Renewables on the Rise 2021

The rapid growth of renewables, electric vehicles and other building blocks of a clean energy future

Environment Texas Research & Policy Center

Frontier Group

Renewables on the Rise 2021

The rapid growth of renewables, electric vehicles and other building blocks of a clean energy future

Written by:

Sarah Nick and Tony Dutzik, Frontier Group

Emma Searson, Environment America Research & Policy Center

November 2021

Acknowledgments

Environment Texas Research & Policy Center sincerely thanks Chris Harto, Senior Transportation Policy Analyst at Consumer Reports; Bill Holland, Senior Director of State Policy and Advocacy for the League of Conservation Voters; Steve Nadel, Executive Director of the American Council for an Energy-Efficient Economy; and John Rogers, Senior Energy Analyst at the Union of Concerned Scientists for their review of drafts of this document, as well as their insights and suggestions. Thanks also to Jamie Friedman, formerly of Frontier Group, for her significant contributions to this analysis, and to Susan Rakov, Bryn Huxley-Reicher, Adrian Pforzheimer and James Horrox of Frontier Group for their contributions and editorial support. Environment Texas Research & Policy Center thanks all those who provided funding to make this project possible.

The authors bear responsibility for any factual errors. The recommendations are those of Environment Texas Research & Policy Center. The views expressed in this report are those of the authors and do not necessarily reflect the views of our funders or those who provided review.

Environment Texas Research & Policy Center is a 501(c)(3) organization. We are dedicated to protecting our air, water and open spaces. We investigate problems, craft solutions, educate the public and decision-makers, and help the public make their voices heard in local, state and national debates over the quality of our environment and our lives. For more information about Environment Texas Research & Policy Center or for additional copies of this report, please visit www.environmenttexascenter.org.

Frontier Group provides information and ideas to build a healthier, more sustainable America. We focus on problems that arise from our nation's material and technological wealth – the problems of abundance. We deliver timely research and analysis that is accessible to the public, applying insights gleaned from diverse fields of knowledge to arrive at new paths forward. For more information about Frontier Group, please visit www.frontiergroup.org.

Layout: Alec Meltzer/meltzerdesign.net

Cover photo: Wind farm in eastern Washington state, Gareth Janzen, via Shutterstock.com

Table of contents

Executive summary

Clean energy is sweeping across America and is poised for more dramatic growth in the coming years.

Wind turbines and solar panels made up a tiny fraction of our energy infrastructure 10 years ago. Today, they are everyday parts of America's energy landscape. The number of homes heated with clean, efficient electric heat pumps increased by 28% in a decade from 2005 to 2015.[1] Just a few years ago, electric vehicles seemed a far-off solution to decarbonize our transportation system. Now, they have broken through to the mass market.

Virtually every day, there are new developments that increase our ability to produce renewable energy, apply it to a wider range of energy needs, and reduce our overall energy use. These developments enable us to envision an economy powered entirely by clean, renewable energy.

In 2020, America produced **almost four times as much renewable electricity** from the sun and the wind as in 2011, with wind and solar producing 11% of our nation's electricity in 2020, up from 3% in 2011.[2]

Between 2011 and 2020, U.S. wind, solar and geothermal generation grew at an annual rate of 15%.[3] If those forms of renewable generation were to **continue to grow by 15% per year, wind, solar and geothermal would produce enough electricity to meet all of our current electricity needs by 2035.**[4]

The last decade has proven that clean energy can power American homes, businesses and industry, and has put America on the cusp of a dramatic shift away from polluting energy sources. With renewable energy prices falling and new energy-saving technologies being developed every day, **businesses, cities, states, and the nation should work to obtain 100% of our energy from clean, renewable sources.**

The last decade has seen explosive growth in the key technologies needed to power America with clean, renewable energy.

- **Solar energy:** America produces over 23 times as much solar power as it did in 2011, enough to power more than 12 million average American homes.[6] In 2011, solar rooftops and utility-scale solar power plants produced 0.14% of U.S. electricity; in 2020, they produced 2.3% of America's electricity. In 2019, the 2 millionth solar PV system was installed, and an additional million installations quickly followed by summer 2021.[7]
- **Wind energy:** America has nearly tripled the amount of wind power it produces since 2011, enough to power over 31 million homes.[8] In 2011, wind turbines produced 3% of the nation's electricity; in 2020, they produced 8.4% of America's electricity.[9]
- **Energy efficiency:** Electric efficiency programs across the U.S. saved over 17% more energy in 2019 than in 2011, as states ramped up their investments in efficiency. In 2019, these programs saved enough electricity to power more than 2.5 million homes.[10]
- **Electric vehicles:** In 2011, just over 16,000 battery and plug-in hybrid electric vehicles were sold in the U.S. As of December 2020, cumulative sales had grown 100-fold to nearly 1.7 million vehicles.[11] By mid-2021, plug-in electric vehicle sales had surpassed 2 million.[12]

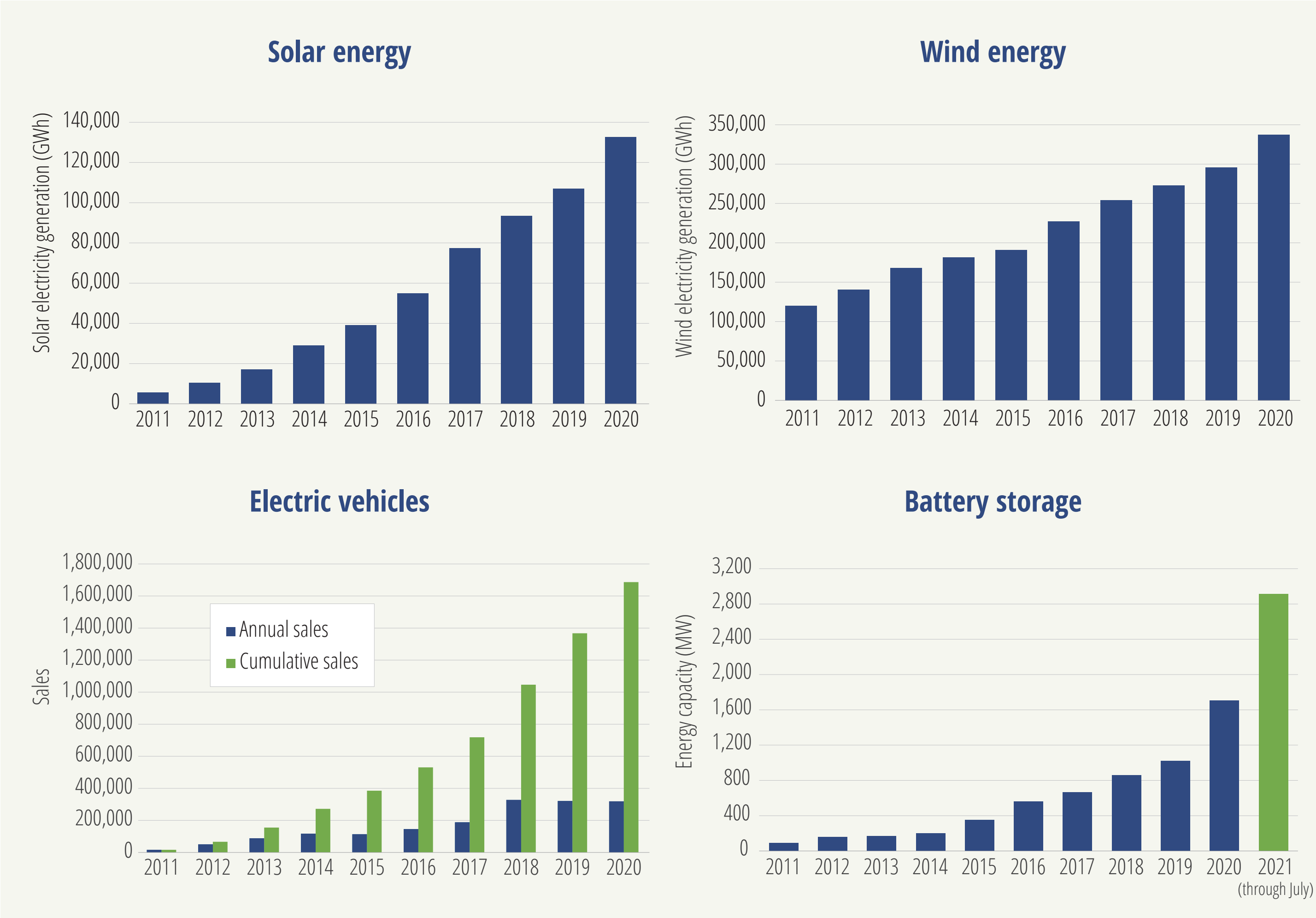

Figure ES-1. Growth in clean energy technologies[5]

- **Battery storage:** In 2020, the U.S. had over 1.7 GW of battery storage capacity. America's battery storage capacity grew more than 18-fold from 2011 to 2020 and grew by 67% in 2020 alone.[13]

- **Heat pumps:** The efficiency of heat pumps has improved to the point where they are now an attractive and realistic option for homes across the country. In 2015, 12% of all U.S. homes with heat used heat pumps, up from just 8% a decade earlier.[14] Shipments of efficient air-source heat pumps from U.S. manufacturers nearly doubled between 2011 and 2020, increasing by 10% in 2020 alone.[15]

The recent growth in renewable energy across America is due in part to strong and supportive public policies. To accelerate the transition to clean energy, cities, states and the federal government should:

- Set ambitious targets for renewable energy, following the example of the nine states and nearly 200 cities and towns that have committed to getting 100% of their electricity from clean or renewable sources of energy within the next several decades.[16] In addition, governments should set specific targets for deployment of key clean energy technologies, such as solar power, offshore wind energy and energy storage.

- Establish strong incentives for renewable energy adoption, including extension of federal tax credits that have helped to fuel the growth of renewable energy over the last decade and local and state clean energy incentives. Policy-makers should expand and improve existing clean energy incentives to make them easier to use and to ensure that they deliver benefits to everyone wanting to participate in the drive toward a clean energy future.

- Ensure that utility policies fully and fairly compensate investors in clean energy technology for the benefits they bring to the environment, society and the electric system through mechanisms such as net metering for rooftop solar systems, and adopt policies for permitting and interconnection that make adoption of clean energy technologies easy and hassle-free.

- Encourage the transition to electric vehicles and electric buildings through strong clean cars standards, local commitments to transition to electric transit and school buses, and policies to support fuel-switching in residential and commercial buildings from gas and oil to electricity.

- Support the integration of technologies and practices that will enable America to take full advantage of its renewable energy potential, including the integration of energy storage into the grid, the development of resilient local microgrids powered by renewable energy, and the appropriate expansion of transmission infrastructure to allow for the transport of renewable energy from the places where it is abundant to the places where it is needed.

- Encourage continued steady progress on energy efficiency by continuing and expanding local, state, utility and federal programs and policies, including utility energy efficiency programs, building energy codes, and appliance efficiency standards.

Introduction

Imagine a world powered by clean, renewable energy.

A world without the threat of oil spills in our ocean waters, without the specter of precious Arctic wilderness being destroyed forever to provide the world with a few months of oil, without leak-prone oil pipelines traversing natural lands and critical waterways, and without the air pollution from vehicle tailpipes that puts the health and lives of millions of Americans at risk.

A world in which mountaintops aren't removed to access the coal beneath, abandoned coal mines don't leak acid into our waterways, coal ash ponds at power plants don't pose an imminent threat of destruction to the wildlife in our rivers and streams, and the flow of soot into our skies from power plant smokestacks disappears.

A world in which our homes are no longer dependent for heat upon leaky gas delivery systems, the combustion of gas for cooking doesn't jeopardize our health, and fracking does not put the health of our communities and the water they drink at risk.

And a world in which the United States taps our abundant clean energy resources to lead the globe in eliminating the carbon pollution that threatens the future of our children and grandchildren.

That world is not here yet. Far from it. But the outlines of it can be seen in the extraordinary progress the United States has made in the last decade in renewable energy.

Solar panels and wind turbines, electric vehicles and electric heat pumps, energy storage systems and LED light bulbs – all of them were uncommon, even exotic, technologies in recent memory, but are becoming increasingly common features of everyday life. While fossil fuels still dominate America's energy system, it is now possible for more and more Americans to envision a future in which most of the daily tasks of life can be powered with clean, renewable energy.

The growth of renewable energy in the United States is inspiring, but it is no accident. It is built on the foundation of decades of research and strong public policies that have helped to bring exciting clean energy technologies out of the lab and into our communities.

This report describes the dramatic growth of renewable energy and clean energy technologies across America – a shift that has touched every corner of America. Yet there remains much work to be done to convert the promise of renewable energy into the cleaner, healthier and more sustainable future we now know is possible.

It is time for America to redouble its commitment to a clean energy future – and adopt the public policies that can make it a reality.

Clean energy technologies are booming across America

In the last 10 years, the U.S. has made rapid progress toward repowering our economy with clean, renewable energy.

Ten years ago, key clean energy technologies were limited to niche markets and only just beginning to gain momentum. Today, the rapid adoption of wind and solar power and energy efficiency technologies – along with the emergence of electric vehicles and energy storage – provides a glimpse of what is possible in the transition to an economy powered entirely with clean, renewable energy.

Solar energy has grown 23-fold since 2011

Energy from the sun is emission-free and virtually unlimited: enough sunlight hits the earth every hour to supply the world's energy needs for an entire year.[17]

Despite its abundance, tapping into solar energy for electricity was difficult and prohibitively expensive for most people until the early part of the 21st century. By 2011, years of intensive research, along with pioneering pro-solar policies adopted by states such as California and New Jersey, had begun to pave the way for increased adoption of solar energy. In 2011, solar energy accounted for 0.14% of America's electricity, or enough to power nearly 530,000 of today's average American homes.[18]

The pace of solar adoption in the U.S. has been accelerating. In 2016, the U.S. saw its millionth solar panel installation; the 2 millionth installation came just three years later, in 2019.[19] In 2021, the U.S. passed the benchmark of 3 million solar panel installations.[20]

What is clean, renewable energy?

Not all renewable energy sources have equal benefits for the environment. Some forms of biomass and hydroelectric power, for example, can create serious environmental problems. Truly clean, renewable energy is:

- Virtually pollution-free, producing little to no global warming pollution or health-threatening pollution;
- Inexhaustible, coming from natural sources that are regenerative or practically unlimited. No matter how much we use, there will always be more;
- Safe, with minimal impacts on the environment, community safety and public health, and those impacts that do occur are temporary, not permanent; and,
- Efficient, representing a wise use of resources.

Although all energy sources must be deployed responsibly, solar and wind energy generally meet these criteria, as do many types of ocean, tidal, river current and geothermal energy. Energy efficiency technologies also count as "clean energy" – delivering continuous environmental benefit at limited to no environmental cost.

In 2020, solar power generated 2.3% of America's electricity, over 23 times as much as in 2011, and a 24% increase from 2019.[21] Solar power provided enough electricity to power over 12.4 million homes, or more electricity than was produced by power plants in all of New England that year.[22]

Solar energy is growing both in small-scale residential installations and in utility-scale plants. Small-scale solar grew over 10-fold from 2011 to 2020, and utility-scale solar grew 50-fold in the same period.[23] America is projected to add 15.4 GW of new utility-scale solar power by the end of 2021, accounting for 39% of the nation's new electricity generating capacity. That is an increase of 28% compared with the nearly 12 GW of new utility-scale capacity installed in 2020.[24]

California has the largest market for solar power in the country, and has been a long-time model of renewable energy adoption.[25] California's installed solar capacity provides almost a quarter of the state's electricity, enough to power over 4.5 million typical American homes.[26] The Million Solar Roofs Initiative, adopted in 2006 and largely completed a decade later, was a major driving force for accelerating solar growth in the first half of the decade, growing California's solar capacity more than 12-fold.[27] California has also adopted policies to ensure that homeowners and businesses investing in solar power are fully compensated for the benefits they deliver to the environment, society and the grid. Among those policies is "net metering," which has played an important role in supporting the growth of solar power in the territories of the state's three major investor-owned utilities.[28] California has also committed to further growth in solar by adopting a requirement stating that all new homes built in California must have solar.[29]

Texas is expected to experience a solar boom in upcoming years. In 2020, Texas installed 2.5 GW of solar capacity, and is expected to install another 10 GW by 2023.[30] The growth in utility-scale solar power in states like Texas, as well as Arizona, Nevada and other sunny states, is driven in part by the rapidly declining cost of solar power, as well as policies both incentivizing and requiring solar production.[31]

Many of the states with the most rapid solar energy growth – including Massachusetts and New Jersey – have also benefited from a suite of strong solar policies. Solar carve-outs in renewable electricity standards set solar energy adoption requirements, and policies such as net metering ensure that solar PV system owners are appropriately compensated for the energy they supply to the grid.[32]

TABLE 1: TOP STATES FOR SOLAR ELECTRICITY GROWTH, 2011 TO 2020[34]

State	Solar electricity net generation (GWh)		Growth from 2011-2020 (GWh)	Rank by increase
	2011	2020		
California	2,635	48,012	45,377	1
Texas	77	9,519	9,442	2
North Carolina	35	9,293	9,258	3
Arizona	477	8,922	8,445	4
Florida	160	7,677	7,517	5
Nevada	341	6,142	5,801	6
Georgia	25	4,230	4,205	7
Massachusetts	82	3,905	3,823	8
New Jersey	644	4,117	3,473	9
New York	97	3,422	3,325	10

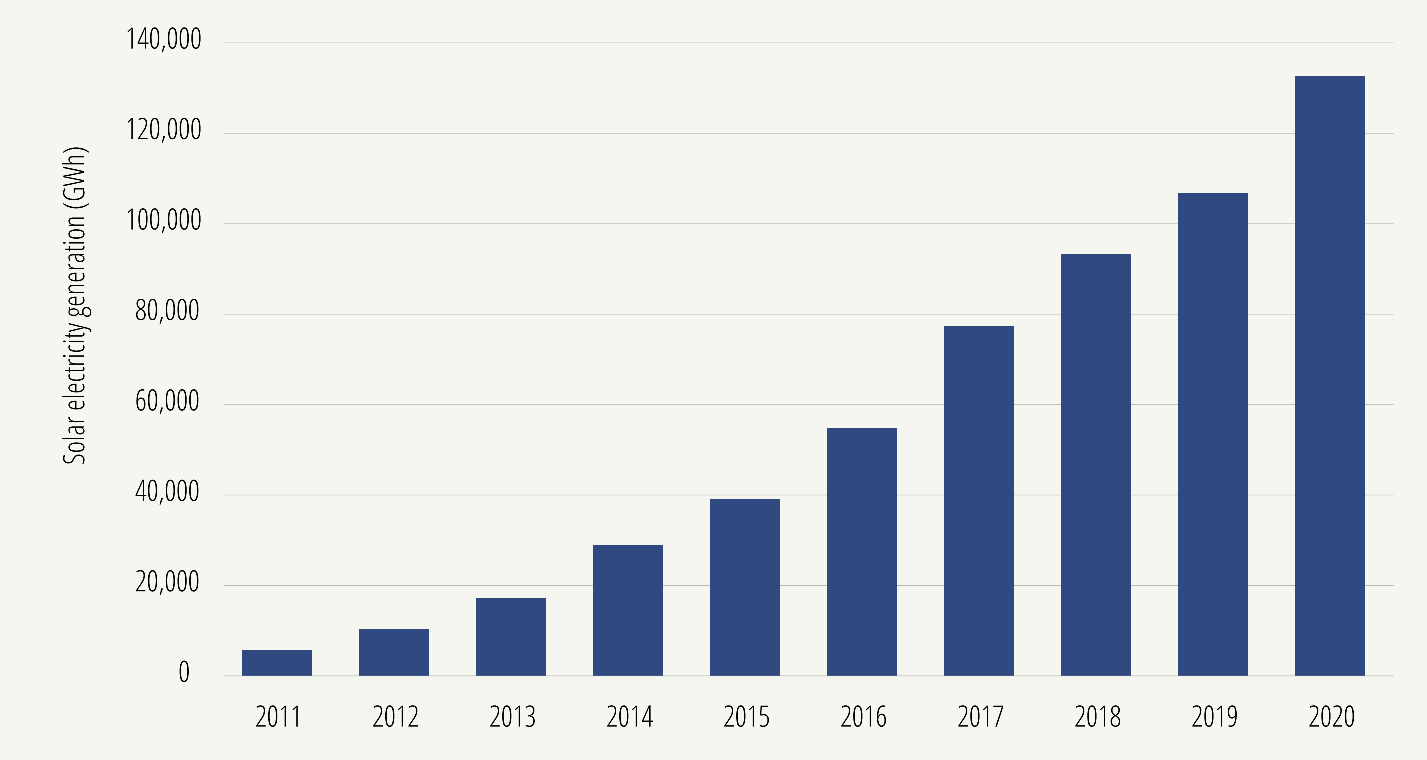

Figure 1: Solar electricity generation grew more than 23-fold from 2011 to 2020[33]

