Renewables on the Rise 2019

A Decade of Progress Toward a Clean Energy Future

ENVIRONMENT TEXAS RESEARCH & POLICY CENTER

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Written by:

Jonathan Sundby and Gideon Weissman
Frontier Group

Rob Sargent
Environment America Research & Policy Center

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Executive Summary

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

Wind turbines and solar panels were novelties ten years ago; today, they are everyday parts of America's energy landscape. Energy-saving LED light bulbs cost $40 apiece as recently as 2010; today, they cost a few dollars at the hardware store.[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 renewable energy more widely and flexibly to meet a wide range of energy needs, and reduce our overall energy use – developments that enable us to envision an economy powered entirely with clean, renewable energy.

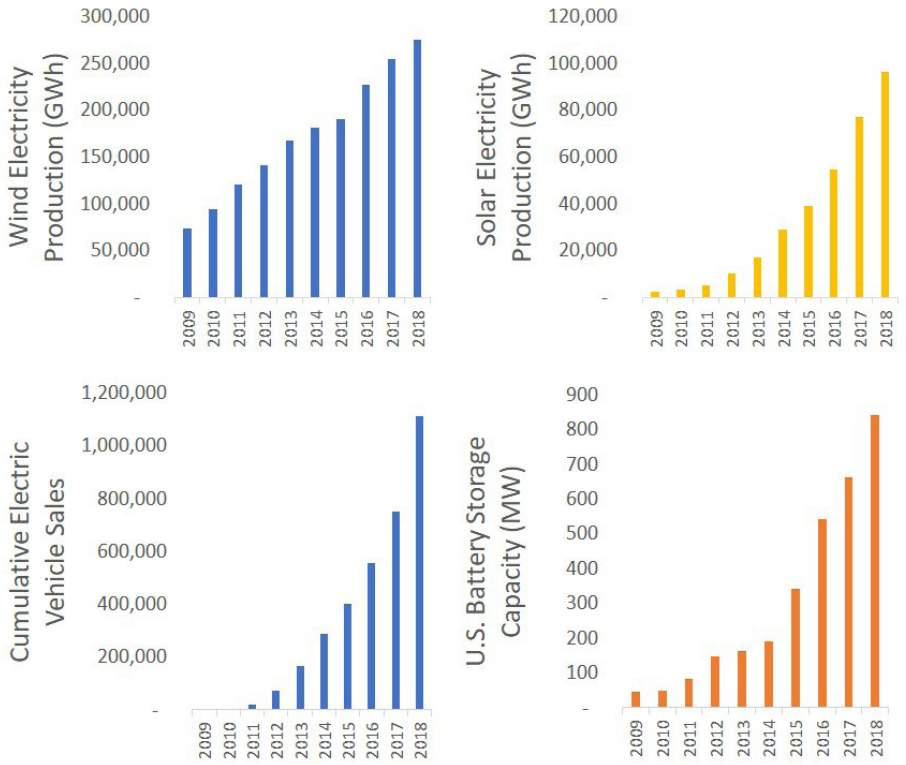
America produces **almost five times as much renewable electricity** from the sun and the wind as in 2009,[2] and currently wind and solar energy provide nearly **10 percent of our nation's electricity**.[3]

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 coming on line every day, **states, cities, businesses and the nation should work to obtain 100 percent 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 40 times more solar power than it did in 2009, enough to power more than 9 million average American homes. In 2009, solar rooftops and utility-scale solar power plants produced 0.07 percent of U.S. electricity; in 2018, they produced 2.53 percent of America's power.[4] In 2019, the 2 millionth solar PV system was installed, and experts expect this number to double in five years.[5]
- **Wind energy:** America has more than tripled the amount of wind power it produces since 2009, enough to power over 26 million homes. In 2009, wind turbines produced 2.1 percent of the nation's electricity; in 2018, they produced 7.2 percent of America's power.[6]
- **Energy efficiency:** According to a survey by the American Council for an Energy-Efficient Economy (ACEEE), electric efficiency programs across the U.S. saved more than twice as much energy in 2017 as in 2009, as states ramped up their investments in efficiency.[7] In 2017, these programs saved enough electricity to power more than 2.5 million homes. Investments in natural gas efficiency programs have also realized massive energy savings, and in 2016 saved 340 million therms of natural gas – equivalent to the usage of over 500,000 homes.[8]

