baseload output emission rate for electricity generation from the U.S. Environmental Protection Agency's eGRID Data Explorer.[138]
- Big box PV potential as a share of current big box electricity consumption was calculated using state estimates of big box electricity consumption; those estimates were based on regional electricity usage statistics from CBECS microdata.[139] To calculate big box electricity use by region, big box average electricity use per square foot was calculated using the weighted fields for annual electricity consumption and square footage, for those buildings of 25,000 or more square feet of area and 15 or fewer stories, in the primary building activity categories of strip shopping mall, enclosed mall, retail other than mall, and food sales. The resulting factors were then multiplied by the previously calculated total square footage for each big box inventory entry in the *2019 City and County Commercial Building Inventories*, with factors applied to inventories in the applicable region.

Calculations for specific brands were made as follows:

- The average U.S. large building rooftop solar electricity generation potential per unit of usable rooftop space was calculated in gigawatt-hours per square meter using estimates of total usable rooftop area and total potential solar electricity generation for large buildings by the National Renewable Energy Laboratory, as described above.[140] This figure was then converted into gigawatt-hours per square foot.
- For each brand, total rooftop area was assumed to be equivalent to total retail area as found in the companies' annual reports or tax filings (see Table 2). That area was multiplied by the generation potential per square foot as calculated above and the average proportion of rooftop area suitable for solar installations, estimated by the National Renewable Energy Laboratory.[141] This gives potential annual solar electricity generation by brand. Because total store area was assumed to be equivalent to rooftop area, this is an overestimate for those brands with many stores of more than one story.
- Potential annual solar electricity generation was adjusted to account for increasing solar panel efficiency since the 2016 NREL report was published, as explained above.
- The number of U.S. households each brand could power if they installed their full potential solar capacity was calculated by dividing total annual solar electricity generation potential by the average electricity consumption of an American household (residential utility customer) in 2019 of 10,649 kilowatt-hours.[142]

Appendix: State and regional data

TABLE A-1. BIG BOX STORE ROOFTOP AREA, NUMBER, ELECTRICITY CONSUMPTION AND SOLAR POTENTIAL, BY STATE[143]

State	Big box store rooftop area (million sq. ft.)	Big box buildings	Annual electricity consumption of big box stores (GWh)	Potential annual solar generation from big box stores (GWh)	Number of U.S. households big box solar could power (thousands)	Number of U.S. Walmarts big box solar could power
Alabama	115.5	1,764	2,727.4	1,384.1	130.0	499
Arizona	175.5	2,288	3,472.5	2,527.0	237.3	912
Arkansas	64.5	1,041	1,663.8	755.6	71.0	273
California	674.5	10,260	14,923.3	9,262.8	869.8	3,342
Colorado	133.2	1,916	2,683.6	1,726.0	162.1	623
Connecticut	81.7	1,140	1,775.3	870.5	81.7	314
Delaware	28.2	355	677.1	319.4	30.0	115
District of Columbia	4.2	72	200.3	46.2	4.3	17
Florida	555.2	6,979	13,317.2	6,973.5	654.9	2,516
Georgia	282.4	3,691	6,721.3	3,293.3	309.3	1,188
Idaho	35.9	501	706.3	439.7	41.3	159
Illinois	309.0	3,834	7,059.5	3,333.7	313.0	1,203
Indiana	186.0	2,344	4,067.0	2,045.8	192.1	738
Iowa	78.3	1,016	1,100.6	873.5	82.0	315
Kansas	77.9	1,072	1,102.2	956.2	89.8	345
Kentucky	94.9	1,378	2,228.3	1,045.2	98.1	377
Louisiana	92.0	1,525	2,824.0	1,087.7	102.1	392
Maine	29.2	397	612.9	313.4	29.4	113
Maryland	139.6	1,801	3,507.1	1,585.6	148.9	572
Massachusetts	132.5	1,804	2,900.7	1,430.5	134.3	516
Michigan	241.1	2,950	5,273.6	2,495.4	234.3	900
Minnesota	128.2	1,594	1,859.5	1,341.3	126.0	484
Mississippi	67.0	989	1,588.7	819.1	76.9	295
Missouri	160.2	2,244	2,307.0	1,854.6	174.2	669
Montana	21.8	313	427.7	272.0	25.5	98
Nebraska	46.8	668	672.8	555.8	52.2	201

TABLE A-1. (CONTINUED)