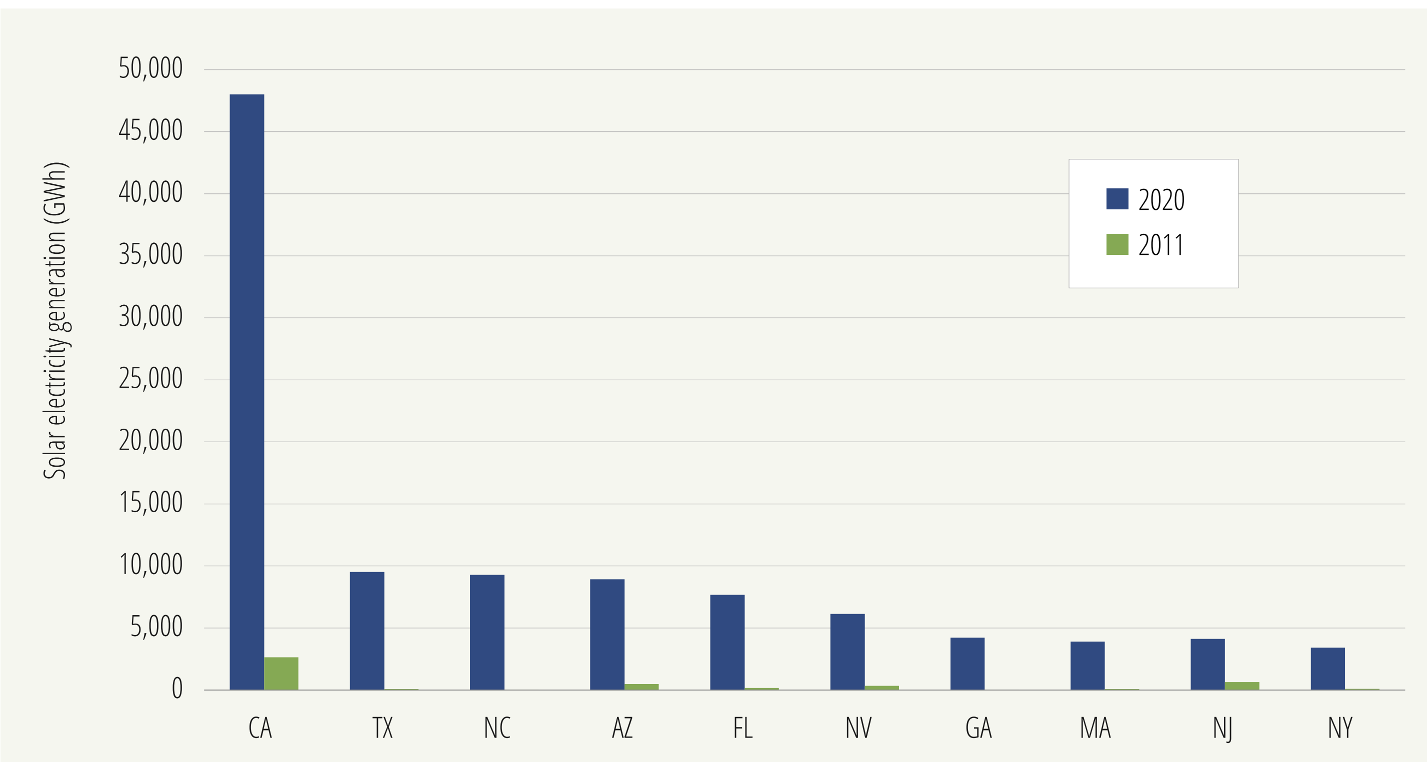

Figure 2: Solar energy production, top states, 2011-2020[35]

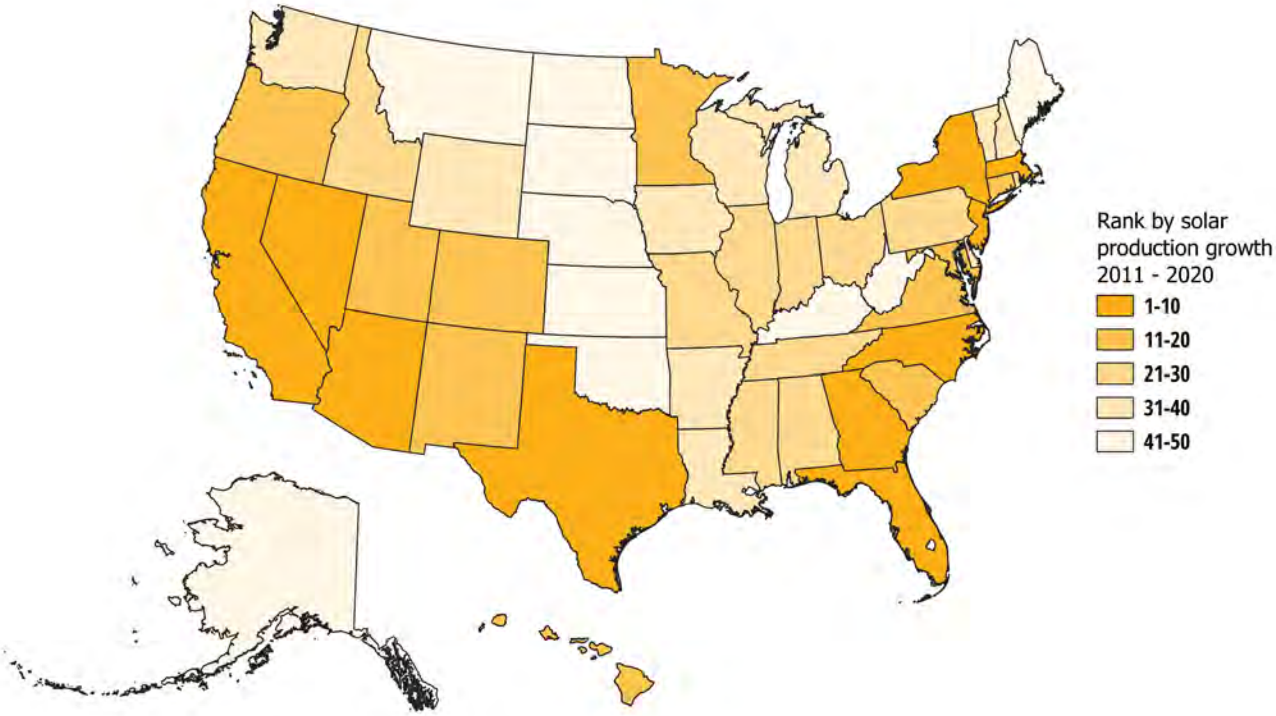

Figure 3: America's top states for growth in solar energy production since 2011[36]

Wind energy has nearly tripled since 2011

Like sunlight, wind is abundant and emission-free, and wind energy has experienced dramatic growth over the last decade.

Wind power is not a new concept. People have used windmills to do work for more than 1,000 years, and the first electricity-generating wind turbine was built in the late 19th century. By 2011, wind energy generation was gaining momentum, producing 3% of America's energy that year, enough to power over 11 million homes.[37]

The last decade has seen dramatic growth in wind energy. From 2011 to 2020, American wind generation nearly tripled.[38] In 2020, wind produced 8.4% of America's electricity, enough to power over 31.6 million homes.[39]

The past decade also saw the construction of America's first offshore wind farm, the 30 MW Block Island Wind Farm off the coast of Rhode Island, which began operation in 2016.[40] More recently, in 2021, Vineyard Wind received approval to build an 800 MW wind farm off the coast of Massachusetts.[41] The project will include 62 GE Haliade-X turbines, among the largest-capacity offshore turbines worldwide.[42] A number of other offshore projects are planned for later years.[43]

The United States has the technical potential to produce more than 7,200 terawatt-hours (TWh) of electricity from offshore wind, which is almost two times the amount of electricity the U.S. consumed in 2019 and about 90% of the amount of electricity the nation would consume in 2050 if we transitioned our buildings, transportation system and industry to run on electricity instead of fossil fuels.[44] The Department of Energy has set a goal of 30 GW of offshore wind power in operation by 2030, significantly more than the current 42 MW capacity.[45] With an ambitious goal in place, upcoming projects in the pipeline, and growth in the domestic supply chain, the U.S. is poised to soon become a major producer of offshore wind turbines and of power from offshore wind.[46]

Midwest and Southwest states have led the nation in growth of wind energy. From 2011 to 2020, Texas, Oklahoma and Iowa were the leading states in additions of wind power. Wind generation more than tripled in Texas and Iowa, and quintupled in Oklahoma.[47]

Texas dominates wind energy generation in the U.S., producing a quarter of the nation's wind energy, the equivalent of nearly 21% of all electricity sold in Texas in 2019.[48] Texas' wind energy growth was initially triggered by the renewable electricity standard it established in 1999, and more recent growth was enhanced by a $7 billion investment in the state grid, completed in 2013, which allowed for the transmission of wind energy from the state's windiest regions to its biggest cities.[49] Texas also benefits from tax exemptions and deductions for wind energy-generating properties and businesses.[50]

TABLE 2: STATES WITH MOST ADDITIONAL WIND GENERATION, 2011 VS. 2020 (GWH)[52]

State	Net wind electricity generation (GWh)		Growth from 2011-2020 (GWh)	Rank by increase
	2011	2020		
Texas	30,548	92,989	62,441	1
Oklahoma	5,605	29,572	23,967	2
Iowa	10,709	34,149	23,440	3
Kansas	3,720	23,513	19,793	4
Illinois	6,213	17,111	10,898	5
North Dakota	5,236	13,183	7,947	6
Nebraska	1,051	8,710	7,659	7
Colorado	5,200	12,727	7,527	8
Michigan	456	6,759	6,303	9
California	7,752	13,645	5,893	10

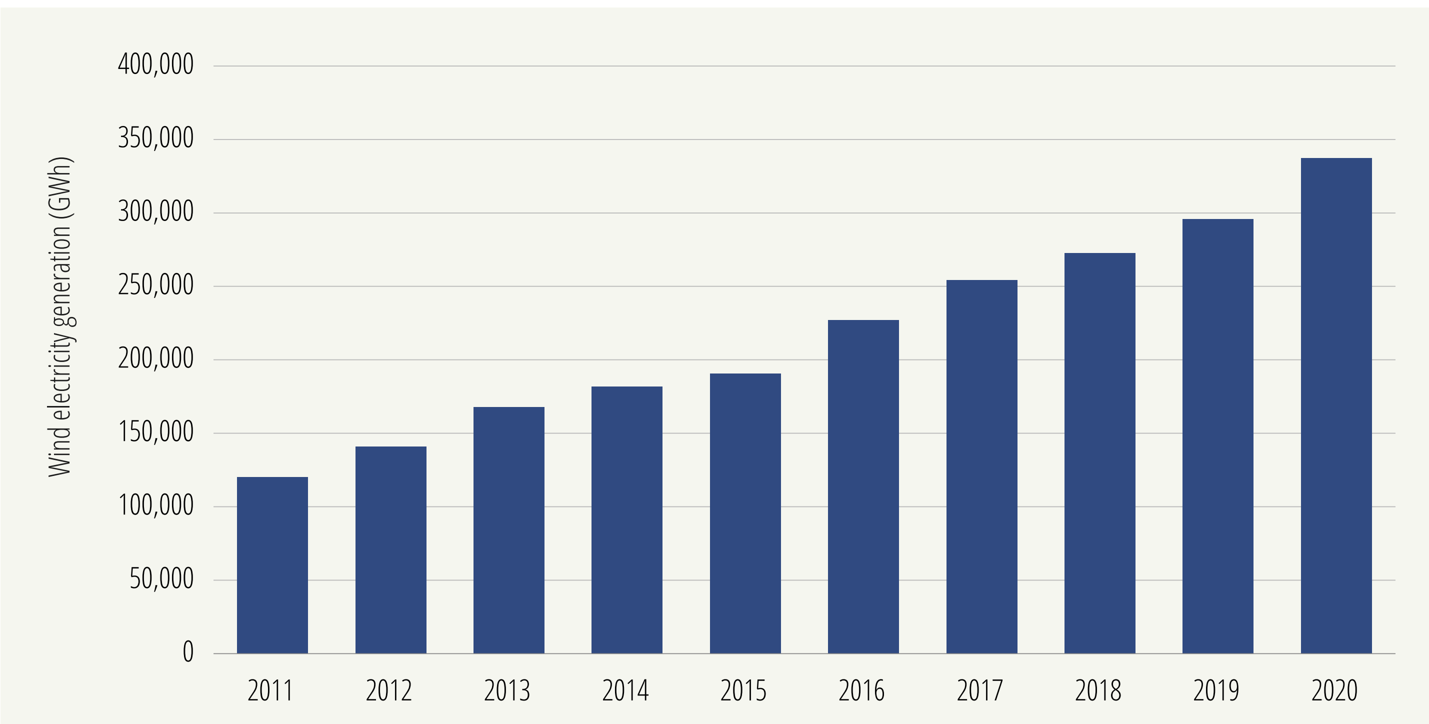

Figure 4: U.S. wind energy production nearly tripled from 2011 to 2020[51]

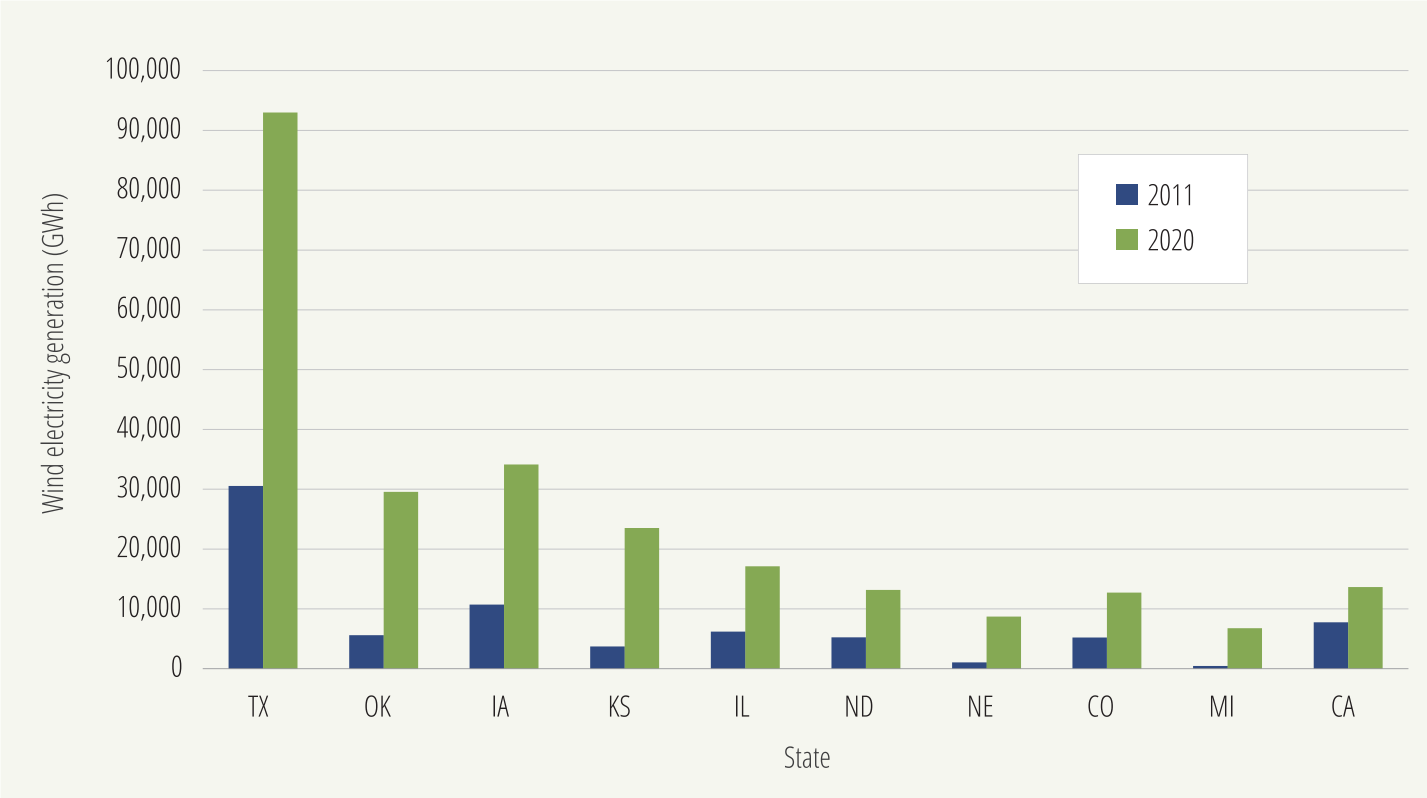

Figure 5: Wind energy production, top states for wind energy growth, 2011-2020[53]

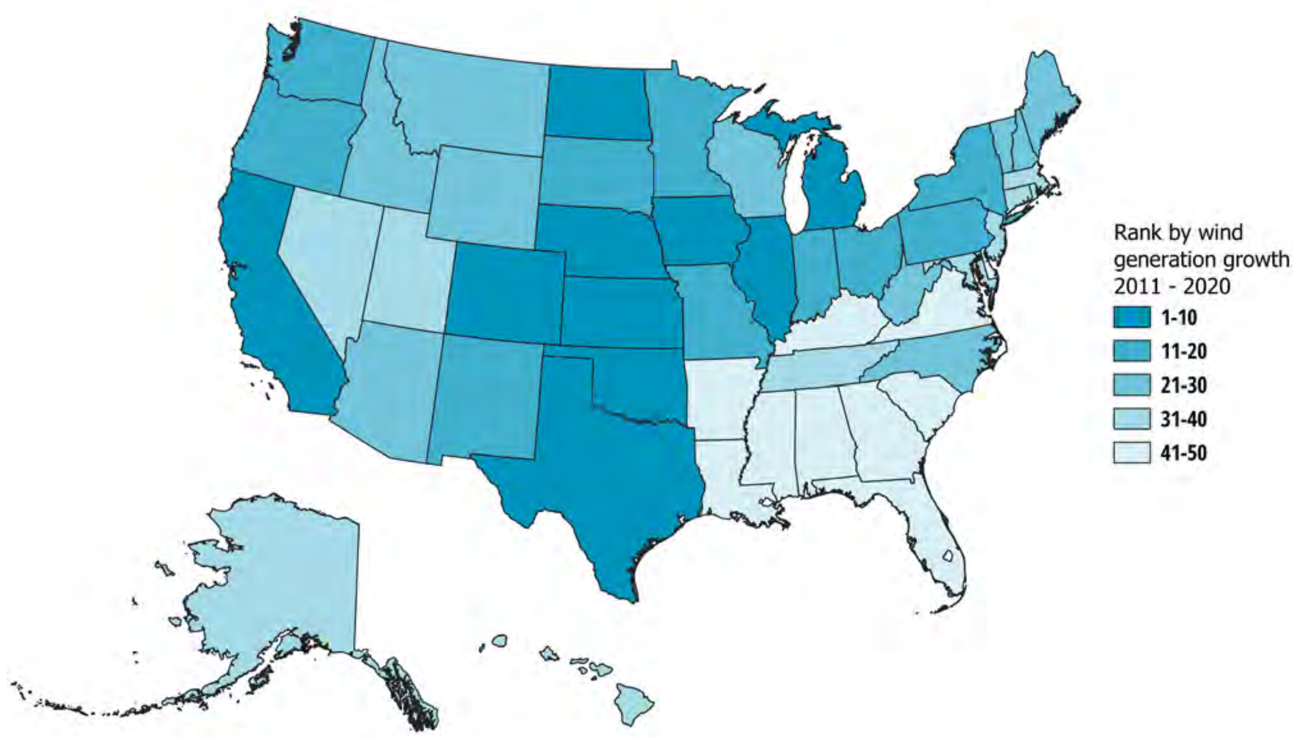

Figure 6: America's top states for wind energy growth since 2011[54]

Three states now produce wind and solar power equivalent to 50% of the electricity they consume

With falling energy use and expanding wind and solar generation, renewable energy now accounts for a significant percentage of U.S. electricity use. In 2020, wind and solar power produced 11% of all U.S. electricity generation.[55] In 2020, 16 states generated wind and solar energy equivalent to at least 20% of the electricity they consumed.[56] Three states – Iowa, North Dakota and Kansas – generated wind and solar power equivalent to at least half of their electricity needs.