Figure ES-1: Clean Energy Technologies Have Seen Dramatic Growth Since 2009.[13]



- **Electric vehicles:** Building an economy reliant on clean, renewable energy means ending the use of fossil fuels for all activities, including transportation. There were over 361,000 electric vehicles sold in the U.S. in 2018, up from virtually none in 2009.[9] Electric vehicle sales surged by nearly 86 percent in 2018 over 2017.[10] In the first seven months of 2019, electric vehicle sales were up an additional 14 percent over that same period in 2018. In 2018, the millionth electric vehicle was sold in America.[11]
- **Energy storage:** Expanding the ability to store electricity can help the nation take full advantage of its vast potential for clean, renewable energy. The United States saw an 18-fold increase in utility-scale battery storage from 2009 to 2018.[12]

Clean energy leadership is not concentrated in one part of the country. Rather, it is distributed across the United States, in states with different economic and demographic makeups, driven by a combination of clean energy attributes and policies that have helped clean energy measures succeed.

- **Solar energy:** California, Arizona, North Carolina, Nevada and Texas have seen the greatest total increases in solar energy generation since 2009.[14] California's landmark "Million Solar Roofs" program, which accelerated the state's solar industry in the mid-2000s, along with its strong renewable electricity standard and other policies, helped to trigger the dramatic rise of solar power there.
- **Wind energy:** Texas, Oklahoma, Kansas, Iowa and Illinois experienced the greatest total increases

in wind energy generation from 2009 to 2018.[15] Texas' policies to upgrade its grid to accommodate more wind power from rural west Texas played an important role in the boom.

- **Energy efficiency:** Rhode Island, Massachusetts, Vermont, Michigan and California saw the greatest increases in the share of electricity saved through efficiency measures, according to the American Council for an Energy-Efficient Economy. By 2017, Rhode Island was implementing efficiency measures designed to save the equivalent of 3 percent of 2016 statewide electricity sales.[16]

- **Electric vehicles:** California, New York, Washington, Florida and Texas have seen the most electric vehicles (EVs) sold.[17] Five of the top 10 states for EV sales require that a certain percentage of each automakers' sales be zero-emission vehicles, including California, which is home to nearly half of the nation's electric vehicles.[18]

- **Energy storage:** California, Illinois, Texas, West Virginia and Hawaii lead the nation in additions to battery storage since 2009, though the industry is still in its infancy.[19] By the end of 2018, California accounted for over a quarter of the nation's total battery storage capacity.[20] 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, for which energy storage was used to minimize grid disruptions.[21]

Rapid improvements in technology and plummeting prices for clean energy suggest that America has only begun to tap its vast clean energy potential.

- Nearly every segment of the clean energy market is experiencing rapid price declines. A National Renewable Energy Laboratory (NREL) survey of clean energy prices found that, from 2010 to 2018, the cost of distributed PV fell by 71 percent and utility-scale PV by 80-82 percent.[22] 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 percent during the same period.[23] It also reports that renewable sources like certain wind and solar energy technologies are "cost-competitive with conventional generation technologies."[24] In Idaho, for example, a record-breaking solar contract was signed in 2019, promising to deliver energy for 2.18 cents per kilowatt-hour.[25]

- One study by NREL found that the cost of wind energy is expected to fall 50 percent by 2030 from 2017 cost levels.[26] One study found that in most cases, building new wind and solar power is cheaper than running existing coal plants.[27] And renewable energy is only expected to get cheaper. Bloomberg New Energy Finance predicts that the cost of an average utility-scale solar plant will fall 71 percent by 2050.[28] It also estimates that by 2030, energy storage costs will fall by 52 percent.[29]

- Technology advances are making renewable energy technologies more efficient and effective. In 2007, the highest-capacity wind turbine in the world was 6 MW, with only one such test prototype actually in operation.[30] Today, an entire wind farm of 8 MW turbines is generating electricity off the coast of England; according to DONG Energy, which led the project, a single revolution of the blades on just one turbine can power a home for 29 hours.[31] This summer, GE expects to deploy the first prototype of its massive "Haliade-X" wind turbine, which has a capacity of 12 MW – enough to supply annual electricity for nearly 6,500 U.S. homes.[32]