State	Big box store rooftop area (million sq. ft.)	Big box buildings	Annual electricity consumption of big box stores (GWh)	Potential annual solar generation from big box stores (GWh)	Number of U.S. households big box solar could power (thousands)	Number of U.S. Walmarts big box solar could power
Nevada	74.1	1,007	1,537.4	1,048.5	98.5	378
New Hampshire	39.9	529	828.7	416.0	39.1	150
New Jersey	191.9	2,528	4,966.0	2,105.7	197.7	760
New Mexico	44.9	601	888.4	638.9	60.0	230
New York	306.1	4,156	8,305.7	3,280.2	308.0	1,183
North Carolina	272.3	3,684	6,441.8	3,241.1	304.4	1,169
North Dakota	17.8	252	253.3	198.9	18.7	72
Ohio	321.4	3,950	7,151.3	3,347.6	314.4	1,208
Oklahoma	76.6	1,366	2,241.5	962.3	90.4	347
Oregon	82.5	1,239	1,740.4	883.5	83.0	319
Pennsylvania	300.5	3,740	7,559.8	3,172.7	297.9	1,145
Rhode Island	20.2	279	435.2	220.4	20.7	80
South Carolina	133.7	1,828	3,067.2	1,655.0	155.4	597
South Dakota	19.2	263	260.6	222.2	20.9	80
Tennessee	136.4	2,372	3,525.3	1,620.0	152.1	584
Texas	517.7	9,567	16,306.7	6,418.5	602.7	2,315
Utah	71.7	992	1,437.7	925.7	86.9	334
Vermont	9.4	153	195.9	98.1	9.2	35
Virginia	235.5	2,985	5,679.7	2,747.6	258.0	991
Washington	142.5	2,093	3,039.8	1,434.5	134.7	518
West Virginia	44.8	542	1,038.1	481.6	45.2	174
Wisconsin	143.1	1,899	3,122.9	1,545.5	145.1	558
Wyoming	11.0	153	211.7	145.2	13.6	52
United States (without AK or HI)	7,168.7	100,114	166,635.1	84,417.3	7,927.3	30,454

TABLE A-2. EMISSIONS REDUCTIONS AND SHARE OF BIG BOX AND TOTAL ELECTRICITY CONSUMPTION FROM SOLAR POWER ON BIG BOX STORES, BY STATE[144]

State	Global warming pollution reduction potential (thousand metric tons CO_2)	Big box solar generation potential as share of total electricity consumption	Big box solar generation potential as share of big box electricity consumption
Alabama	727.1	1.7%	50.7%
Arizona	1,674.3	3.1%	72.8%
Arkansas	533.7	1.7%	45.4%
California	3,621.0	3.7%	62.1%
Colorado	1,234.2	3.1%	64.3%
Connecticut	303.3	3.2%	49.0%
Delaware	122.8	2.9%	47.2%
District of Columbia	13.9	0.5%	23.1%
Florida	3,311.1	2.9%	52.4%
Georgia	2,421.6	2.5%	49.0%
Idaho	171.0	1.8%	62.2%
Illinois	2,837.5	2.5%	47.2%
Indiana	1,703.9	2.2%	50.3%
Iowa	709.0	1.8%	79.4%
Kansas	944.2	2.5%	86.8%
Kentucky	860.7	1.5%	46.9%
Louisiana	566.6	1.2%	38.5%
Maine	86.4	2.8%	51.1%
Maryland	1,177.5	2.8%	45.2%
Massachusetts	583.7	2.9%	49.3%
Michigan	1,974.5	2.6%	47.3%
Minnesota	939.4	2.1%	72.1%
Mississippi	389.9	1.7%	51.6%
Missouri	1,565.5	2.5%	80.4%
Montana	272.6	1.9%	63.6%
Nebraska	529.7	1.8%	82.6%
Nevada	507.1	2.8%	68.2%
New Hampshire	178.3	3.9%	50.2%
New Jersey	929.2	3.0%	42.4%
New Mexico	522.8	2.5%	71.9%
New York	1,516.4	2.4%	39.5%
North Carolina	2,119.4	2.5%	50.3%
North Dakota	185.4	0.9%	78.5%
Ohio	2,801.2	2.4%	46.8%
Oklahoma	609.1	1.6%	42.9%
Oregon	432.3	1.9%	50.8%
Pennsylvania	1,950.9	2.3%	42.0%

TABLE A-2. (CONTINUED)

State	Global warming pollution reduction potential (thousand metric tons CO_2)	Big box solar generation potential as share of total electricity consumption	Big box solar generation potential as share of big box electricity consumption
Rhode Island	91.4	3.0%	50.6%
South Carolina	1,058.3	2.2%	54.0%
South Dakota	152.0	1.8%	85.2%
Tennessee	1,165.4	1.7%	46.0%
Texas	3,844.3	1.6%	39.4%
Utah	699.6	3.0%	64.4%
Vermont	15.1	1.9%	50.1%
Virginia	1,318.1	2.4%	48.4%
Washington	922.4	1.7%	47.2%
West Virginia	450.7	1.5%	46.4%
Wisconsin	1,173.4	2.3%	49.5%
Wyoming	153.5	0.9%	68.6%
United States (without AK or HI)	52,071.7	2.3%	50.7%

TABLE A-3. REGIONAL DATA[145]

Attribute	Region			
	Midwest	Northeast	South	West
Big box store rooftop area (million sq. ft.)	1,729.0	1,111.5	2,860.5	1,467.6
Big box buildings	22,086.0	14,726.0	41,939.0	21,363.0
Annual electricity consumption of big box stores (GWh)	34,230.4	27,580.3	73,755.6	31,068.8
Potential annual solar generation from big box stores (GWh)	18,770.3	11,907.4	34,435.9	19,303.7
Number of U.S. households big box solar could power (thousands)	1,762.6	1,118.2	3,233.7	1,812.7
Number of U.S. Walmarts big box solar could power	6,771.0	4,296.0	12,423.0	6,964.0
Global warming pollution reduction potential (thousand metric tons CO_2)	15,515.9	5,654.7	20,690.3	10,210.9
Big box solar generation potential as share of total electricity consumption	2.3%	2.6%	2.0%	2.9%
Big box solar generation potential as share of big box electricity consumption	54.8%	43.2%	46.7%	62.1%

Notes

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