TABLE 3: TOP 10 STATES BY WIND AND SOLAR GENERATION AS PERCENTAGE OF ELECTRICITY CONSUMPTION[57]

State	Wind and solar generation (GWh)	Retail electricity sales (GWh)	Wind and solar generation as % of electricity sales	Rank, by percentage
Iowa	34,384	49,805	69.0%	1
North Dakota	13,184	21,377	61.7%	2
Kansas	23,620	38,425	61.5%	3
Oklahoma	29,669	61,790	48.0%	4
South Dakota	5,608	12,498	44.9%	5
New Mexico	9,257	25,179	36.8%	6
Wyoming	5,321	15,330	34.7%	7
Nebraska	8,792	30,244	29.1%	8
Hawaii	2,321	8,713	26.6%	9
Colorado	14,947	56,375	26.5%	10

America continues to become more energy efficient

The task of moving to 100% clean, renewable energy can be made dramatically cheaper and easier by reducing the amount of energy wasted in inefficient buildings, cars and equipment.

Between 1950 and 2007, total energy use in the United States nearly tripled. Since then, however, energy use in the United States has stayed roughly the same, despite a growing population and economy. On a per capita basis, energy consumption in the U.S. fell nearly 2% from 2011 to 2019.[58] America experienced a sharper decline in energy use – of 7% – between 2019 and 2020 as the nation experienced widespread shutdowns and disruptions due to the COVID-19 pandemic.[59] In 2020, primary energy consumption in the U.S. was 282 million Btu per capita – the lowest consumption since 1965.[60]

Will 2020 spark new energy-saving trends?

In 2020, the world was struck by the COVID-19 pandemic, leading to business shutdowns, stay-at-home orders, and a severe economic slump. Energy consumption declined dramatically. Some energy savings improvements over the past year are likely temporary. But some of the changes brought about by the pandemic may continue, influencing energy consumption – in either a positive or negative direction – for years to come.

- **Commuting:** 2020 saw an immediate and drastic decrease in travel, especially travel to work. The number of vehicle-miles traveled fell by 13% from 2019 to 2020, while transit ridership fell by 65% in the second half of 2020 compared to pre-pandemic levels.[61] Many workplaces shifted to remote work: an October 2020 Pew Research Center poll found that, among workers whose jobs could mainly be done from home, 71% were working fully remotely, compared to one in five before the pandemic.[62] Many companies are planning to continue with some form of remote work even after the end of the pandemic.[63] The impact of remote work on overall energy consumption is unclear – while most studies suggest that it reduces energy use, some studies suggest that it may have little effect or even increase energy consumption.[64] Maximizing energy savings from telecommuting may require new approaches, such as improving residential energy efficiency and enabling more non-commute car trips to be replaced by transit, biking and walking.
- **Commercial energy efficiency:** A secondary effect of work-from-home is the reduction in demand for office space in urban downtowns and suburban office parks alike. The efficiency with which those spaces are used – or the ability to convert them to other uses – may have long-term effects on energy consumption and the effectiveness of energy efficiency and clean energy policies targeting those buildings.
- **Retail and delivery:** The pandemic also accelerated the growth of online retailers like Amazon and the demise of traditional "brick and mortar" retail. The energy consumption impacts of delivery services like Amazon are – like the impact of telecommuting – uncertain, and dependent on the degree to which delivery replaces trips to the store that would otherwise be taken in cars, the efficiency of the delivery process itself, and other factors.[65] Efforts to electrify and improve the efficiency of the delivery process, minimize the environmental footprint of distribution centers and other infrastructure of the online economy, and repurpose existing retail space in sustainable ways are likely to become more important in the years to come.

The COVID-19 pandemic changed how Americans live their lives in ways that will continue to have ripple effects long after the pandemic is over. Policy-makers must pay attention to those trends, and do their best to ensure that the progress made toward clean energy and energy efficiency continues after the pandemic ends.

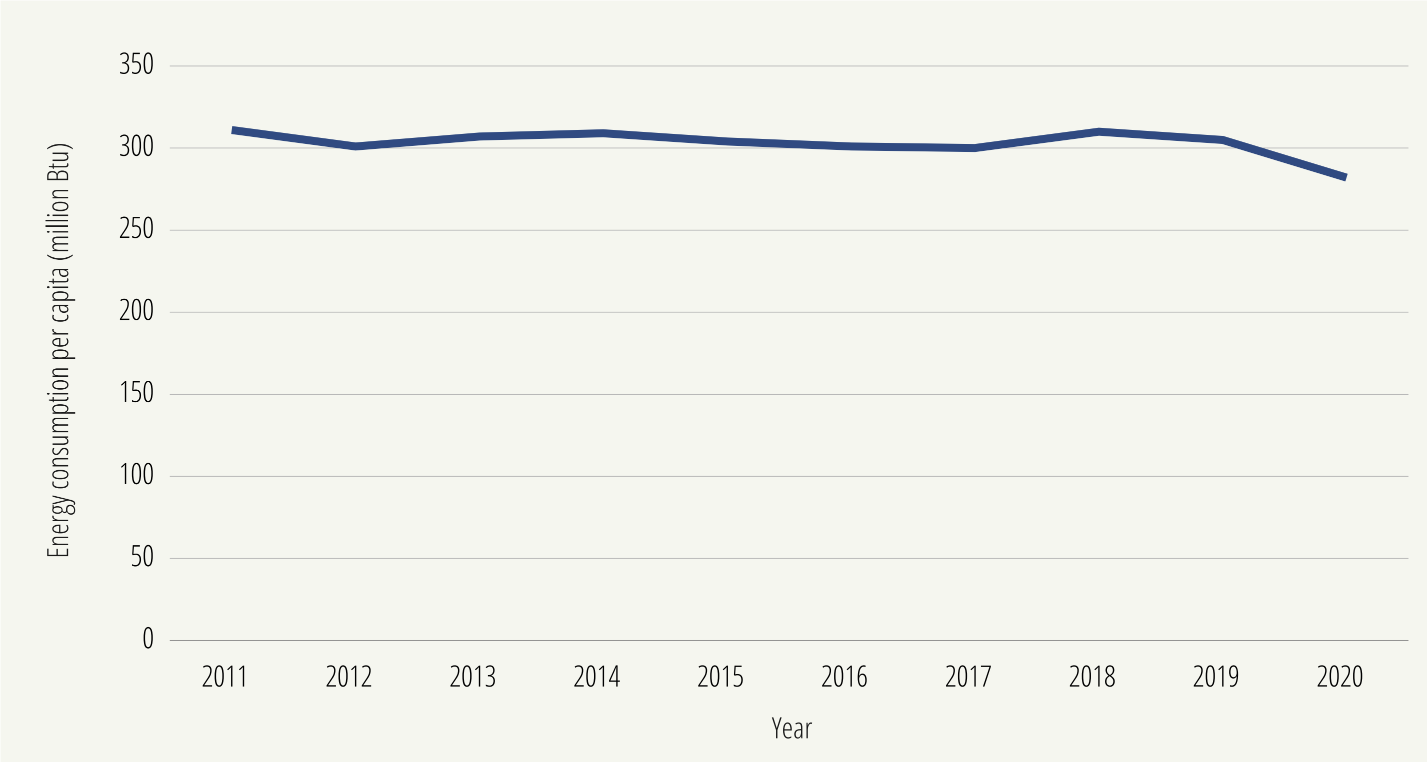

Figure 7: U.S. per capita primary energy consumption has decreased by 9% since 2011, including the impact of COVID-19[66]

From 2011 to 2020, energy consumption per unit of Gross Domestic Product (GDP) fell by more than 17%, even as U.S. GDP increased by 14%.[67]

Energy consumption can vary due to a number of factors – including weather and economic trends – but public policy has played an important role in helping to reduce energy consumption in the U.S.

- Federal fuel economy standards have led to more efficient vehicles.[68] In 2011, the average fuel economy of a new, light-duty vehicle was 22.3 miles per gallon.[69] In 2020, the average fuel economy was 25.7 miles per gallon – an improvement of 15%.[70] Fuel efficiency standards are continuing to improve as new policies come into effect. In August 2021, the U.S. National Highway Traffic Safety Administration (NHTSA) proposed new vehicle emission standards on passenger cars and light trucks made between 2024 and 2026 that would increase standards by 8% annually.[71]
- According to a survey by the American Council for an Energy-Efficient Economy (ACEEE), electricity efficiency programs across the U.S. saved 17% more energy in 2019 than in 2011, as states ramped up investments in efficiency.[72] Energy efficiency measures installed through these programs in 2019 delivered savings of 26.9 million megawatt-hours (MWh) of electricity, enough to power almost 2.5 million homes.[73]
- Energy efficiency policies, including the federal Energy Independence and Security Act of 2007, have driven adoption of efficient appliances and lighting, including light emitting diode (LED) lighting.[74] From 2016 to 2018, the percentage of all installed lighting consisting of LED lights increased from 14.9% to 30%.[75] By 2035, the Department of Energy estimates that LEDs could save 569 terawatts of electricity, equivalent to the annual production of 92 large power plants.[76]
- Utility and state efficiency programs have been able to prevent the usage of vast amounts of natural gas, which contains methane, a powerful greenhouse gas.[77] While making gas appliances and systems more efficient can help avoid more carbon dioxide and methane emissions, a truly carbon-free society

will have to run primarily on electric power in order to be reliant on exclusively renewable sources, necessitating that traditional gas efficiency programs prioritize improving building shells and fuel-switching to electricity over the installation of equipment that will prolong our dependence on gas.

- Building energy codes play a big part in reducing building energy use; residential and commercial buildings account for almost 40% of U.S. energy consumption.[78] Many states have either implemented or updated building energy codes in recent years.[79] In 2014, building energy codes saved approximately 1.1 quadrillion Btu.[80] The updated version of the International Conservation Energy Code (IECC) issued in 2020 is expected to improve the energy efficiency of new commercial and residential buildings by about 10% compared to the previous version of the code.[81]

ACEEE produces an annual scorecard of state progress in energy efficiency. ACEEE's data on energy efficiency reveals improvements in state-level programs and policies to reduce electricity use. Maryland, Rhode Island and Massachusetts saw the greatest increases in electricity efficiency savings as measured by percentage of retail sales. California, Massachusetts, Vermont, Rhode Island and New York were ranked as the top five states on the ACEEE 2020 State Energy Efficiency Scorecard, and were among the top eight states in 2019 energy efficiency savings as a percentage of 2018 retail sales.[82]

California's savings increased by about 1 million megawatt-hours (MWh) from 3.4 million MWh annually in 2011 to about 4.4 million MWh in 2019, according to ACEEE, the most savings of any state that year.[83] California has adopted strong building energy codes and appliance efficiency standards, leading energy efficiency efforts at a national level and serving as a model for other states. In 2020, California increased investments in high-efficiency heat pump water heaters, updated its building energy code, and improved appliance standards for light bulbs.[84]

New York has an ambitious energy savings goal of 185 trillion Btu by 2025 and has enacted policies to support that goal.[85] In 2020, New York adopted the NYStretch Energy Code, which serves as an improvement upon the state building code efficiency standards by 11%.[86] New York City, as well as a number of other municipalities, have adopted the code.[87] New York City, Washington, D.C., St. Louis and other cities and states have also adopted mandatory building performance standards for large commercial buildings.[88]

TABLE 4: MOST IMPROVED STATES FOR ELECTRICITY EFFICIENCY, BASED ON ACEEE STATE ENERGY EFFICIENCY SCORECARDS[89]

State	Energy efficiency savings 2019 (% of retail sales)	Energy efficiency savings 2011 (% of retail sales)	Change (percentage points)	Rank, by increase
Maryland	2.14	0.58	1.56	1
Rhode Island	2.51	1.25	1.26	2
Massachusetts	2.25	1.43	0.82	3
Illinois	1.44	0.67	0.77	4
Arkansas	0.63	0.13	0.50	5
Michigan	1.41	1.00	0.41	6
California	1.74	1.35	0.39	7
Colorado	0.95	0.65	0.30	8
New Hampshire	0.93	0.64	0.29	9
North Carolina	0.64	0.39	0.25	10 (tied)
Oklahoma	0.45	0.20	0.25	10 (tied)

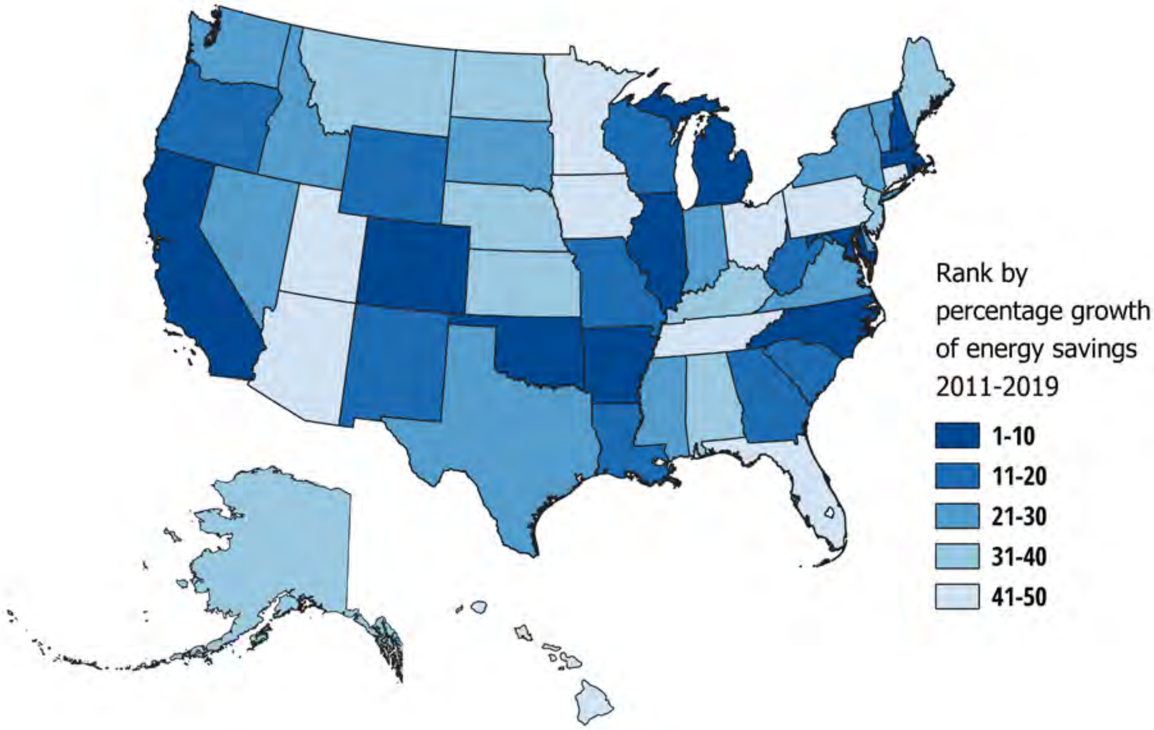

Figure 8: America's top states for electricity efficiency gains, 2011-2019 (data: ACEEE)

Heat pump technology continues to improve

Energy efficiency investments will play an important role in the transition from natural gas to electricity for heating and cooling buildings. The technology for electric heat pumps has improved dramatically in recent years, to the point that they are now a viable heating system across America, even in cold climates.[90] To achieve a zero-carbon future, buildings across the nation will need to transition to an electric source of heat within the next couple of decades. Already, states like Maine and Vermont have established ambitious goals that will result in more electric heating systems.[91]

In 2019, nearly 20 million residential heat pump systems were sold globally.[92] Instead of heating or cooling air like other temperature regulation systems, heat pumps move air to warm or cool a space. Air-source heat pumps, the most common system used, move air between the inside and outside of a home. Air-source heat pumps can save about half the electricity used to heat the same space with electric resistance heat sources like electric baseboard heaters or furnaces.[93] On average, heat pumps can save $1,287 annually in electricity costs and 7.6 tons of carbon emissions compared to baseboard heaters.[94]

Heat pumps are becoming much more common around the United States. In 2015, 12% of all U.S. homes with heating used heat pumps, up from just 8% a decade earlier.[95] Shipments of efficient air-source heat pumps from U.S. manufacturers nearly doubled between 2011 and 2020, increasing by 10% in 2020 alone.[96]

The efficiency of heat pumps has improved to the point where they are a realistic and comfortable option for heating homes in all climates. Cold winters in northern climates of the U.S. have historically limited heat pump adoption, but more robust systems specifically designed for cold climates have kickstarted the transition to clean heating, even in the coldest states. To transition the 84% of New York homes using fossil fuels for heating to electricity, New York started the NYS Clean Heat program in 2020, which incentivizes heat pumps for both contractors and customers through rebates for systems designed for cold weather, as well as funding for workforce and consumer training.[98] In 2019, Maine set a goal to install 100,000 more heat pumps by 2025, and has supported that goal with financial incentives.[99] Efficiency Maine provides rebates for residential, low-income and commercial customers.[100]