- Advanced new products are also helping to reduce energy consumption. For example, light emitting diode (LED) lighting uses only a quarter the energy of a traditional, incandescent light and lasts up to 25 times longer.[33] From 2009 to 2015, the percentage of homes with at least one energy-efficient lightbulb in the house – typically either

an LED or CFL bulb – increased from 58 percent to 86 percent.[34] By 2027, the Department of Energy estimates that LEDs could save 348 terawatts of electricity, equivalent to the annual production of 44 large power plants.[35]

- America's renewable energy resources are enough to power the nation several times over. The technologies needed to harness and apply renewable energy are advancing rapidly. And researchers from a wide variety of academic and governmental institutions have developed a variety of scenarios suggesting renewable energy can meet all or nearly all of our society's needs.[36]

The U.S. should plan to meet all of its energy needs – for electricity, transportation and industry – with clean, renewable energy, and put policies and programs in place to achieve that goal.

- Repowering America with clean, renewable energy is a key strategy for phasing out carbon pollution by 2050 – a necessary step to prevent the worst impacts of global warming. 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.
- While clean, renewable energy is advancing rapidly, fully replacing fossil fuels will require additional commitment and action. If the nation were to install as much renewable energy every year as we did in 2018, by 2050 America would be producing enough electricity to only meet 43 percent of today's electricity demand, before accounting for non-electricity energy needs.
- To accelerate progress, a growing number of businesses, cities and states are adopting bold renewable energy targets and goals. More than a dozen states substantially increased their renewable electricity standards. Hawaii, California, New Mexico, Maine, New York and Washington state have all set targets for 100 percent clean energy.[37]
- Local governments, utilities and companies are also taking action. 127 cities across the country have committed to 100 percent renewable energy, and six cities have already achieved it.[38] Several utilities, including Xcel Energy, Platte River Power Authority and MidAmerican Energy, have made commitments to source their electricity from carbon-free or renewable sources.[39] The organization RE100 has also collected 100 percent renewable energy commitments from 191 companies, including IKEA, Google, and Anheuser-Busch InBev.[40]

America has already made incredible progress toward getting its energy from clean, renewable sources. Policymakers at all levels should fully commit to repowering America with clean, renewable energy.

Introduction

Seven years ago, Georgetown, a mid-sized city situated in the heart of Texas, had a choice to make. Its energy purchasing contract with the Lower Colorado River Authority was set to expire, and instead of renewing, it decided to search for a better deal.[41]

The city sent out requests for proposals to numerous electricity providers and came back with several offers from both fossil fuel and renewable energy companies. For accountant and Georgetown Mayor Dale Ross, the choice was surprising but clear: it made sense for Georgetown to be powered by 100 percent renewable energy.[42]

As Georgetown evaluated its options, the benefits of renewable energy became apparent. Prices for solar and wind energy were cost-competitive with natural gas and could be locked in for the duration of a 25-year contract – price stability that natural gas couldn't provide.[43] The city government also saw the utilization of wind and solar energy as an economic benefit, as it mitigated regulatory risk that could raise prices. In an interview with CityLab, Ross recognized that Georgetown's citizens "want reliability, and they wanted the cheapest possible price."[44]

Today the city is powered by two wind farms and a new utility-scale solar installation, producing more electricity than it consumes. It sends the excess energy onto the Texas grid to power other cities. In 2019 Georgetown is expected to buy over 1 billion kWh of clean energy, enough to power over 104,000 homes and almost 40 percent more electricity than it consumes.[45]

While Georgetown is the first city in Texas to be powered by renewable energy, it certainly won't be the last – either in Texas or across the country. Wind turbines are now a common sight across the plains of the Midwest and solar panels have popped up on rooftops of America's cities and towns from Maine to California. In the past decade, America's production of wind energy has increased over 270 percent and our solar energy capacity by 40-fold. Over that same time frame, energy storage technologies have become more efficient and cost-effective, improving the ability of homeowners, businesses and utilities to save abundant, pollution-free renewable energy for later. And, thanks to increasing gains in energy efficiency, the energy these resources produce can go even further in meeting our energy needs.

Cities, states, companies and institutions around the country are increasingly coming to the same conclusion as Georgetown: that renewable energy sources offer the cleanest, healthiest and often the least expensive choice for our energy future. The path to a nation powered by 100 percent renewable energy is far from clear, but the rapid growth in solar power, wind power, energy efficiency and electric vehicles over the last decade, along with the clean energy success of pioneering cities like Georgetown, shows that it can be done – and that it's worth doing.

Clean Energy Technologies Are Booming Across America

Since 2009, America has made rapid progress toward repowering our economy with clean, renewable energy.

Ten years ago, many key clean energy technologies were limited to niche markets or perceived as too expensive. 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 40-Fold Since 2009

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.[46]

Despite its abundance, tapping into solar energy was too difficult and prohibitively expensive for most people until the early part of the 21st century. By 2009, years of intensive research, along with pioneering pro-solar policies adopted by states such as California, had begun to pave the way for increased adoption of solar energy. That year, solar rooftops and utility-scale solar power plants produced 0.07 percent of America's electricity, or enough electricity to power 227,983 average American homes.[47]

What Is Clean, Renewable Energy?

Not all renewable energy sources have an equal benefit 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.

Solar panels being installed on a rooftop. Credit: skeeze via pixabay, CC-BY-1.0

Since 2009, however, solar power has boomed. By 2012, solar power was generating enough electricity to power one million average U.S. homes. In April 2016, the U.S. saw its one-millionth solar panel installation.[48]

By the end of 2018, the U.S. had wrapped up its biggest solar year in history, generating 40 times as much solar power as in 2009. In 2018, solar power generated 2.53 percent of America's electricity, a 24 percent increase over the previous year and enough to power more than 9 million average American homes.[49] Solar energy continued its rapid growth in early 2019, as the nation produced 6 percent more solar electricity in the first two months of the year than it did in the first two months of 2018.[50]

Solar energy may still produce only a small share of America's electricity, but it is growing rapidly. Small-scale solar energy, including panels installed on residential and commercial rooftops, almost tripled from 2014 to 2018, and utility-scale generation grew 74-fold from 2009 to 2018. America's capacity to produce electricity from concentrating solar power – in which mirrors focus sunlight on a central point, capturing solar energy as heat – has increased significantly since 2009.[51] Altogether, solar energy accounted for nearly a quarter of U.S. power plant capacity additions in 2018.[52]

The growth of solar energy can be seen not only in the proliferation of solar panels on rooftops but also in changes in the workforce. The growth of solar energy has created a wide variety of employment opportunities, from research to manufacturing to installation to sales. The solar industry now employs 242,000 solar workers, more than twice as many as are employed by the coal industry.[53]

Figure 1. Solar Electricity Generation Grew 40-Fold from 2009 to 2018[54]