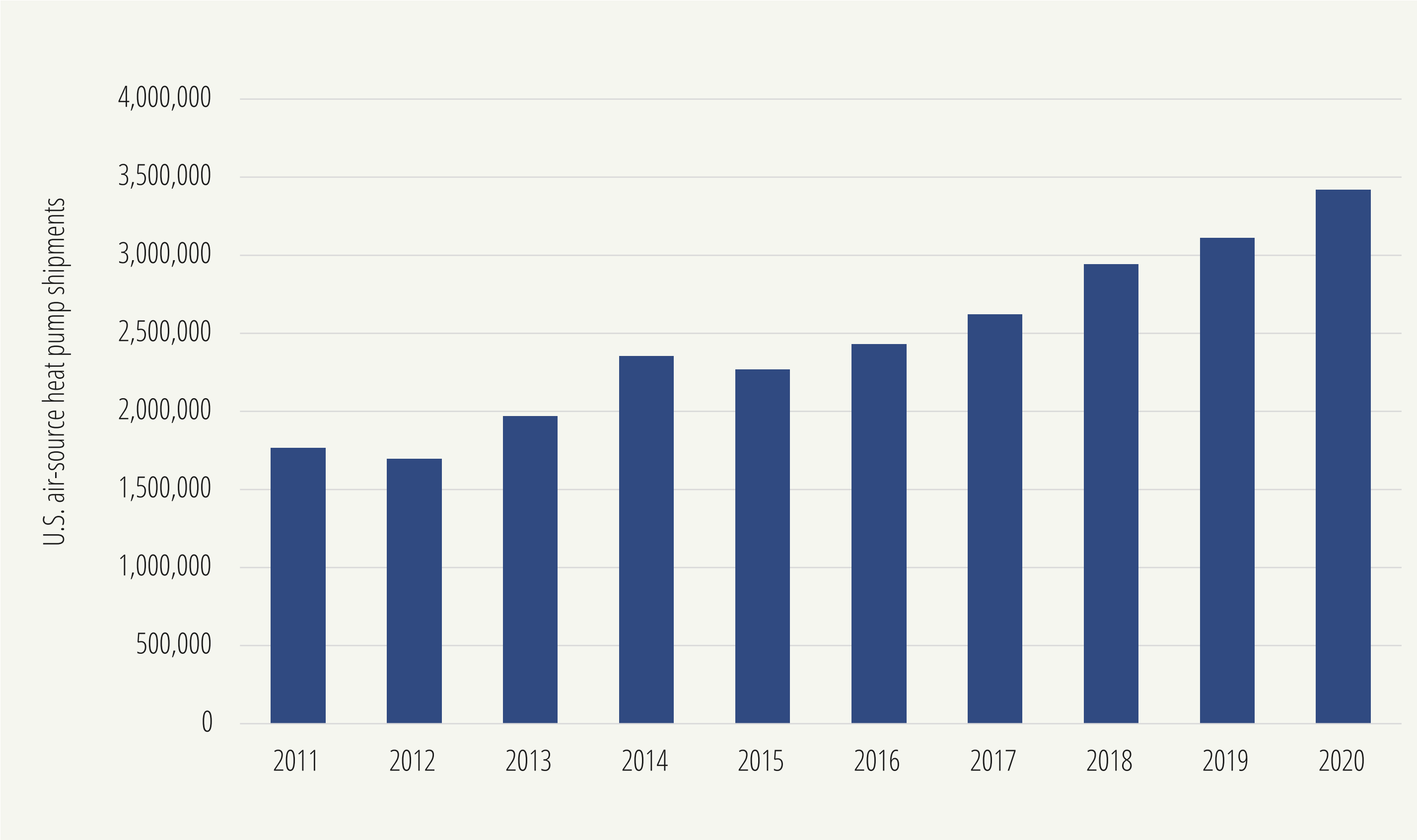

Figure 9. Shipments of air-source heat pumps from U.S. manufacturers[97]

More than 2 million plug-in electric vehicles have been sold

Achieving an economy powered by 100% renewable energy means ending the use of fossil fuels for all activities, not just the generation of electricity. That means ending the use of petroleum for transportation – a sizable task, given that it currently powers the overwhelming majority of our vehicles. There are several strategies for reducing transportation fossil fuel use – such as encouraging public transportation, walking and biking. But as long as Americans continue driving cars and trucks, adopting electric vehicles (combined with a renewable electric grid) is a necessity.

The first modern electric vehicles (EVs) did not appear on American roads until the late 2000s, and as late as 2010 the number of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) on American roads was in the hundreds.

However, 1.7 million plug-in EVs had been sold in the U.S. as of the end of 2020.[101] By mid-2021, plug-in electric vehicle sales had surpassed 2 million.[102] The availability of models expands every year, with 55 models currently available, ranging from the Toyota RAV4 Prime to the Jaguar I-PACE.[103] By the end of 2024, automakers plan to have almost 100 different models of EVs on the market.[104] In spite of a severe economic downturn, over 318,000 EVs were sold in 2020, nearly 20 times as many as in 2011.[105]

California leads the nation in electric vehicle adoption. Nearly half of all EVs ever sold in the country have been sold in California.[106] Six of the states leading the nation in EV sales – California, New Jersey, New York, Colorado, Washington and Massachusetts – have requirements that a certain percentage of each automaker's sales be zero-emission vehicles.[107] All of the top 10 offer a rebate or grant towards EV purchases.[108]

TABLE 5: TOP STATES FOR CUMULATIVE ELECTRIC VEHICLE SALES THROUGH 2020[110]

State	Battery electric vehicle sales	Plug-in hybrid sales	All plug-in vehicle sales (battery electric and plug-in hybrid)	Rank, by number of sales
California	467,441	304,980	772,421	1
New York	36,578	42,641	79,219	2
Florida	55,105	22,292	77,397	3
Washington	49,291	16,320	65,611	4
Texas	36,460	17,828	54,288	5
New Jersey	30,685	18,490	49,175	6
Georgia	36,866	7,614	44,480	7
Massachusetts	21,925	17,269	39,194	8
Illinois	26,574	11,474	38,048	9
Colorado	25,961	10,860	36,821	10

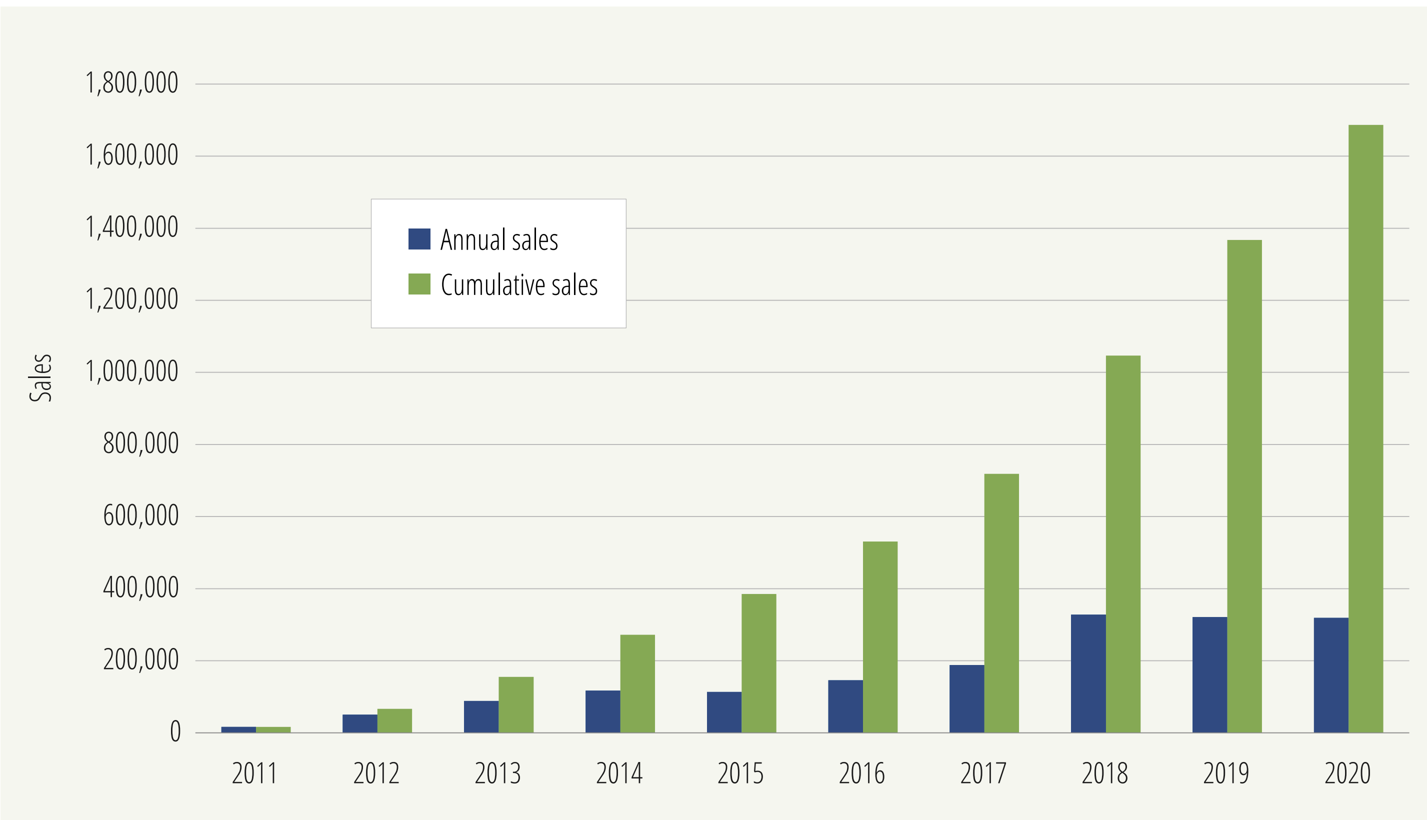

Figure 10: Cumulative electric vehicle sales reached 1.7 million in 2020[109]

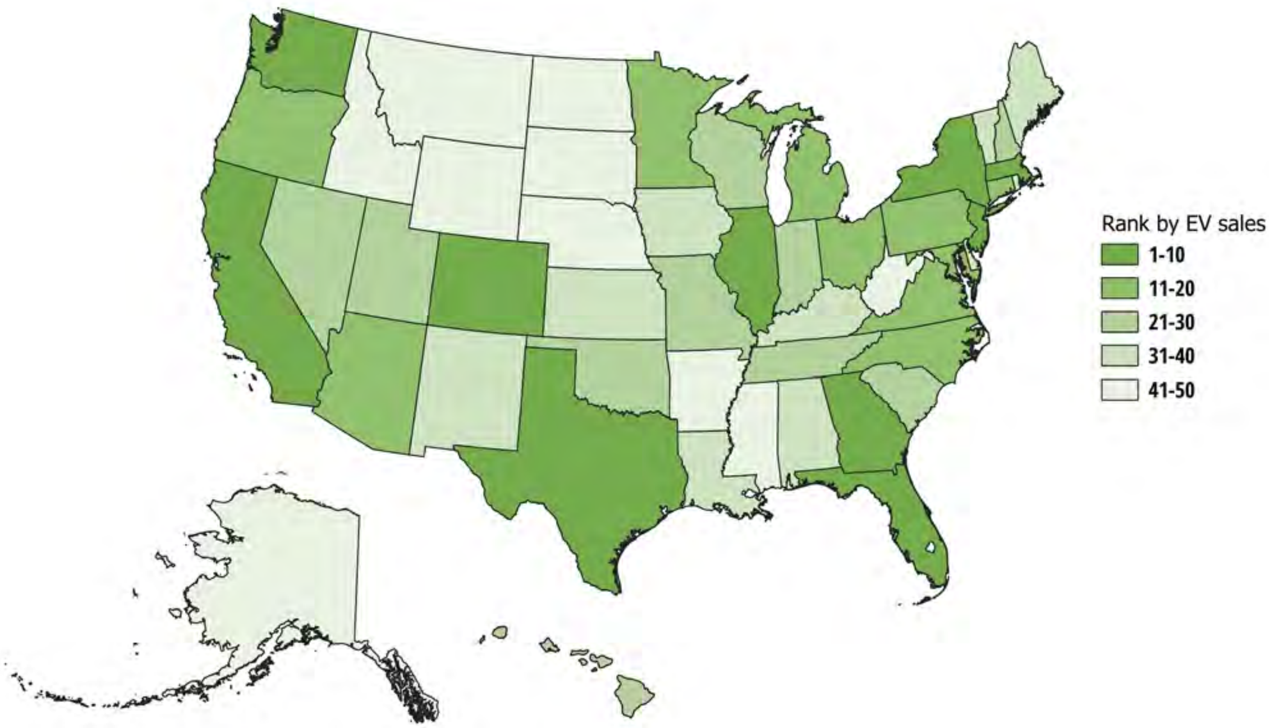

Figure 11: America's top states for electric vehicle sales through 2020

Recent years have also seen the widespread deployment of electric vehicle charging stations across the country. Currently there are more than 100,000 charging ports, located in more than 44,000 stations across the country, including along major highways.[111]

TABLE 6: TOP STATES FOR PUBLIC EV CHARGING PORTS AS OF SEPTEMBER 2021[112]

State	EV charging ports	Rank, by number of ports
California	34,219	1
New York	6,554	2
Florida	5,656	3
Texas	4,940	4
Massachusetts	4,118	5
Washington	3,769	6
Georgia	3,753	7
Colorado	3,356	8
Maryland	2,825	9
Virginia	2,507	10

Battery energy storage has grown 18-fold since 2011

America has vast resources of clean, renewable energy, but taking full advantage of that potential requires an energy system that can accommodate daily and seasonal variations in the availability of energy sources such as solar and wind power. Many strategies can be used to integrate renewable energy into a reliable grid. Upgrades to the U.S. transmission system to create an interconnected national grid could allow wind energy to be sent from the western plains to East Coast cities when needed. The use of "smart grid" technology can allow real-time changes in energy use to reduce demand during times of lower generation. In the long run, it may be economical and prudent to build sufficient wind and solar capacity to provide adequate generation even on days when there is less sun and wind.[122]

Energy storage technologies can also help to enable a 100% renewable energy future. Energy storage technologies like batteries can smooth the deployment of renewable energy by storing excess energy for later use. When the sun shines during the day, excess energy

Electrified transit

Like electric passenger cars, electric buses have the potential to help cities reduce pollution and cut carbon emissions. Currently, most buses run on diesel, which produces emissions that not only contribute to global warming but may also cause cancer and other illnesses.[113] Replacing all of America's diesel buses with clean electric buses would avoid an average of 7.3 million tons of greenhouse gas emissions annually.[114] Furthermore, electric buses can also save transit agencies money. A 2020 analysis by researchers with the National Renewable Energy Laboratory (NREL) estimated that transit agencies receiving federal grants for the purchase of four electric buses charged centrally at bus depots could achieve savings of $785,000 over the course of the buses' lifetimes.[115]

The transition to electric buses has already begun. In 2014, the Chicago Transit Authority was the first major transportation agency to deploy an electric bus in its fleet.[116] Three years later, hundreds of electric buses were running across the country and 9% of all transit agencies had an electric bus in service or ordered.[117] King County Metro Transit, which serves Seattle and the surrounding areas, has plans to incorporate 120 electric buses into its fleet in the near term, and has set a larger goal to electrify its entire fleet by 2040.[118] The state of California has made a similar commitment, setting a goal to make the 12,000 transit buses in the state fully electric by 2040.[119] School districts around the country are also beginning to incorporate electric school buses into their fleets. Montgomery County, Maryland, for example, contracted in early 2021 to lease 300 electric school buses, the largest such purchase by an individual school district in the nation at the time.[120]

Electric buses are still a relatively new technology, but they are growing quickly. In 2011, 1.1 MWh of electricity were used in transit vehicles operating on batteries; by 2019, that figure had risen to 23.8 gigawatt-hours (GWh), an indication of the growing number of buses powered by electricity.[121]

can be stored for use at night. Storage also allows for a more flexible grid that can adapt to evolving sources of demand, such as electric vehicles, and new sources of local generation, such as rooftop solar panels. Battery storage can also play an important role in providing backup power that enhances community resilience in the face of disaster without dependence on fossil fuels.

As states begin committing to robust renewable energy standards and carbon-free futures, energy storage can help facilitate their transitions.[123] By 2020, the U.S. had over 24 GW of installed electricity storage capacity.[124] Pumped hydropower storage accounts for the vast majority of the grid storage capacity in the U.S. and the world and was the only major form of energy storage on the U.S. grid as of 2011.[125] In these systems, water is pumped to a higher elevation during periods of surplus generation and allowed to flow back down through a hydroelectric generator when electricity is later needed.

Since 2011, one sector of energy storage has seen dramatic progress: battery storage.

Much of the energy storage added since 2011 has been in the form of battery storage, which increased 18-fold in terms of capacity through 2020.[126] Aided in part by the rise of battery-powered electric vehicles, recent price declines, and technology improvements, batteries have become a viable and flexible option for expanding energy storage capacity. These developments have enabled widespread installations of home and business-scale energy storage – often paired with solar energy – as well as growth in large-scale battery storage by utilities.[127]

Experts predict that improving batteries will propel rapid growth in energy storage in the coming years. BloombergNEF predicts that the cost of utility-scale lithium-ion batteries will fall by 52% between 2018 and 2030, and that the U.S. will exceed 100 GW of installed battery storage capacity by 2040.[128]

Federal policy regulating wholesale electricity markets can have an important influence on the amount of energy storage added to the grid. The Federal Energy Regulatory Commission (FERC) issued Order 841 in 2018, removing barriers to energy storage and allowing storage to compete with fossil fuels to provide capacity to the grid.[129] Among the impacts of the order was the adoption of revised rules for the market participation of energy storage in the PJM regional grid, which covers much of the Mid-Atlantic and parts of the Midwest. The revised rules will allow for participation of a wider variety of types of storage in capacity markets.[130]

At the state level, California, Texas, Illinois, Massachusetts and Hawaii led the nation in battery storage additions from 2011 to 2020. California installed 589.3 MW of capacity between 2011 and 2020, accounting for over a third of the nation's total battery storage capacity.[131] California's aggressive adoption of energy storage was due in part to a California Public Utilities Commission requirement that utilities increase energy storage capacity. Additions also increased rapidly in response to the Aliso Canyon natural gas leak in 2015-2016, for which energy storage was used to minimize grid disruptions.[132] Eight other states have followed California's lead in setting energy storage mandates, goals or targets.[133] In total, as of mid-2020 11,000 MW of new storage systems were outlined in targets, with much of that capacity due to be installed in the next decade.[134]

As climate change spurs extreme weather events, reliable energy backup becomes increasingly critical. In February 2021, Texas's power grid failed, leaving millions without power.[135] Electric vehicles became a critical source for many, enabling some residents to power their homes – or at least recharge battery-powered devices like cellphones – from their car batteries.[136] Automakers are beginning to use the potential to deliver backup power as a selling point for their vehicles, with Ford and Sunrun announcing a partnership in 2021 to market vehicle-to-home technology that could allow homeowners to draw up to three days' worth of emergency power from the batteries of their F-150 Lightning electric trucks.[137]

In March 2021, Tesla started planning for a 100 MW energy storage system located 40 miles outside Houston, which would be able to power about 20,000 homes. Standard & Poor's states that Tesla's project is not alone, with nearly a dozen projects starting this past summer ranging from 50 MW to over 200 MW of capacity.[138]

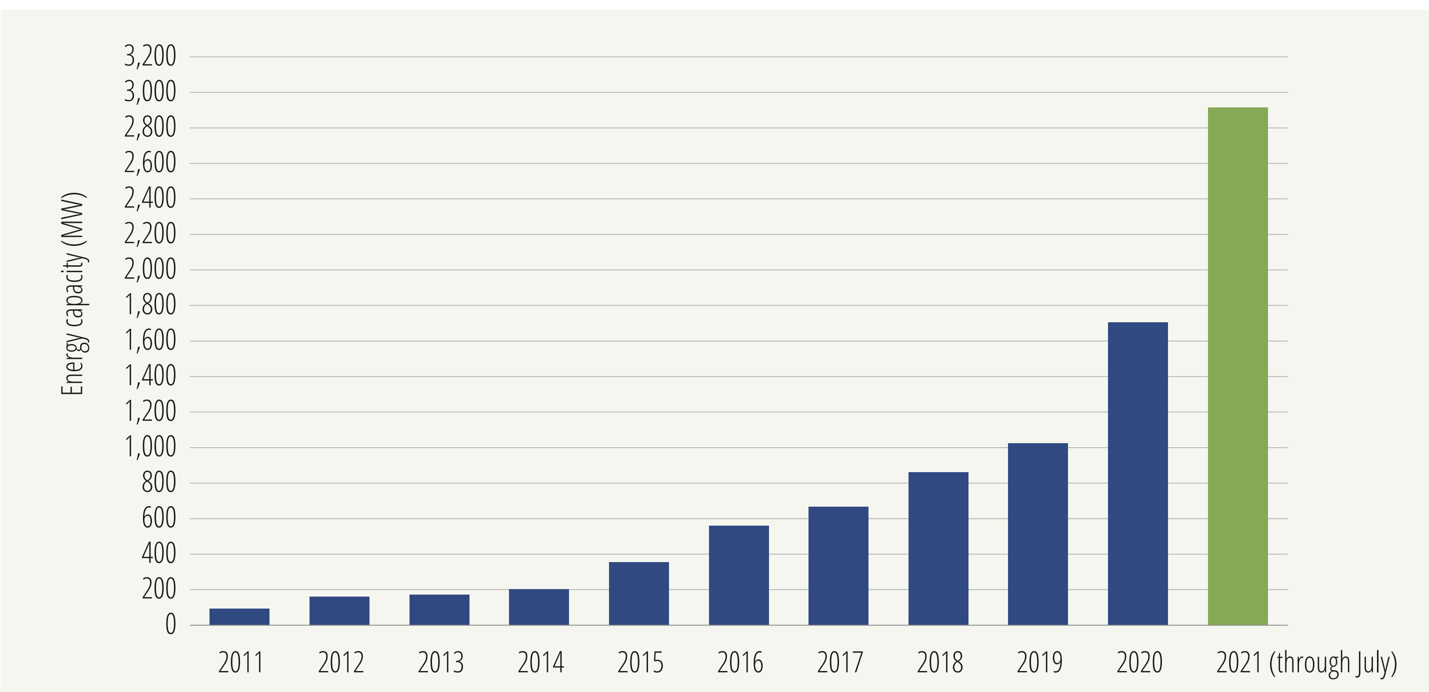

Figure 12: Annual U.S. battery storage capacity[139]

TABLE 7: STATES THAT ADDED THE MOST BATTERY STORAGE, 2011-2020[140]

State	Battery storage nameplate capacity (MW)		Net growth (MW)	Rank, by increase
	2011	2020		
California	0	589.3	589	1
Texas	5	323.1	318	2
Illinois	0	132.7	133	3
Massachusetts	0	70.9	71	4
Hawaii	15	63.0	48	5
Maine	0	43.1	43	6
New Jersey	0	42.6	43	7
Arizona	0	42.0	42	8
New York	11	48.1	37	9
Indiana	2	38.0	36	10

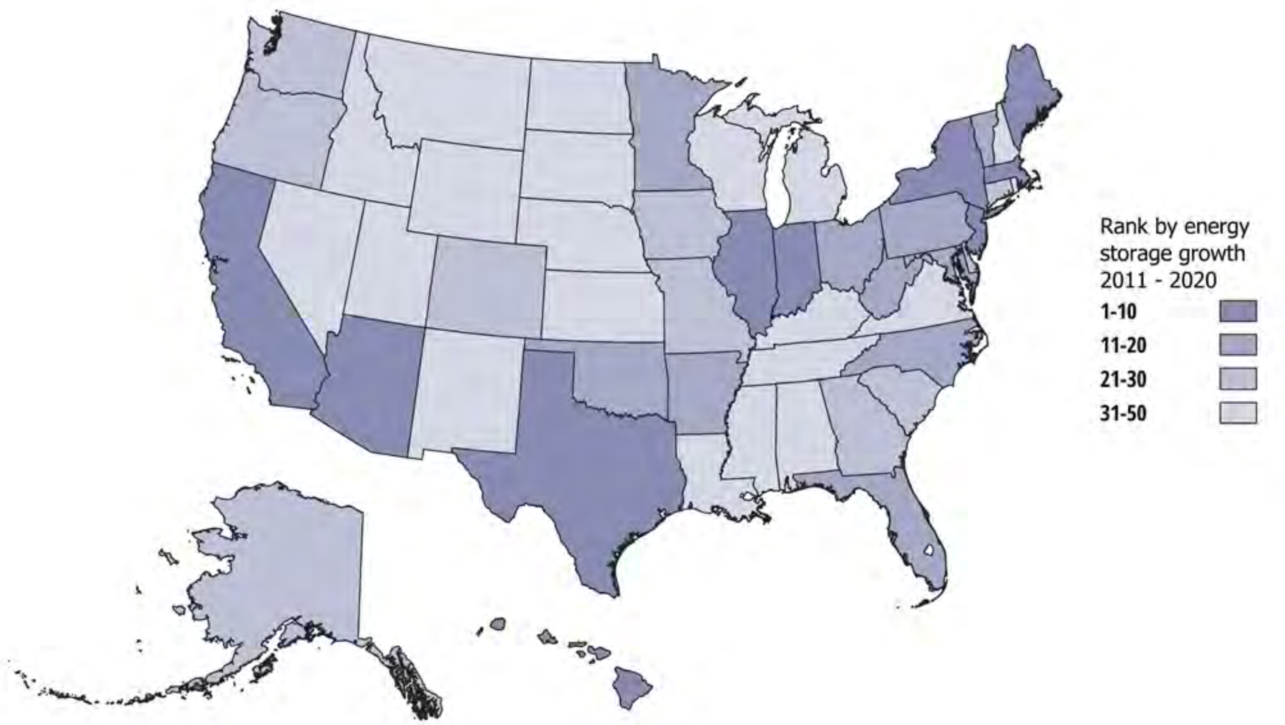

Figure 13: America's top states for battery storage additions since 2011

The U.S. can and must accelerate clean energy progress

To prevent the worst impacts of global warming, the U.S. must rapidly phase out the use of fossil fuels. Transitioning to clean, renewable energy will also improve our health by preventing hazardous air pollution and increase our safety by protecting us from the hazards of extracting, transporting and processing dangerous fuels.

Fortunately, the United States has more than enough renewable energy potential to support all of our energy needs. According to the National Renewable Energy Laboratory, the United States has the technical potential to meet its current electricity needs 78 times over with solar energy and more than 11 times over with wind energy.[141] Every state in the country has enough potential from either solar or wind energy alone to supply all of its electricity needs.[142]

Transitioning to an economy powered entirely by clean, renewable energy will require us to find ways to tap more of that clean energy potential, to take advantage of advances in technology, and to integrate clean energy thoughtfully into our energy system.

Accelerating the pace of change

The United States is adding renewable energy at a record pace. But that pace is not fast enough to eliminate our dependence on fossil fuels by mid-century – a critical deadline for preventing the worst impacts of global warming.

If the nation were to add as much wind, solar and geothermal power every year as we did in 2020, by 2050 America would be producing enough renewable electricity to meet just 54% of projected electricity demand.[143]

If America can continue to accelerate its adoption of renewable energy as we have over the past decade, the goal of fully repowering our electricity system, and eventually our entire economy, begins to come into view. Between 2011 and 2020, U.S. wind, solar and geothermal generation grew at an annual rate of 15%.[144] If those forms of renewable generation were to continue to grow by 15% per year, wind, solar and geothermal would produce enough electricity to meet all of our current electricity needs by 2035.[145]

Technology is improving

Recent improvements in technology and reductions in cost – along with predictions that those trends will continue over the coming years – suggest that America can continue to accelerate its progress toward a clean energy economy.

Wind turbine technology has seen enormous improvements over the past decade. In 2019, the average installed wind turbine had 42% greater power capacity than one installed in 2010, and the area swept by the average turbine's rotors doubled in that time period.[146] The average new wind turbine capacity rose from 1.8 MW in 2010 to 2.6 MW in 2019.[147]

In November 2019, GE's "Haliade-X" wind turbine prototype set a world record and produced 262 MWh of electricity within 24 hours, enough to power 30,000 households in the area. The prototype model has a capacity of 12 MW.[148] By 2030, experts suggest that these large-scale wind turbines will be regularly installed offshore, with enormous rotors with "a swept area more than five times the size of a football field."[149]

Other developments in offshore wind, like the development of floating turbines, could allow the U.S. to tap into the enormous wind potential off the West Coast, as well as the coast of Maine, where the ocean is too deep to allow the installation of traditional seafloor-mounted turbines.[150] Based on data from the National Renewable Energy Laboratory, the West Coast has the potential to generate more than ten times as much electricity from the wind as it uses in a given year.[151]

Recent years have also seen rapid progress in solar energy technology. The median new residential solar panel installed in 2019 was around 37% more efficient than one installed in 2010.[152] Utility-scale solar energy systems have benefited from improvements in tracking technology that allow panels to change angles to follow the sun, or to maximize generation from diffuse light on cloudy days.[153] Efficiency improvements are reducing the cost of utility-scale projects by allowing developers to use less land, or fewer modules, to achieve desired project capacity; or to boost the amount of capacity possible on already developed land.[154]

Advanced new products are also helping to reduce energy consumption and enable smarter energy use. Among them are technologies that fall under the banner of what the ACEEE calls "intelligent efficiency," a category of energy-saving strategies that harness the power of information technology. Smart thermostats, which give homeowners more control over home energy use and have been shown to reduce the energy used for heating and cooling, accounted for an estimated 40% of thermostat sales by the end of 2018.[155]

Industrial operations are embracing intelligent efficiency.[156] In 2018, the market for industrial energy management systems – systems that allow monitoring and adjustment of energy use in industrial settings – reached $21.6 billion in revenue, having experienced double-digit annual growth rates in the previous couple of years.[157] Efficiency technologies and advances in building design, combined with on-site renewable energy, are enabling the spread of net zero energy buildings, which generate more energy than they consume over a year. A survey by the NetZero Energy Coalition found more than 6,000 net zero energy buildings in the U.S. and Canada in 2017, almost a 50% increase from 2016.[158]

Improvements in battery technology are enabling both improvements in energy storage and long-range electric vehicles. The median range for an EV grew to over 250 miles between 2011 and 2020 – well over triple the range of 2011.[159] On the upper end, the growth in range is even more dramatic. The newest version of the Tesla Roadster will have a 620-mile range, which is 208 miles more than an average gasoline-powered car.[160] Advances in range are due to improved battery technology, advances in aerodynamics and reductions in rolling resistance.[161] Meanwhile, auto companies continue to invest resources in improving battery technology; in May 2021, Ford announced the upcoming introduction of an electric version of its F-150 pickup truck, the best-selling vehicle in America.[162] Other non-luxury brands are announcing battery and plug-in hybrid vehicle options as well, like the Honda Clarity, Hyundai Kona EV, and Subaru Solterra.[163] In addition to reducing reliance on fossil fuels, widespread adoption of electric vehicles would also reduce overall energy use, because electric vehicles are approximately three times more efficient at converting energy to wheel power than gasoline-powered vehicles.[164]

New advances in longer-term energy storage also hold promise.[165] The U.S. Department of Energy aims to drive down the cost of grid-scale, long-duration energy storage technologies that can add flexibility to the grid by 90% or more within a decade.[166]

Prices are falling

Advancing technology and increasing economies of scale have led to rapidly falling prices for clean energy technology.

An NREL survey of clean energy prices found that, from 2010 to 2018, the cost of distributed PV fell by 71% and utility-scale PV by 80-82%.[167] Lazard, a consulting firm that conducts an annual levelized cost of energy survey, found that the cost of land-based wind power fell by 66% during the same period.[168]

These and other recent price declines have made many clean energy technologies price competitive when compared to conventional fossil-fuel technology. Lazard now reports that renewable sources like certain wind and solar energy technologies are "cost competitive with conventional generation technologies."[169] In Los Angeles, for example, a record-breaking solar contract was proposed in 2019, promising to deliver energy for 1.99 cents per kilowatt-hour – a fraction of the 7.4 cents per kilowatt-hour average wholesale price of electricity in California in 2019.[170]

LED light bulbs used to cost over $40 apiece a decade ago, but technology improvements mean that they now cost less than $2 per bulb.[171] They use at least 75% less energy than incandescent bulbs, and last 25 times as long.[172] If the U.S. were to transition entirely to LED light bulbs, by 2035, 569 TWh of electricity could be saved annually. This is equivalent to the energy output of 92 large-scale power plants.[173]

As adoption increases and technology improves, prices are expected to continue to fall. One study by NREL found that the cost of wind energy is expected to fall 50% by 2030 from 2017 cost levels.[174] BloombergNEF found that constructing solar and wind power is "already cheaper than building new large-scale coal and gas plants" and predicts that the cost of an average utility-scale solar plant will fall 71% by 2050.[175] It also estimates that by 2030, energy storage costs will fall by 52%.[176]

Battery-electric vehicles, meanwhile, are already cheaper than gasoline-powered vehicles over their entire lifespan, due to lower costs for fuel and maintenance. A 2020 report by Consumer Reports found that the lifetime ownership costs of the most popular EV models are thousands of dollars lower than those of comparable gasoline-powered vehicles, with typical savings of between $6,000 and $10,000.[177] Further reductions in battery costs could bring the upfront costs of EVs down to the level of gasoline-powered vehicles by the mid-2020s.[178]

Conclusion and recommendations

America has virtually limitless potential to produce energy from the wind and sun, and many opportunities to curb our energy use. Technological improvements and growing markets for clean energy are making it easier and cheaper to harness that potential with each passing year. At the same time, advances such as those in energy storage and electric vehicles are making it possible for us to put renewable energy to use in new ways, accelerating the transition away from fossil fuels.

It is now possible to envision an energy future for America in which we rely completely on clean, renewable sources of energy – eliminating our dependence on the fossil fuels that contribute to global warming and on other damaging sources of energy. Researchers from a wide variety of academic and governmental institutions have put forward scenarios by which America can power all, or nearly all, of our electricity system – and even our entire economy – with renewable energy.[179] Many other such scenarios are likely to emerge in the years to come as technology advances and leading communities, states and nations gain experience with the transition.

To get there, however, America will need to build upon the nation's history of adopting strong, proven policies to accelerate the deployment and use of renewable energy. For example, roughly half of all growth in renewable electricity in the United States since 2000 has been attributed to state adoption of renewable electricity standards.[180]

Among the most important steps that federal, state and local governments can take are the following:

- Set ambitious targets for renewable energy, following the example of the nine states and nearly 200 cities and towns that have committed to getting 100% of their electricity from clean or renewable sources of energy within the next several decades.[181] The most effective renewable energy targets will also include strong intermediate goals that ensure continuous progress in renewable energy adoption over time.

- Set similar targets for the adoption of specific clean energy technologies, including solar power, offshore wind energy, and energy storage. These technology-specific targets can ensure a market for new and developing sources of clean energy, increasing the confidence of would-be investors in clean energy and creating economies of scale that bring prices down.

- Establish strong incentives for renewable energy adoption, including extension of federal tax credits that have helped to fuel the growth of renewable energy over the last decade and local and state clean energy incentives. Policy-makers should expand and improve existing clean energy incentives to make them easier to use and to ensure that they deliver benefits to everyone wanting to participate in the drive toward a clean energy future.

- Ensure that utility regulations and policies fully and fairly compensate investors in clean energy technologies, such as energy storage and distributed solar power, for the benefits they deliver to the environment, society and the electric system. Utility regulators should implement or continue net metering for rooftop solar customers, which has been a key enabler of the growth of solar energy capacity, or adopt similar compensation structures that support continued rapid growth in rooftop solar.

- Encourage the transition to electric vehicles and electric buildings through strong clean cars standards, local commitments to transition to electric transit and school buses, and policies to support fuel-switching in residential and commercial buildings from gas and oil to electricity.
- Support the integration of technologies and practices that will enable America to take full advantage of its renewable energy potential, including the integration of energy storage into the grid, the development of resilient local microgrids powered by renewable energy, and the appropriate expansion of transmission infrastructure to allow for the transport of renewable energy from the places where it is abundant to the places where it is needed.
- Encourage continued steady progress on energy efficiency by continuing and expanding local, state, utility and federal programs and policies, including utility energy efficiency programs, building energy codes, and appliance efficiency standards.