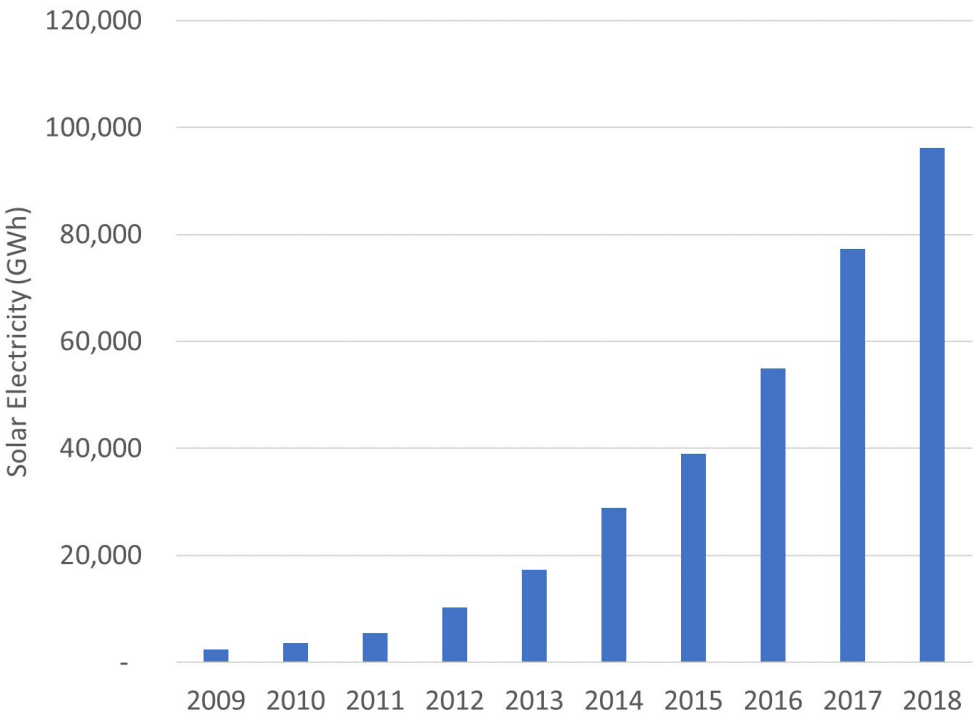


Table 1. Top States for Solar Electricity Growth 2009 to 2018 (GWh)[58]

State	Solar Electricity Production, 2009	Solar Electricity Production, 2018	Increase, 2009-2018	Rank, by Increase
California	1,602	39,997	38,395	1
Arizona	64	7,477	7,413	2
North Carolina	11	7,209	7,198	3
Nevada	198	5,144	4,946	4
Texas	12	4,063	4,051	5
Massachusetts	19	3,194	3,175	6
New Jersey	181	3,219	3,038	7
Florida	24	2,904	2,880	8
Utah	1	2,575	2,574	9
Georgia	1	2,439	2,438	10

Figure 2. Solar Energy Production, Top States, 2009 and 2018

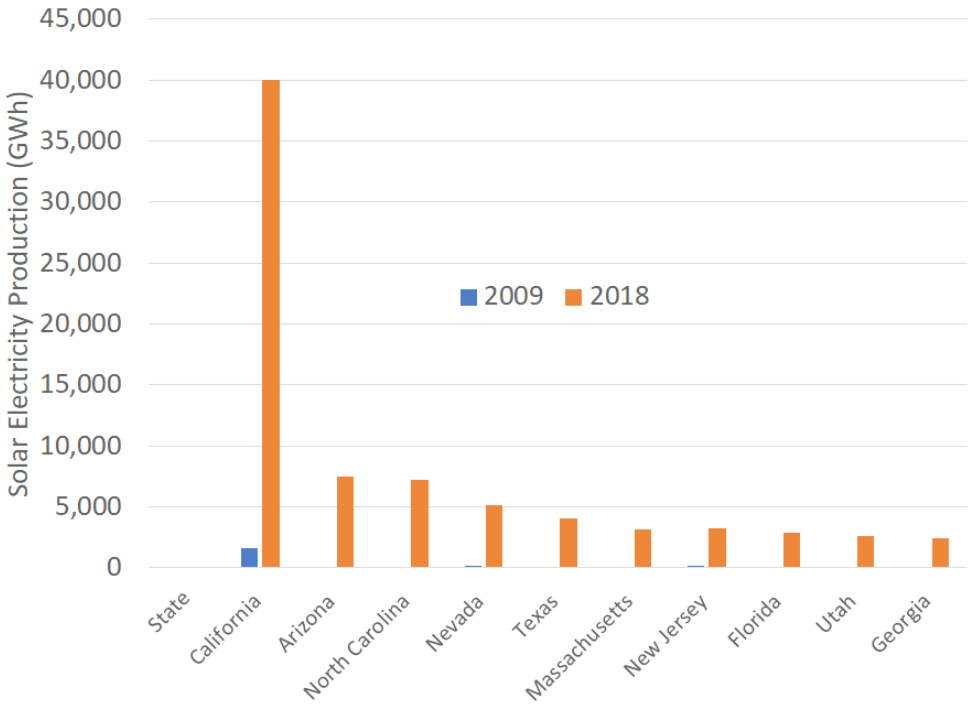
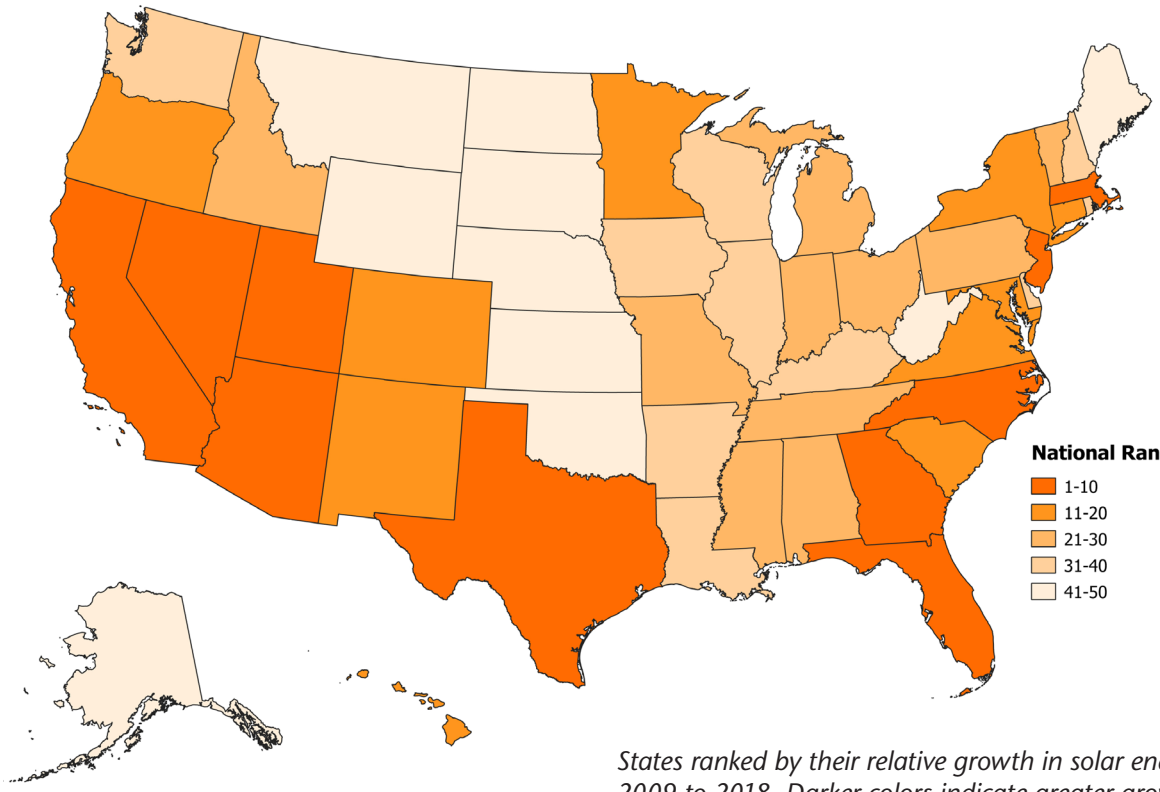


Figure 3. America's Top States for Growth in Solar Energy Production Since 2009



States ranked by their relative growth in solar energy from 2009 to 2018. Darker colors indicate greater growth in solar energy production.

California stands apart in solar energy growth and overall production of solar energy. California was responsible for 40 percent of the growth in solar energy production nationwide between 2009 and 2018, with the amount of solar electricity produced in the state increasing 25-fold over that time.[55] California's booming solar market has benefited from strong policy support, including the innovative "Million Solar Roofs" program that accelerated solar energy growth in the mid-2000s.[56]

The top 10 states for solar energy additions since 2009 include some of America's sunniest states, like Arizona and Nevada, as well as northeastern states such as New Jersey and Massachusetts that have provided strong policy support for solar energy. Many of the states with the most rapid solar energy growth have benefited from a suite of strong solar policies; including solar carve-outs in renewable electricity standards and policies that ensure that solar PV system owners are appropriately compensated for the excess energy they supply to the grid, such as net metering.[57]

Wind Energy Has More Than Tripled Since 2009

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

Wind power is not a new concept. Humans 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 2009, America had built up modest capacity for generating electricity from the wind, producing 2.1 percent of the nation's electricity, enough to power more than 7 million homes.[59]

The last decade has seen dramatic growth in wind energy. From 2009 through 2018, American wind generation more than tripled. In 2018, wind turbines produced 7.2 percent of America's power, an increase of 8 percent over the previous year and enough to power more than 26 million homes.[60]

Wind turbines tower over farm fields in Northern Iowa. Credit: Carl Wycoff via Flickr, CC-BY-2.0

Today, the U.S. is also just beginning its offshore wind era: In 2016, America's first utility-scale offshore turbines began spinning off the coast of Rhode Island, where the 30 MW wind farm generates enough electricity to power 17,000 homes.[61] Other states are also moving toward offshore wind. In Massachusetts, there is already a contract to build 800 MW of wind turbines near Martha's Vineyard, and the state legislature recently voted to double its commitment to offshore wind, mandating 3,200 MW of offshore wind power along its coasts.[62] In January 2019, New York set a goal to acquire 9,000 MW of offshore wind capacity by 2035.[63]