Appendix: Detailed state data

TABLE A1. CLEAN ENERGY PROGRESS BY STATE

State	Increase in solar electricity generation, 2011 - 2020 (GWh)[182]	Increase in wind electricity generation, 2011 - 2020 (GWh)[183]	Increase in electricity efficiency savings, 2011 - 2019 (percentage point increase in savings as share of electricity consumption)[184]	Number of electric vehicles sold through 2020[185]	Increase in battery storage capacity 2011 - 2020 (MW)[186]
Alabama	384	0	-0.07	4,480	1
Alaska	7	151	-0.02	839	5
Arizona	8,445	379	-0.41	32,637	42
Arkansas	357	0	0.50	2,165	12
California	45,377	5,893	0.39	772,421	589
Colorado	1,952	7,527	0.30	36,821	9
Connecticut	932	12	-0.11	17,537	2
Delaware	150	0	0.01	3,511	8
Florida	7,517	0	-0.15	77,397	29
Georgia	4,205	0	0.12	44,480	2
Hawaii	1,631	238	-0.12	15,333	48
Idaho	651	1,435	0.06	2,607	0
Illinois	525	10,898	0.77	38,048	133
Indiana	594	3,256	0.04	10,393	36
Iowa	235	23,440	-0.34	4,287	1
Kansas	107	19,793	-0.08	4,423	0
Kentucky	95	0	-0.07	3,919	0
Louisiana	327	0	0.11	3,175	1
Maine	124	1,791	-0.02	4,524	43
Maryland	1,572	275	1.56	31,688	23
Massachusetts	3,823	207	0.82	39,194	71
Michigan	313	6,303	0.41	24,081	1

TABLE A1 (CONTINUED)

State	Increase in solar electricity generation, 2011 - 2020 (GWh)[182]	Increase in wind electricity generation, 2011 - 2020 (GWh)[183]	Increase in electricity efficiency savings, 2011 - 2019 (percentage point increase in savings as share of electricity consumption)[184]	Number of electric vehicles sold through 2020[185]	Increase in battery storage capacity 2011 - 2020 (MW)[186]
Minnesota	1,883	5,514	-0.15	15,761	16
Mississippi	451	0	0.02	1,199	0
Missouri	466	2,247	0.19	11,019	2
Montana	64	1,727	-0.03	1,679	0
Nebraska	82	7,659	-0.03	2,955	0
Nevada	5,801	323	-0.01	12,901	0
New Hampshire	154	459	0.29	5,445	0
New Jersey	3,473	11	-0.07	49,175	43
New Mexico	1,910	5,086	0.09	3,612	1
New York	3,325	2,124	0.04	79,219	37
North Carolina	9,258	546	0.25	23,889	10
North Dakota	1	7,947	-0.06	485	0
Ohio	405	2,101	-0.27	23,888	31
Oklahoma	96	23,967	0.25	6,433	10
Oregon	1,286	3,775	0.07	34,976	5
Pennsylvania	582	2,079	-0.32	32,019	28
Rhode Island	498	228	1.26	3,433	0
South Carolina	2,166	0	0.20	6,303	4
South Dakota	4	2,936	0.06	745	1
Tennessee	430	1	-0.31	11,235	0
Texas	9,442	62,441	-0.01	54,288	318
Utah	3,037	230	-0.20	12,566	0
Vermont	355	351	0.00	5,352	11
Virginia	1,688	0	0.01	29,784	0
Washington	288	2,064	0.06	65,611	7
West Virginia	14	795	0.13	1,305	32
Wisconsin	213	593	0.07	12,201	0
Wyoming	178	531	0.15	533	0

TABLE A2. SOLAR GENERATION BY STATE[187]

State	2011 solar electricity generation (GWh)	2020 solar electricity generation (GWh)	Growth from 2011-2020 (GWh)	Rank, by growth
Alabama	1	385	384	30
Alaska	0	7	7	48
Arizona	477	8,922	8,445	4
Arkansas	3	360	357	31
California	2,635	48,012	45,377	1
Colorado	268	2,220	1,952	13
Connecticut	34	966	932	20
Delaware	36	186	150	40
Florida	160	7,677	7,517	5
Georgia	25	4,230	4,205	7
Hawaii	111	1,742	1,631	17
Idaho	1	652	651	21
Illinois	21	546	525	24
Indiana	3	597	594	22
Iowa	0	235	235	36
Kansas	0	107	107	42
Kentucky	2	97	95	44
Louisiana	8	335	327	33
Maine	1	125	124	41
Maryland	47	1,619	1,572	18
Massachusetts	82	3,905	3,823	8
Michigan	12	325	313	34
Minnesota	5	1,888	1,883	15
Mississippi	0	451	451	27
Missouri	2	468	466	26
Montana	3	67	64	46
Nebraska	0	82	82	45
Nevada	341	6,142	5,801	6
New Hampshire	3	157	154	39
New Jersey	644	4,117	3,473	9
New Mexico	157	2,067	1,910	14
New York	97	3,422	3,325	10
North Carolina	35	9,293	9,258	3

TABLE A2 (CONTINUED)

State	2011 solar electricity generation (GWh)	2020 solar electricity generation (GWh)	Growth from 2011-2020 (GWh)	Rank, by growth
North Dakota	0	1	1	50
Ohio	33	438	405	29
Oklahoma	1	97	96	43
Oregon	47	1,333	1,286	19
Pennsylvania	194	776	582	23
Rhode Island	7	505	498	25
South Carolina	2	2,168	2,166	12
South Dakota	0	4	4	49
Tennessee	3	433	430	28
Texas	77	9,519	9,442	2
Utah	6	3,043	3,037	11
Vermont	9	364	355	32
Virginia	7	1,695	1,688	16
Washington	9	297	288	35
West Virginia	1	15	14	47
Wisconsin	12	225	213	37
Wyoming	0	178	178	38

TABLE A3. WIND GENERATION BY STATE[188]

State	2011 wind electricity generation (GWh)	2020 wind electricity generation (GWh)	Growth from 2011-2020 (GWh)	Rank, by growth
Alabama	0	0	0	41 (tie)
Alaska	12	163	151	37
Arizona	256	635	379	29
Arkansas	0	0	0	41 (tie)
California	7,752	13,645	5,893	10
Colorado	5,200	12,727	7,527	8
Connecticut	0	12	12	38
Delaware	5	5	0	41 (tie)
Florida	0	0	0	41 (tie)
Georgia	0	0	0	41 (tie)
Hawaii	341	579	238	33
Idaho	1,307	2,742	1,435	23
Illinois	6,213	17,111	10,898	5
Indiana	3,285	6,541	3,256	14
Iowa	10,709	34,149	23,440	3
Kansas	3,720	23,513	19,793	4
Kentucky	0	0	0	41 (tie)
Louisiana	0	0	0	41 (tie)
Maine	707	2,498	1,791	21
Maryland	271	546	275	32
Massachusetts	61	268	207	36
Michigan	456	6,759	6,303	9
Minnesota	6,726	12,240	5,514	11
Mississippi	0	0	0	41 (tie)
Missouri	1,178	3,425	2,247	16
Montana	1,265	2,992	1,727	22
Nebraska	1,051	8,710	7,659	7
Nevada	0	323	323	31
New Hampshire	66	525	459	28
New Jersey	11	22	11	39
New Mexico	2,104	7,190	5,086	12
New York	2,828	4,952	2,124	17
North Carolina	0	546	546	26

TABLE A3 (CONTINUED)

State	2011 wind electricity generation (GWh)	2020 wind electricity generation (GWh)	Growth from 2011-2020 (GWh)	Rank, by growth
North Dakota	5,236	13,183	7,947	6
Ohio	198	2,299	2,101	18
Oklahoma	5,605	29,572	23,967	2
Oregon	4,775	8,550	3,775	13
Pennsylvania	1,794	3,873	2,079	19
Rhode Island	3	231	228	35
South Carolina	0	0	0	41 (tie)
South Dakota	2,668	5,604	2,936	15
Tennessee	53	54	1	40
Texas	30,548	92,989	62,441	1
Utah	573	803	230	34
Vermont	33	384	351	30
Virginia	0	0	0	41 (tie)
Washington	6,262	8,326	2,064	20
West Virginia	1,103	1,898	795	24
Wisconsin	1,188	1,781	593	25
Wyoming	4,612	5,143	531	27

TABLE A4. WIND AND SOLAR GENERATION AS PERCENTAGE OF STATE ELECTRICITY CONSUMPTION BY STATE[189]

State	Total wind and solar generation, 2020 (GWh)	Wind and solar generation as percentage of state electricity consumption	Rank, by percentage of consumption
Alabama	385	0.5%	48
Alaska	170	2.9%	40
Arizona	9,557	11.7%	22
Arkansas	360	0.8%	46
California	61,657	24.9%	12
Colorado	14,947	26.5%	10
Connecticut	978	3.6%	35
Delaware	191	1.8%	43
Florida	7,677	3.2%	37
Georgia	4,230	3.2%	38
Hawaii	2,321	26.6%	9
Idaho	3,394	14.0%	19
Illinois	17,657	13.4%	20
Indiana	7,138	7.6%	26
Iowa	34,384	69.0%	1
Kansas	23,620	61.5%	3
Kentucky	97	0.1%	50
Louisiana	335	0.4%	49
Maine	2,623	23.4%	13
Maryland	2,165	3.8%	34
Massachusetts	4,173	8.4%	25
Michigan	7,084	7.4%	28
Minnesota	14,128	22.6%	14
Mississippi	451	1.0%	45
Missouri	3,893	5.2%	33
Montana	3,059	21.3%	15
Nebraska	8,792	29.1%	8
Nevada	6,465	17.0%	17
New Hampshire	682	6.4%	29
New Jersey	4,139	5.8%	32
New Mexico	9,257	36.8%	6
New York	8,374	6.0%	30
North Carolina	9,839	7.6%	27

TABLE A4 (CONTINUED)

State	Total wind and solar generation, 2020 (GWh)	Wind and solar generation as percentage of state electricity consumption	Rank, by percentage of consumption
North Dakota	13,184	61.7%	2
Ohio	2,737	2.0%	42
Oklahoma	29,669	48.0%	4
Oregon	9,883	20.8%	16
Pennsylvania	4,649	3.3%	36
Rhode Island	736	10.1%	24
South Carolina	2,168	2.8%	41
South Dakota	5,608	44.9%	5
Tennessee	487	0.5%	47
Texas	102,508	25.0%	11
Utah	3,846	12.4%	21
Vermont	748	14.1%	18
Virginia	1,695	1.5%	44
Washington	8,623	10.1%	23
West Virginia	1,913	6.0%	31
Wisconsin	2,006	3.0%	39
Wyoming	5,321	34.7%	7

Notes

1 2005: U.S. Energy Information Administration, *2005 Residential Energy Consumption Survey: Preliminary Housing Characteristics Tables*, Table HC9.4 space heating characteristics by climate zone, 2005, 2005, accessed 21 October 2021 at https://www.eia.gov/consumption/residential/data/2005/hc/pdf/tablehc9.4.pdf; 2015: U.S. Energy Information Administration, *2015 Residential Energy Consumption Survey*, Table HC6.1 Space heating in U.S. homes by housing unit type, 2015, revised May 2018 at https://www.eia.gov/consumption/residential/data/2015/hc/php/hc6.1.php.

2 For 2014 and subsequent years, based on sum of net generation from utility-scale solar, small-scale solar and wind, divided by sum of all utility-scale generation plus small-scale solar. All data for 2014 and subsequent years from U.S. Energy Information Administration, *Electricity Data Browser*, accessed 15 August 2021 at https://www.eia.gov/electricity/data/browser/; For 2013 and previous years, based on sum of total solar energy consumption for all sectors and wind generation divided by (total solar energy consumption plus (utility-scale generation minus utility-scale solar)) with total solar energy consumption data from U.S. Energy Information Administration, *State Energy Data System 2020 Update*, accessed 7 September 2021 at https://www.eia.gov/state/seds/.

3 U.S. Energy Information Administration, *Electricity Data Browser*, accessed 7 September 2021 at https://www.eia.gov/electricity/data/browser/.

4 Based on 2020 generation from wind, solar and geothermal power and total U.S. net generation from U.S. Energy Information Administration, *Electricity Data Browser: Net Generation for United States*, downloaded 18 August 2021 from https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2&fuel=vtvv&linechart=ELEC.GEN.ALL-US-99.A~ELEC.GEN.COW-US-99.A~ELEC.GEN.PEL-US-99.A~ELEC.GEN.PC-US-99.A~ELEC.GEN.NG-US-99.A~ELEC.GEN.OOG-US-99.A~ELEC.GEN.NUC-US-99.A~ELEC.GEN.HYC-US-99.A~ELEC.GEN.WND-US-99.A~ELEC.GEN.SUN-US-99.A~ELEC.GEN.GEO-US-99.A~ELEC.GEN.BIO-US-99.A~ELEC.GEN.WWW-US-99.A~ELEC.GEN.WAS-US-99.A~ELEC.GEN.HPS-US-99.A~ELEC.GEN.OTH-US-99.A~ELEC.GEN.TSN-US-99.A~ELEC.GEN.DPV-US-99.A&columnchart=ELEC.GEN.ALL-US-99.A&map=ELEC.GEN.ALL-US-99.A&freq=A&start=2001&end=2020&ctype=linechart&ltype=pin&rtype=s&maptype=0&rse=0&pin=.

5 Solar: U.S. Energy Information Administration, *Electricity Data Browser*, accessed 15 August 2021 at https://www.eia.gov/electricity/data/browser/; U.S. Energy Information Administration, *State Energy Data System 2020 Update*, downloaded 7 September 2021 from https://www.eia.gov/state/seds/seds-data-complete.php?sid=US; wind: U.S. Energy Information Administration, *Electricity Data Browser: Net Generation for United States*, downloaded 18 August 2021 from https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2&fuel=vtvv&linechart=ELEC.GEN.ALL-US-99.A~ELEC.GEN.COW-US-99.A~ELEC.GEN.PEL-US-99.A~ELEC.GEN.PC-US-99.A~ELEC.GEN.NG-US-99.A~ELEC.GEN.OOG-US-99.A~ELEC.GEN.NUC-US-99.A~ELEC.GEN.HYC-US-99.A~ELEC.GEN.WND-US-99.A~ELEC.GEN.SUN-US-99.A~ELEC.GEN.GEO-US-99.A~ELEC.GEN.BIO-US-99.A~ELEC.GEN.WWW-US-99.A~ELEC.GEN.WAS-US-99.A~ELEC.GEN.HPS-US-99.A~ELEC.GEN.OTH-US-99.A~ELEC.GEN.TSN-US-99.A~ELEC.GEN.DPV-US-99.A&columnchart=ELEC.GEN.ALL-US-99.A&map=ELEC.GEN.ALL-US-99.A&freq=A&start=2001&end=2020&ctype=linechart&ltype=pin&rtype=s&maptype=0&rse=0&pin=; electric vehicles: Alliance for Automotive Innovation, *The Electric Vehicle Sales Dashboard*, accessed 11 August 2021 at https://www.autosinnovate.org/resources/electric-vehicle-sales-dashboard; battery storage: U.S. Energy Information Administration, *Form EIA-860 Detailed Data with Previous Form Data (EIA-860A/860B)*, 3 June 2021, downloaded 14 August 2021 from https://www.eia.gov/electricity/data/eia860/; U.S. Energy Information Administration, *Preliminary Monthly Electric Generator Inventory* (based on Form EIA-860M as a supplement to Form EIA-860), 24 June 2021, downloaded 15 July 2021 from https://www.eia.gov/electricity/data/eia860m/.

6 23 times more solar: U.S. Energy Information Administration, *Electricity Data Browser*, accessed 15 August 2021 at https://www.eia.gov/electricity/data/browser/; U.S. Energy Information Administration, *State Energy Data System 2020 Update*, downloaded 7 September 2021 from https://www.eia.gov/state/seds/seds-data-complete.php?sid=US; average American homes: U.S. Energy Information Administration, *Frequently Asked Questions (FAQs): How much electricity does an American home use?*, updated 9 October 2020, archived at http://web.archive.org/web/20210421225706/https://www.eia.gov/tools/faqs/faq.php?id=97.

7 2 millionth: Solar Energy Industries Association, *United States Surpasses 2 Million Solar Installations* (press release), 9 May 2019, archived at https://web.archive.org/web/20211019155542/https://www.seia.org/news/united-states-surpasses-2-million-solar-installations; additional million: U.S. Department of Energy, *DOE Kicks Off "Summer of Solar 2021" With Tool That Fast-Tracks Solar Power For Communities Nationwide*, 15 July 2021, archived at http://web.archive.org/web/20210828204022/https://www.energy.gov/articles/doe-kicks-summer-solar-2021-tool-fast-tracks-solar-power-communities-nationwide.

8 Nearly tripled: U.S. Energy Information Administration, *Electricity Data Browser*, accessed 15 August 2021 at https://www.eia.gov/electricity/data/browser/; U.S. Energy Information Administration, *State Energy Data System 2020 Update*, downloaded 7 September 2021 from https://www.eia.gov/state/seds/seds-data-complete.php?sid=US; U.S. Energy Information Administration, *Frequently Asked Questions (FAQs): How much electricity does an American home use?*, updated 9 October 2021, archived at http://web.archive.org/web/20210421225706/https://www.eia.gov/tools/faqs/faq.php?id=97.

9 U.S. Energy Information Administration, *Electricity Data Browser*, accessed 15 August 2021 at https://www.eia.gov/electricity/data/browser/; U.S. Energy Information Administration, *State Energy Data System 2020 Update*, downloaded 7 September 2021 from https://www.eia.gov/state/seds/seds-data-complete.php?sid=US.

10 2011: The American Council for an Energy-Efficient Economy (ACEEE), *The 2013 State Energy Efficiency Scorecard*, 4 November 2013, archived at http://web.archive.org/web/20210627173103/https://www.aceee.org/sites/default/files/publications/researchreports/e13k.pdf; 2019: The American Council for an Energy-Efficient Economy (ACEEE), *The 2020 State Energy Efficiency Scorecard*, 16 December 2020, archived at http://web.archive.org/web/20210501220112/https://www.aceee.org/research-report/u2011; average American homes: U.S. Energy Information Administration, *Frequently Asked Questions (FAQs): How much electricity does an American home use?*, updated 9 October 2020, archived at http://web.archive.org/web/20210421225706/https://www.eia.gov/tools/faqs/faq.php?id=97.

11 Alliance for Automotive Innovation, *The Electric Vehicle Sales Dashboard*, accessed 11 August 2021 at https://www.autosinnovate.org/resources/electric-vehicle-sales-dashboard.

12 Argonne National Laboratory, *Light Duty Electric Drive Vehicles Monthly Sales Updates*, accessed 10 September 2021 at https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates.

13 U.S. Energy Information Administration, *Form EIA-860 Detailed Data with Previous Form Data (EIA-860A/860B)*, 3 June 2021, downloaded 14 August 2021 from https://www.eia.gov/electricity/data/eia860/; U.S. Energy Information Administration, *Preliminary Monthly Electric Generator Inventory* (based on Form EIA-860M as a supplement to Form EIA-860), 24 June 2021, downloaded 15 July 2021 from https://www.eia.gov/electricity/data/eia860m/.

14 U.S. Energy Information Administration, "One in four U.S. homes is all-electric," *Today in Energy*, 1 May 2019, archived at https://web.archive.org/web/20210911140229/https://www.eia.gov/todayinenergy/detail.php?id=39293.

15 94% increase between 2011 and 2020: Air-Conditioning, Heating and Refrigeration Institute, *AHRI Releases December 2020 U.S. Heating and Cooling Equipment Shipment Data*, 12 February 2021, archived at https://web.archive.org/web/20210814001020/https://www.ahrinet.org/App_Content/ahri/files/Statistics/Monthly%20Shipments/2020/December_2020.pdf, and Air-Conditioning, Heating and Refrigeration Institute, *AHRI Releases December 2012 U.S. Heating and Cooling Equipment Shipment Data*, 19 February 2013, archived at https://web.archive.org/web/20210730032433/https://www.ahrinet.org/App_Content/ahri/files/Statistics/Monthly%20Shipments/2012/December2012.pdf.

16 Nine states: Maine, New York, Virginia, New Mexico, Washington, Oregon, California and Hawaii, plus Illinois, which adopted a 100% clean energy standard in September 2021. All states but Illinois: Environment America, *Our Campaigns: 100% Renewable*, accessed 21 September 2021, archived at https://web.archive.org/web/20210921193458/https://environmentamerica.org/feature/ame/100-renewable; Illinois: NPR Illinois, "Pritzker signs climate plan to get Illinois on a path to 100% clean energy with help from ratepayer hike," 15 September 2021, archived at https://web.archive.org/web/20210921041608/https://www.nprillinois.org/statehouse/2021-09-15/pritzker-signs-climate-plan-to-get-illinois-on-path-to-100-clean-energy-with-help-from-ratepayer-hike; nearly 200 cities: Sierra Club, *Ready for 100: Committed*, accessed 21 September 2021, archived at https://web.archive.org/web/20210921193917/https://www.sierraclub.org/ready-for-100/commitments.

17 Office of Science, U.S. Department of Energy, *Basic Research Needs for Solar Energy Utilization,* April 2005, archived at http://web.archive.org/web/20210320163233/https://science.osti.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_for_Solar_Energy_Utilization_rpt.pdf.

18 See note 8.

19 Millionth: Julia Pyper, "The US Solar Market Is Now 1 Million Installations Strong," *Greentech Media*, 21 April 2016, available at https://web.archive.org/web/20211019154839/https://www.greentechmedia.com/articles/read/The-U-S-Solar-Market-Now-One-Million-Installations-Strong; 2 millionth: Solar Energy Industries Association, *United States Surpasses 2 Million Solar Installations* (press release), 9 May 2019, archived at https://web.archive.org/web/20211019155542/https://www.seia.org/news/united-states-surpasses-2-million-solar-installations.

20 U.S. Department of Energy, *DOE Kicks Off "Summer of Solar 2021" With Tool That Fast-Tracks Solar Power For Communities Nationwide*, 15 July 2021, archived at http://web.archive.org/web/20210828204022/https://www.energy.gov/articles/doe-kicks-summer-solar-2021-tool-fast-tracks-solar-power-communities-nationwide.

21 See note 9.

22 U.S. Energy Information Administration, *Frequently Asked Questions (FAQs): How much electricity does an American home use?*, updated 9 October 2020, archived at http://web.archive.org/web/20210421225706/https://www.eia.gov/tools/faqs/faq.php?id=97.

23 See note 9.

24 U.S. Energy Information Administration, *Today In Energy: Renewables account for most new U.S. electricity generating capacity in 2021*, 11 January 2021, archived at http://web.archive.org/web/20210907221857/https://www.eia.gov/todayinenergy/detail.php?id=46416.

25 Solar Energy Industries Association, *California Solar*, accessed 8 September 2021, archived at https://web.archive.org/web/20210908175545/https://www.seia.org/state-solar-policy/california-solar.

26 Solar Energy Industries Association, *State Solar Spotlight: California* (fact sheet), June 2021, accessed 30 August 2021 at https://www.seia.org/sites/default/files/2019-09/Factsheet_California.pdf.

27 Lindsey Hallock, Frontier Group, and Michelle Kinman, Environment California Research & Policy Center, *California's Success Story: How the Million Solar Roofs initiative transformed the state's energy landscape*, 7 July 2015, accessed at http://environmentcalifornia.org/sites/environment/files/reports/CA_Solar_Success_scrn_FINAL_7-7-2015.pdf.

28 Tony Dutzik and Bryn Huxley-Reicher, Frontier Group; Laura Deehan, Environment California Research & Policy Center; and Bronte Payne, Environment America Research & Policy Center, *Rooftop Solar at Risk: Cuts to net metering could threaten California's clean energy progress*, July 2021, available at https://frontiergroup.org/sites/default/files/reports/ECA%20FRG%20Rooftop%20Solar%20at%20Risk%2027Jul21.pdf.

29 Ivan Penn, "California panel backs solar mandate for new buildings," *New York Times*, updated 8 September 2021, accessed at https://www.nytimes.com/2021/08/11/business/energy-environment/california-solar-mandates.html.

30 U.S. Energy Information Administration, "Texas likely to add record utility-scale solar capacity in the next two years," *Today in Energy,* 21 April 2021, archived at http://web.archive.org/web/20210816074233/https://www.eia.gov/todayinenergy/detail.php?id=47636.

31 Texas price drop: Solar Energy Industries Association, *State Solar Spotlight: Texas*, 15 June 2021, accessed 10 September 2021 at https://www.seia.org/sites/default/files/2021-06/Texas.pdf; Arizona RPS: Solar Energy Industries Association, *RPS Solar Carve Out Arizona* (fact sheet), 12 December 2013, accessed 10 September 2021 at https://www.seia.org/sites/default/files/resources/RPS%20Solar%20Fact%20Sheet%20AZ.pdf; Nevada policies: Solar Energy Industries Association, *State Solar Spotlight: Nevada* (fact sheet), 15 June 2021, accessed 10 September 2021 at https://www.seia.org/sites/default/files/2021-06/Nevada.pdf.

32 Solar carve-outs: Spencer Fields, Energy Sage, *Solar Carve-outs*, 7 May 2021, archived at http://web.archive.org/web/20210126112613/https://news.energysage.com/solar-carve-outs/; policies ensure: Gideon Weissman, Frontier Group; Bret Fanshaw and Rob Sargent, Environment America Research & Policy Center, *Lighting the Way IV: The top states that helped drive America's solar energy boom in 2015*, July 2016, available at http://environmentamerica.org/sites/environment/files/reports/AME%20LightingTheWay%20Jul16%201.3.pdf.

33 See note 9.

34 Ibid.

35 Ibid.

36 Ibid.

37 By 2011: U.S. Energy Information Administration, *State Energy Data System 2020 Update*, downloaded 7 September 2021 from https://www.eia.gov/state/seds/seds-data-complete.php?sid=US; 11 million homes: U.S. Energy Information Administration, *Frequently Asked Questions (FAQs): How much electricity does an American home use?*, accessed August 2021, archived 21 April 2021 at http://web.archive.org/web/20210421225706/https://www.eia.gov/tools/faqs/faq.php?id=97.

38 See note 9.

39 See note 8.

40 Ben Rosen, "Block Island wind farm opens: Will the breeze keep blowing for wind power?" *Christian Science Monitor*, 13 December 2016, archived at https://web.archive.org/web/20210910234706/https://www.csmonitor.com/Environment/2016/1213/Block-Island-wind-farm-opens-Will-the-breeze-keep-blowing-for-wind-power.

41 U.S. Bureau of Ocean Energy Management, *Vineyard Wind 1*, accessed 21 September 2021, archived at https://web.archive.org/web/20210921195512/https://www.boem.gov/vineyard-wind.

42 Anmar Frangoul, "'A huge moment': U.S. gives go-ahead for its first major offshore wind farm," *CNBC*, 12 May 2021, archived at http://web.archive.org/web/20210901003516/https://www.cnbc.com/2021/05/12/us-gives-go-ahead-for-first-major-offshore-wind-farm-.html; one of the largest: Michelle Lewis, "EGEB: World's largest offshore wind turbines chosen for first commercial project," *Elektrek*, 12 July 2021, archived at https://web.archive.org/web/20210819020535/https://electrek.co/2021/07/12/egeb-worlds-largest-offshore-wind-turbines-chosen-for-first-commercial-project/.

43 Nana Terra, Airswift, *5 US Offshore Wind Projects and Skills Needed for the 'Green New Deal',* 17 June 2021, archived at http://web.archive.org/web/20210714134340/https://www.airswift.com/blog/offshore-wind-energy-projects-usa.

44 Bryn Huxley-Reicher, Frontier Group, and Hannah Read, Environment America Research & Policy Center, *Offshore Wind for America: The promise and potential of clean energy off our coasts,* March 2021, available at http://web.archive.org/web/20210410194005/https://frontiergroup.org/reports/fg/offshore-wind-america.

45 See note 43.

46 U.S. Energy Information Administration, "First offshore wind farm in the United States begins construction," *Today in Energy,* 14 August 2015, archived at http://web.archive.org/web/20210625061024/https://www.eia.gov/todayinenergy/detail.php?id=22512.

47 See note 9.

48 Powering Texas, *About the Powering Texas Alliance*, 2020, accessed 16 July 2021, archived at http://web.archive.org/web/20210716223249/https://poweringtexas.com/. Wind energy production based on 2020 figures.

49 Renewable Electricity Standard: DSIRE, NC Clean Energy Technology Center, *Renewable Generation Requirement: Texas RPS*, updated 26 June 2018, accessed at http://programs.dsireusa.org/system/program/detail/182; Jim Malewitz, "$7 Billion Wind Power Project Nears Finish," *The Texas Tribune*, 14 October 2013, archived at http://web.archive.org/web/20210620220834/https://www.texastribune.org/2013/10/14/7-billion-crez-project-nears-finish-aiding-wind-po/.

50 Donald R. Looper, IR Global, *US and Texas Tax Incentives For Renewable Energy*, 15 July 2020, archived at http://web.archive.org/web/20201225174108/https://www.irglobal.com/article/tax-incentives-for-renewable-energy/.

51 See note 9.

52 Ibid.

53 Ibid.

54 Ibid.

55 U.S. Energy Information Administration, *State Energy Data System 2020 Update*, downloaded 7 September 2021 from https://www.eia.gov/state/seds/seds-data-complete.php?sid=US.

56 Ibid.

57 Renewable energy production vs. electricity consumption is for comparison purposes only. Because of the interconnected nature of U.S. electricity grids, much of the power generated in states with high renewable energy production is exported for consumption elsewhere. Energy consumption: Energy Information Administration, *State Electricity Profiles*, 2 November 2020, accessed 31 August 2021 at https://www.eia.gov/electricity/state/; renewable generation: U.S. Energy Information Administration, *Electricity Data Browser*, accessed 15 August 2021 at https://www.eia.gov/electricity/data/browser/; U.S. Energy Information Administration, *State Energy Data System 2020 Update*, downloaded 7 September 2021 from https://www.eia.gov/state/seds/seds-data-complete.php?sid=US.

58 U.S. Energy Information Administration, *Monthly Energy Review*, August 2021, archived at http://web.archive.org/web/20210904164258/https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf.

59 Ibid.

60 Ibid.

61 Vehicle travel: U.S. Department of Transportation, Federal Highway Administration, *Traffic Volume Trends*, December 2020, archived at https://web.archive.org/web/20210921200421/https://www.fhwa.dot.gov/policyinformation/travel_monitoring/20dectvt/; transit: EBP U.S., *The Impact of the COVID-19 Pandemic on Public Transit Funding Needs in the U.S.*, prepared for the American Public Transportation Association, 27 January 2021, archived at https://web.archive.org/web/20210921200706/https://www.apta.com/wp-content/uploads/APTA-COVID-19-Funding-Impact-2021-01-27.pdf.

62 Kim Parker, Juliana Menasce Horowitz and Rachel Minkin, Pew Research Center, *How the Coronavirus Outbreak Has – and Hasn't – Changed the Way Americans Work*, 9 December 2020, archived at https://web.archive.org/web/20210918010901/https://www.pewresearch.org/social-trends/2020/12/09/how-the-coronavirus-outbreak-has-and-hasnt-changed-the-way-americans-work/.

63 PwC, *It's Time to Reimagine Where and How Work Will Get Done; PwC's U.S. Remote Work Survey,* 12 January 2021, archived at https://web.archive.org/web/20210921120346/https://www.pwc.com/us/en/library/covid-19/us-remote-work-survey.html.

64 Andrew Hook et al., "A systematic review of the energy and climate impacts of telecommuting," *Environmental Research Letters* 15(9):093003, doi: 10.1088/1748-9326/ab8a84, 19 August 2020.

65 Fred Pearce, "In store or online – what's the most environmentally friendly way to shop?" *GreenBiz*, 4 June 2019, archived at https://web.archive.org/web/20210921202346/https://www.greenbiz.com/article/store-or-online-whats-most-environmentally-friendly-way-shop.

66 See note 58.

67 Ibid.

68 U.S. Environmental Protection Agency, *The 2020 EPA Automotive Trends Report*, January 2021, archived at http://web.archive.org/web/20210623205557/https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf.

69 Ibid.

70 Ibid. 2020 estimate is preliminary.

71 U.S. Department of Transportation, National Highway Traffic Safety Administration, *Corporate Average Fuel Economy*, accessed 8 September 2021, archived at http://web.archive.org/web/20210908002240/https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.

72 2011: American Council for an Energy-Efficient Economy, *The 2013 State Energy Efficiency Scorecard,* November 2013, archived at http://web.archive.org/web/20210627173103/https://www.aceee.org/sites/default/files/publications/researchreports/e13k.pdf; 2019: Weston Berg et al., ACEEE, *The 2020 State Energy Efficiency Scorecard,* December 2020, archived at https://web.archive.org/web/20210910205752/https://www.aceee.org/sites/default/files/pdfs/u2011.pdf.

73 2019: Weston Berg et al., ACEEE, *The 2020 State Energy Efficiency Scorecard,* December 2020, archived at https://web.archive.org/web/20210910205752/https://www.aceee.org/sites/default/files/pdfs/u2011.pdf; average American homes: U.S. Energy Information Administration, *Frequently Asked Questions (FAQs): How much electricity does an American home use?*, updated 9 October 2020, archived 21 April 2021 at http://web.archive.org/web/20210421225706/https://www.eia.gov/tools/faqs/faq.php?id=97.

74 Lowell Ungar, American Council for an Energy-Efficient Economy, "How a bill signed by Bush and implemented by Obama is saving consumers billions," *ACEEE Blog*, 29 October 2015, archived at http://web.archive.org/web/20170611070107/http://aceee.org/blog/2015/10/how-bill-signed-bush-and-implemented.

75 For general illumination lighting. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, *Adoption of Light-Emitting Diodes in Common Lighting Applications*, August 2020, archived at http://web.archive.org/web/20210410144520/https://www.energy.gov/sites/default/files/2020/09/f78/ssl-led-adoption-aug2020.pdf.

76 U.S. Department of Energy, *LED Lighting Energy Saver,* accessed 7 September 2021, archived at http://web.archive.org/web/20210901140655/https://www.energy.gov/energysaver/led-lighting.

77 Robert Walton, "Efficiency significantly cheaper than natural gas, DOE study concludes," *Utility Dive*, 1 June 2020, archived at http://web.archive.org/web/20210308223250/https://www.utilitydive.com/news/efficiency-significantly-cheaper-than-natural-gas-doe-study-concludes/578926/.

78 U.S. Energy Information Administration, *Frequently Asked Questions: How Much Energy Is Consumed in U.S. Buildings?,* 3 May 2021, archived at http://web.archive.org/web/20210302174328/https://www.eia.gov/tools/faqs/faq.php?id=86.

79 U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, *Status of State Energy Code Adoption*, accessed 21 September 2021 at https://www.energycodes.gov/status.

80 American Council for an Energy-Efficient Economy, "Which energy efficiency policies saved the most last year?" *ACEEE Blog*, 28 July 2015, archived at http://web.archive.org/web/20210705180147/https://www.aceee.org/blog/2015/07/which-energy-efficiency-policies.

81 Evelyn Long, Building Enclosure, *What We Can Learn From the IECC 2021 Energy Code* (blog post), 9 December 2020, archived at http://web.archive.org/web/20210128023929/https://www.buildingenclosureonline.com/blogs/14-the-be-blog/post/89440-what-we-can-learn-from-the-iecc-2021-energy-code.

82 Weston Berg et al., American Council for an Energy-Efficient Economy, *The 2020 State Energy Efficiency Scorecard,* December 2020, archived at https://web.archive.org/web/20210910205752/https://www.aceee.org/sites/default/files/pdfs/u2011.pdf.

83 See note 72.

84 See note 82.

85 NYSERDA, *New Efficiency: New York,* accessed 8 September 2021 at https://www.nyserda.ny.gov/About/Publications/New%20Efficiency.

86 NYSERDA, *Building Energy Code Development, Compliance, and Enforcement*, accessed 27 April 2021, archived at http://web.archive.org/web/20210427184806/https://www.nyserda.ny.gov/All-Programs/Programs/Energy-Code-Training.

87 NYSERDA, *NYSERDA Clean Energy Communities: NYStretch Energy Code-2020*, available at https://cdrpc.org/wp-content/uploads/2021/05/NYSERDA-STRETCH-CODE-QA.pdf.

88 Steven Nadel and Adam Hinge, American Council for an Energy-Efficient Economy, *Mandatory Building Performance Standards: A key policy for achieving climate goals*, June 2020, archived at https://web.archive.org/web/20210721155033/https://www.aceee.org/sites/default/files/pdfs/buildings_standards_6.22.2020_0.pdf.

89 See note 72. Efficiency savings in 2019 are expressed as a percentage of 2018 retail sales.

90 Justin Gerdes, "Maine decides to go big on heat pumps," *Greentech Media*, 27 June 2019, archived at http://web.archive.org/web/20210708163037/https://www.greentechmedia.com/articles/read/maine-wants-to-install-100000-heat-pumps-by-2025.

91 Vermont Electric Cooperative, *2018 Tier III Plan*, 1 November 2017, archived at https://web.archive.org/web/20210908154423/https://www.vpirg.org/wp-content/uploads/2017/12/2018-VEC-Tier-III-Filing.pdf.

92 Thibaut Abergel, International Energy Agency, *Heat Pumps,* June 2020, archived at http://web.archive.org/web/20210715211931/https://www.iea.org/reports/heat-pumps.

93 U.S. Department of Energy, *Heat Pump Systems Energy Saver,* accessed 5 September 2021, archived at http://web.archive.org/web/20210905193801/https://www.energy.gov/energysaver/heat-pump-systems.

94 Carbon Switch, *How to Save Money and Energy by Switching to a Heat Pump,* accessed 25 February 2021, archived at http://web.archive.org/web/20210225154325/https://carbonswitch.co/heat-pump-savings.

95 U.S. Energy Information Administration, "One in four U.S. homes is all-electric," *Today in Energy*, 1 May 2019, archived at https://web.archive.org/web/20210911140229/https://www.eia.gov/todayinenergy/detail.php?id=39293.

96 See note 15.

97 From Air-Conditioning, Heating and Refrigeration Institute, *AHRI Releases December 2020 U.S. Heating and Cooling Equipment Shipment Data*, 12 February 2021, and previous publications in this series, accessed at https://www.ahrinet.org/statistics.

98 Steven Nadel, American Council for an Energy-Efficient Economy, *Programs to Electrify Space Heating in Homes and Buildings,* 11, June 2020, archived at http://web.archive.org/web/20210714185911/https://www.aceee.org/sites/default/files/pdfs/programs_to_electrify_space_heating_brief_final_6-23-20.pdf.

99 Ibid.

100 Efficiency Maine, *Heat Pumps*, accessed 6 May 2021, archived at http://web.archive.org/web/20210506022838/https://www.efficiencymaine.com/heat-pumps/.

101 Alliance for Automotive Innovation, *Electric Vehicle Sales Dashboard,* accessed 11 August 2021 at https:/www.autosinnovate.org/resources/electric-vehicle-sales-dashboard.

102 Argonne National Laboratory, *Light Duty Electric Drive Vehicles Monthly Sales Updates,* accessed 10 September 2021 at https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates.

103 EVAdoption, *EV Models Currently Available in the U.S.*, accessed 18 August 2021, archived at http://web.archive.org/web/20210818055300/https://evadoption.com/ev-models/.

104 Ben Preston and Jeff S. Bartlett, "Automakers are adding electric vehicles to their lineups. Here's what's coming," *Consumer Reports*, updated 7 September 2021, archived at https://web.archive.org/web/20211004220416/https://www.consumerreports.org/hybrids-evs/why-electric-cars-may-soon-flood-the-us-market-a9006292675/.

105 See note 11.

106 Ibid.

107 Laura Shields, National Conference of State Legislatures, *State Lawmakers Driving EV Policies in 2021*, 26 March 2021, archived at http://web.archive.org/web/20210817124744/https://www.ncsl.org/research/transportation/state-lawmakers-driving-ev-policies-in-2021-magazine2021.aspx.

108 Kristy Hartman and Laura Shields, National Conference of State Legislatures, *State Policies Promoting Hybrid and Electric Vehicles,* 20 August 2021, archived at http://web.archive.org/web/20210817205423/https://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx.

109 See note 11.

110 Ibid.

111 U.S. Department of Energy, *Alternative Fueling Station Counts by State*, accessed 6 October 2021 at https:/afdc.energy.gov/stations/states.

112 Ibid.

113 International Agency for Research on Cancer, World Health Organization, *IARC: Diesel Engine Exhaust Carcinogenic* (press release), 12 June 2012, archived at http://web.archive.org/web/20210727190646/https://www.iarc.who.int/wp-content/uploads/2018/07/pr213_E.pdf.

114 Matt Casale and Brendan Mahoney, U.S. PIRG Education Fund, *Paying for Electric Buses: Financing tools for cities and agencies to ditch diesel*, Fall 2018, archived at http://web.archive.org/web/20210901164457/https://uspirg.org/reports/usp/paying-electric-buses.

115 Caley Johnson et al., National Renewable Energy Laboratory, *Financial Analysis of Battery Electric Transit Buses*, June 2020, archived at https://web.archive.org/web/20211011143448/https://afdc.energy.gov/files/u/publication/financial_analysis_be_transit_buses.pdf.

116 Alana Miller and Hye-Jin Kim, Frontier Group; Jeffrey Robinson and Matthew Casale, U.S. PIRG Education Fund, *Electric Buses: Clean transportation for healthier neighborhoods and cleaner air,* May 2018, available at https://uspirg.org/sites/pirg/files/reports/Electric%20Buses%20-%20National%20-%20May%20 2018%20web.pdf.

117 "Electric bus sales to public transit agencies nearly doubles in 2017," *Mass Transit Magazine*, 26 January 2018, archived at http://web.archive.org/web/20190814151025/https://www.masstransitmag.com/home/press-release/12393848/eb-start-consulting-electric-bus-sales-to-public-transit-agencies-nearly-doubles-in-2017.

118 Al Sanders, King Country Metro, "Metro invites vendors to build battery-electric bus charging facility," *Metro Matters,* 11 January 2021, archived at http://web.archive.org/web/20210218095936/https://kingcountymetro.blog/2021/01/11/metro-invites-vendors-to-build-battery-electric-bus-charging-facility/.

119 Jeff St. John, "California commits to zero-emissions bus fleet by 2040," *Greentech Media*, 18 December 2018, archived at http://web.archive.org/web/20210313212656/https://www.greentechmedia.com/articles/read/california-commits-to-zero-emissions-bus-fleet-by-2040.

120 Steven Mufson and Sarah Kaplan, "A lesson in electric school buses," *Washington Post*, 24 February 2021.

121 U.S. Department of Transportation Federal Transit Administration, *National Transit Database*, 2019 Fuel and Energy data table (Excel file) and 2011 Table T17: Energy Consumption (Excel file), accessed 25 August 2021 at https://www.transit.dot.gov/ntd/ntd-data.

122 Cory Budischak et al., "Cost-minimized combinations of wind power, solar power and electrochemical storage, powering the grid up to 99.9% of the time," *Journal of Power Sources,* 225: 60-74, http://dx.doi.org/10.1016/j.jpowsour.2012.09.054, 15 June 2013.

123 Dan Gearino, "100% renewable energy needs lots of storage. This polar vortex test showed how much," *Inside Climate News*, 20 February 2019, archived at http://web.archive.org/web/20210507121500/https://insideclimatenews.org/news/20022019/100-percent-renewable-energy-battery-storage-need-worst-case-polar-vortex-wind-solar/.

124 University of Michigan Center for Sustainable Systems, *U.S. Grid Energy Storage Factsheet,* 2020, downloaded 7 September 2021 from https://css.umich.edu/factsheets/us-grid-energy-storage-factsheet.

125 Vast majority: Ibid.; only major form: Electricity Advisory Committee, *Energy Storage Activities in the United States Electricity Grid,* May 2011, 3, archived at http://web.archive.org/web/20210826222555/https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/FINAL_DOE_Report-Storage_Activities_5-1-11.pdf.

126 See note 13.

127 U.S. Energy Information Administration, "U.S. large-scale battery storage capacity up 35% in 2020, rapid growth set to continue," *Today in Energy,* 20 August 2021, archived at http://web.archive.org/web/20210906065207/https://www.eia.gov/todayinenergy/detail.php?id=49236.

128 BloombergNEF, *Energy Storage Is a $620 Billion Investment Opportunity in 2040* (blog), 6 November 2018, archived at http://web.archive.org/web/20190330164127/https:/about.bnef.com/blog/energy-storage-620-billion-investment-opportunity-2040/.

129 Deanna R. Reitman and Jeffrey Bourdon, DLA Piper, "Energy storage tax credits and climate goals: Latest developments in Washington," *Lexology*, accessed 7 September 2021, archived at https://web.archive.org/web/20210907184059/https://www.lexology.com/library/detail.aspx?g=1d418ef7-6d8b-47af-89d9-b51a7e55739b; David Roberts, "This federal agency is quietly, profoundly shaping climate policy," *Vox,* 22 May 2019, archived at http://web.archive.org/web/20210507133252/https://www.vox.com/energy-and-environment/2019/5/22/18631994/climate-change-renewable-energy-ferc.

130 Deanna R. Reitman and Jeffrey Bourdon, DLA Piper, "Energy storage tax credits and climate goals: Latest developments in Washington," *Lexology*, accessed 7 September 2021, archived at https://web.archive.org/web/20210907184059/https://www.lexology.com/library/detail.aspx?g=1d418ef7-6d8b-47af-89d9-b51a7e55739b; Julian Boggs, U.S. Energy Storage Association, personal communication, 1 October 2021.

131 See note 13.

132 U.S. Energy Information Administration, *Battery Storage in the United States: An Update on Market Trends*, July 2020, archived at http://web.archive.org/web/20210608091108/https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf.

133 In addition to California, Connecticut, Maine, Massachusetts, Nevada, New York, New Jersey, Oregon and Virginia. Ryan Kennedy, "Reviewing energy storage targets as Maine becomes the ninth state to participate," *PV Magazine*, 25 June 2021, archived at https://web.archive.org/web/20210708120104/https://pv-magazine-usa.com/2021/06/25/reviewing-energy-storage-targets-as-maine-becomes-the-ninth-state-to-participate/.

134 Jason Burwen, Energy Storage Association, "Energy storage goals, targets, mandates: What's the difference?," *The ESA Blog,* 24 April 2020, archived at http://web.archive.org/web/20210525094748/https://energystorage.org/energy-storage-goals-targets-and-mandates-whats-the-difference/.

135 "Winter Storm 2021," *The Texas Tribune,* archived at http://web.archive.org/web/20210903193710/https://www.texastribune.org/series/winter-storm-power-outage/.

136 Matt Casale, "Texas blackouts reveal how electric vehicles can provide power," *EcoWatch*, 24 February 2021, archived at http://web.archive.org/web/20210520043434/https://www.ecowatch.com/electric-vehicles-texas-blackout-2650741199.html.

137 Steve Hanley, "Ford & Sunrun team up to make V2H technology a reality. Is V2G next?", *CleanTechnica*, 30 May 2021, archived at https://web.archive.org/web/20211007051855/https://cleantechnica.com/2021/05/30/ford-sunrun-team-up-to-make-v2h-technology-a-reality-is-v2g-next/.

138 Jason Plautz, "Texas adding energy storage ahead of risky summer months: S&P analysis," *Utility Dive*, 16 June 2021, archived at http://web.archive.org/web/20210721174238/https://www.utilitydive.com/news/texas-adding-energy-storage-ahead-of-risky-summer-months-sp-analysis/601868/.

139 See note 13; U.S. Energy Information Administration, *Preliminary Monthly Electric Generator Inventory* (based on Form EIA-860M as a supplement to Form EIA-860) July 2021, 24 September 2021, downloaded from https://www.eia.gov/electricity/data/eia860m/.

140 Ibid.

141 Gideon Weissman, Frontier Group; Emma Searson, Environment America Research & Policy Center, *We Have the Power,* 3 June 2021, archived at https://web.archive.org/web/20210910204313/https://frontiergroup.org/sites/default/files/reports/AME%20FRG%20We%20Have%20The%20Power%20May21%20web.pdf.

142 Ibid.

143 Assumes no increases post-2020 in other forms of renewable energy. See note 5; 2050 electricity consumption based on U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2021*, Table 8: Electricity supply, disposition, prices and emissions, downloaded 18 August 2021 from https://www.eia.gov/outlooks/aeo/data/browser/#/?id=8-AEO2021&sourcekey=0.

144 U.S. Energy Information Administration, Electricity Data Browser, accessed 7 September 2021 at https://www.eia.gov/electricity/data/browser/.

145 See note 5.

146 Based on data summary tables from: Lawrence Berkeley Lab National Laboratory, *Wind Technologies Market Report*, August 2020, downloaded from https://emp.lbl.gov/wind-technologies-market-report.

147 Ibid.

148 Tomas Kellner, *Prime Mover: World's Most Powerful Wind Turbine To Supply Electricity To Dutch Customers For The First Time*, General Electric, 17 December 2019, archived at http://web.archive.org/web/20210119131513/https://www.ge.com/news/reports/prime-mover-worlds-most-powerful-wind-turbine-to-supply-electricity-to-dutch-customers-for-the-first-time.

149 Ryan Miser et al., Lawrence Berkeley National Laboratory, *The Future of Wind Energy, Part 3: Reducing Wind Energy Costs through Increased Turbine Size: Is the Sky the Limit?,* 1 November 2016, archived at http://web.archive.org/web/20210329004457/https://emp.lbl.gov/news/future-wind-energy-part-3-reducing-wind.

150 West Coast: Rob Nikolewski, "California tries to capture offshore wind energy," *The San Diego Union-Tribune*, 16 June 2016, archived at http://web.archive.org/web/20210511140241/https://www.sandiegouniontribune.com/sdut-offshore-floating-wind-2016jun16-story.html on 11 May 2021; Maine: David Thill, "Why floating turbines are so important to Maine's offshore wind prospects," *Energy News Network*, 7 August 2020, archived at https://web.archive.org/web/20211007053112/https://energynews.us/2020/08/07/why-floating-turbines-are-so-important-to-maines-offshore-wind-prospects/.

151 Anthony Lopez et al., National Renewable Energy Laboratory, *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis,* July 2012, archived at http://web.archive.org/web/20210820161156/https://www.nrel.gov/docs/fy12osti/51946.pdf.

152 Based on summary data tables from: Lawrence Berkeley Lab National Laboratory, *Tracking the Sun 2020 Data Update*, December 2020, downloaded from https://emp.lbl.gov/tracking-the-sun.

153 Lawrence Berkeley Lab National Laboratory, *Utility-Scale Solar 2020 Data Update*, November 2020, archived at http://web.archive.org/web/20210320022435/https://emp.lbl.gov/sites/default/files/2020_utility-scale_solar_data_update.pdf; Billy Ludt, "What is a solar tracker and how does it work?," *Solar Power World*, 16 January 2020, available at https://www.solarpowerworldonline.com/2020/01/what-is-a-solar-tracker-and-how-does-it-work/.

154 Mark Bolinger and Joachim Seel, Lawrence Berkeley National Laboratory, *Utility-Scale Solar 2015: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States*, 2016, archived at http://web.archive.org/web/20210416082021/https://emp.lbl.gov/publications/utility-scale-solar-2015-empirical .

155 Smart thermostats: Nest, *Energy Savings from the Nest Learning Thermostat: Energy Bill Analysis Results,* February 2015, archived at https://web.archive.org/web/20210907202354/https://www.achrnews.com/ext/resources/2015/02-2015/02-02-2015/Nest_energy_savings_white_paper2215.pdf; 40% of thermostat sales: Maria Taylor, "Smart thermostats are making their way into existing homes," *Air-Conditioning Heating Refrigeration News*, 22 October 2018, archived at http://web.archive.org/web/20210318072104/https://www.achrnews.com/articles/139920-smart-thermostats-are-making-their-way-into-existing-homes.

156 Ethan Rogers, American Council for an Energy-Efficient Economy, *Intelligent Efficiency Technology and Market Assessment,* 25 April 2017, archived at http://web.archive.org/web/20210305223418/https://www.aceee.org/research-report/ie1701.

157 Advanced Energy Economy, *Advanced Energy Now 2019 Market Report*, 2019, available at https://info.aee.net/hubfs/Market%20Report%202019/AEN%202019%20Market%20Report.pdf.

158 Zero Energy Project, *Net Zero Buildings in North America,* accessed 23 August 2021, archived at http://web.archive.org/web/20210823181204/https://zeroenergyproject.org/net-zero-buildings-in-north-america/.

159 U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "FOTW# 1167, January 4, 2021: Median driving range of all-electric vehicles tops 250 miles for model year 2020," *Fact of the Week*, 4 January 2021, archived at http://web.archive.org/web/20210630005037/https://www.energy.gov/eere/vehicles/articles/fotw-1167-january-4-2021-median-driving-range-all-electric-vehicles-tops-250.

160 Tesla Roadster: Tesla, *Tesla Roadster,* Tesla, accessed 31 August 2021, archived at http://web.archive.org/web/20210831173858/https://www.tesla.com/roadster; 208 miles more: EVAdoption, *Statistics of the Week: Comparing Vehicle Ranges for Gas, BEV and PHEV Models,* 27 January 2018, archived at https://web.archive.org/web/20190816235018/https://evadoption.com/statistics-of-the-week-comparing-vehicle-ranges-for-gas-bevs-and-phevs/.

161 Kristen Korosec, "Tesla Roadster now has a 400-mile range – for a price," *Fortune*, 1 September 2015, archived at http://web.archive.org/web/20210310170850/https://fortune.com/2015/09/01/tesla-roadster-battery-upgrade/.

162 Announced: Connor Hoffman, "Ford confirms electric F-150 will be called Lightning," *Car and Driver*, 10 May 2021; archived at https://web.archive.org/web/20210924151753/https://www.caranddriver.com/news/a36384035/ford-f-150-lightning-name-confirmed/; best-selling: Matthew DeBord, "The all-new Ford F-150 pickup arrives this week. Here's why it's been America's best-selling truck for over 4 decades," *Business Insider*, 23 June 2020, archived at https://web.archive.org/web/20210924152231/https://www.businessinsider.com/new-ford-f-150-pickup-why-its-americas-bestselling-truck-2020-6.

163 Honda Clarity: Honda, *2021 Clarity Plug-In Hybrid,* accessed 29 August 2021, archived at http://web.archive.org/web/20210829201834/https://automobiles.honda.com/clarity-plug-in-hybrid; Hyundai Kona EV: Hyundai, *2022 KONA Electric Overview*, accessed 13 August 2021, archived at http://web.archive.org/web/20210813202623/https://www.hyundaiusa.com/us/en/vehicles/kona-electric; Subaru Solterra: Subaru, *Introducing the All-New Subaru Solterra,* accessed 2 September 2021, archived at http://web.archive.org/web/20210902203222/https://www.subaru.com/solterra-ev.

164 U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *All-Electric Vehicles,* accessed 17 August 2021, archived at http://web.archive.org/web/20210817001233/https://www.fueleconomy.gov/feg/evtech.shtml.

165 See, for example, Jason Plautz, "Form Energy's $20/kWh, 100-hour iron-air battery could be a 'substantial breakthrough'," *Utility Dive*, 26 July 2021, archived at https://web.archive.org/web/20211007054056/https://www.utilitydive.com/news/form-energys-20kwh-100-hour-iron-air-battery-could-be-a-substantial-br/603877/.

166 U.S. Department of Energy, *Secretary Granholm Announces New Goal to Cut Costs of Long Duration Energy Storage by 90 Percent*, 14 July 2021, archived at https://web.archive.org/web/20211007053854/https://www.energy.gov/articles/secretary-granholm-announces-new-goal-cut-costs-long-duration-energy-storage-90-percent.

167 Ran Fu, David Feldman and Robert Margolis, National Renewable Energy Laboratory, *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018,* November 2018, archived at http://web.archive.org/web/20210430234401/https://www.nrel.gov/docs/fy19osti/72399.pdf.

168 Lazard, *Lazard's Levelized Cost of Energy Analysis – Version 12.0,* November 2018, archived at http://web.archive.org/web/20210831052121/https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf.

169 Ibid.

170 1.99 cents: John Fitzgerald Weaver, "Los Angeles seeks record setting solar power price under 2¢/kWh," *PV Magazine*, 28 June 2019, archived at http://web.archive.org/web/20210404023413/https://pv-magazine-usa.com/2019/06/28/los-angeles-seeks-record-setting-solar-power-price-under-2%C2%A2-kwh/; 7.4 cents: Robert Walton, "2019 wholesale solar prices more than double wind, gas as renewables use reaches record levels: EIA," *UtilityDive*, 20 October 2020, archived at https://web.archive.org/web/20210924212900/https://www.utilitydive.com/news/2019-us-wholesale-solar-prices-more-than-double-wind-gas-nuclear-eia/587364/.

171 $40: Martin LaMonica, CNET, *Sylvania 60-watt Replacement LED Coming to Lowes*, 18 November 2010, archived at http://web.archive.org/web/20201021210843/https://www.cnet.com/news/sylvania-60-watt-replacement-led-coming-to-lowes/; less than $2: The Home Depot, *60-Watt Equivalent A19 Non-Dimmable LED Light Bulb Daylight (8-Pack)*, accessed 21 October 2020, archived at http://web.archive.org/web/20210901023349/https://www.homedepot.com/p/EcoSmart-60-Watt-Equivalent-A19-Non-Dimmable-LED-Light-Bulb-Daylight-8-Pack-B7A19A60WUL38/303574493.

172 U.S. Department of Energy, *LED Lighting Energy Saver*, accessed 7 September 2021, archived at http://web.archive.org/web/20210901140655/https://www.energy.gov/energysaver/led-lighting.

173 Ibid.

174 Katherine Dykes et al., National Renewable Energy Laboratory, *Enabling the SMART Wind Power Plant of the Future Through Science-Based Innovation*, August 2017, archived at http://web.archive.org/web/20210318125543/https://www.nrel.gov/docs/fy17osti/68123.pdf?gathStatIcon=true.

175 Bloomberg NEF, *New Energy Outlook 2018*, accessed 16 August 2019, archived at https://web.archive.org/web/20190816003449/https://bnef.turtl.co/story/neo2018?src=-pressrelease&utm_source=pressrelease.

176 Tom Kenning, "Energy storage economics being 'transformed' with 52% drop in costs up to 2030 – BNEF," *PV Tech*, 8 November 2018, accessed at https://www.pv-tech.org/energy-storage-economics-being-transformed-with-52-drop-in-costs-up-to-2030/.

177 Chris Harto, Consumer Reports, *Electric Vehicle Ownership Costs: Today's electric vehicles offer big savings for consumers*, October 2020, archived at https://web.archive.org/web/20210814052421/https://advocacy.consumerreports.org/wp-content/uploads/2020/10/EV-Ownership-Cost-Final-Report-1.pdf.

178 Consumer Reports, *Consumer Reports Comments on EPA's "Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions Standards" (Docket No. EPA-HQ-OAR-2021-02087)*, 27 September 2021, 16.

179 See note 141.

180 Galen Barbose, Lawrence Berkeley National Laboratory, *U.S. Renewables Portfolio Standards: 2021 Status Update: Early Release*, February 2021, archived at https://web.archive.org/web/20211011180432/https://eta-publications.lbl.gov/sites/default/files/rps_status_update-2021_early_release.pdf.

181 See note 16.

182 See note 9.

183 Ibid.

184 The American Council for an Energy-Efficient Economy (ACEEE), The 2013 State Energy Efficiency *Scorecard, 4 November 2013, archived at http://web.archive.org/web/20210627173103/https://www.aceee.org/sites/default/files/publications/researchreports/e13k.pdf.*

185 See note 11.

186 See note 58.

187 See note 9.

188 See note 9.

189 U.S. Energy Information Administration, *Electricity Data Browser*, accessed 15 August 2021 at https://www.eia.gov/electricity/data/browser/; Energy Information Administration, *State Electricity Profiles*, 2 November 2020, accessed 31 August 2021 at https://www.eia.gov/electricity/state/.