State polices, with an assist from the federal tax incentives, have enabled the dramatic rise of wind and solar power. A study by the Natural Resources Defense Council estimated that the extension of those tax credits in late 2015 "will prompt the development of nearly 29,000 megawatts of additional new utility-scale wind and solar capacity by 2020, enough to power nearly 8 million homes."[64]

To date, Midwest and Southwest states have led the American wind energy revolution. From 2009 to 2018, Texas, Oklahoma and Kansas led the nation in added wind power. In Oklahoma and Kansas, wind generation grew more than six-fold over that period. Renewable electricity standards (RES) have helped spur the development of renewable energy resources throughout the country, and while economics has been the primary driver of wind growth in the Mid-

Figure 4. U.S. Wind Energy Production More Than Tripled from 2009 to 2018[65]

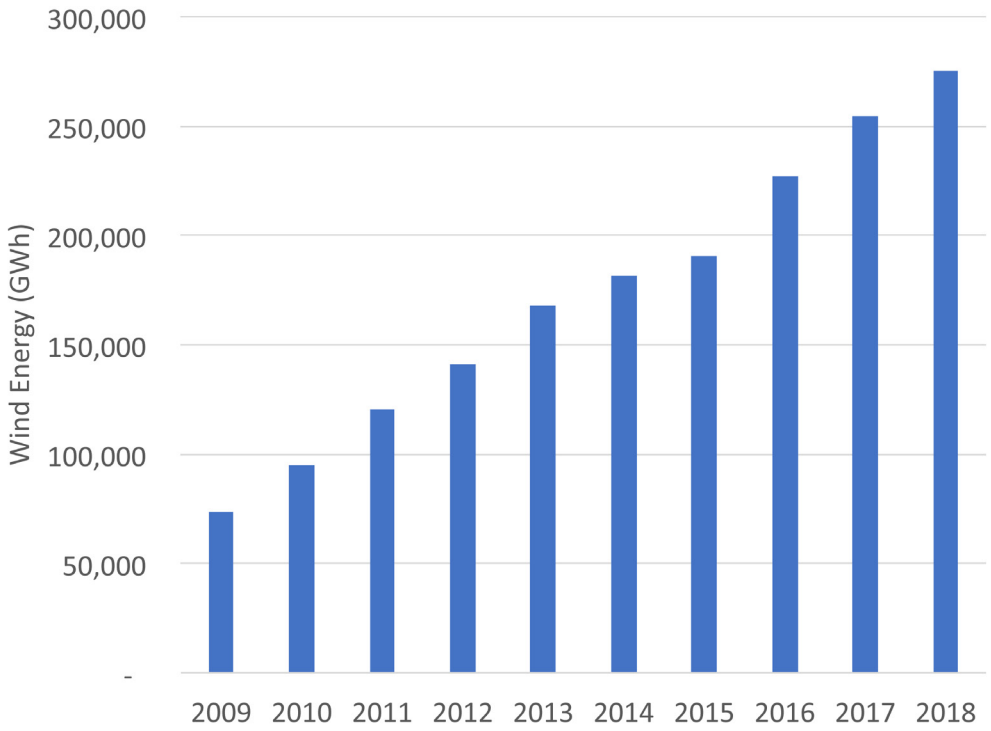


Table 2. States with Most Additional Wind Generation 2018 versus 2009 (GWh)[69]

State	Wind Energy Production, 2009	Wind Energy Production, 2018	Increase, 2009 - 2018	Rank, by Increase
Texas	20,026	75,753	55,727	1
Oklahoma	2,698	27,593	24,895	2
Kansas	2,863	19,295	16,432	3
Iowa	7,421	21,685	14,264	4
Illinois	2,820	12,812	9,992	5
California	5,840	13,650	7,810	6
North Dakota	2,998	10,764	7,766	7
Colorado	3,164	9,819	6,655	8
Minnesota	5,053	11,346	6,293	9
Michigan	300	5,330	5,030	10

Figure 5. Wind Energy Production, Top States, 2009 and 2018

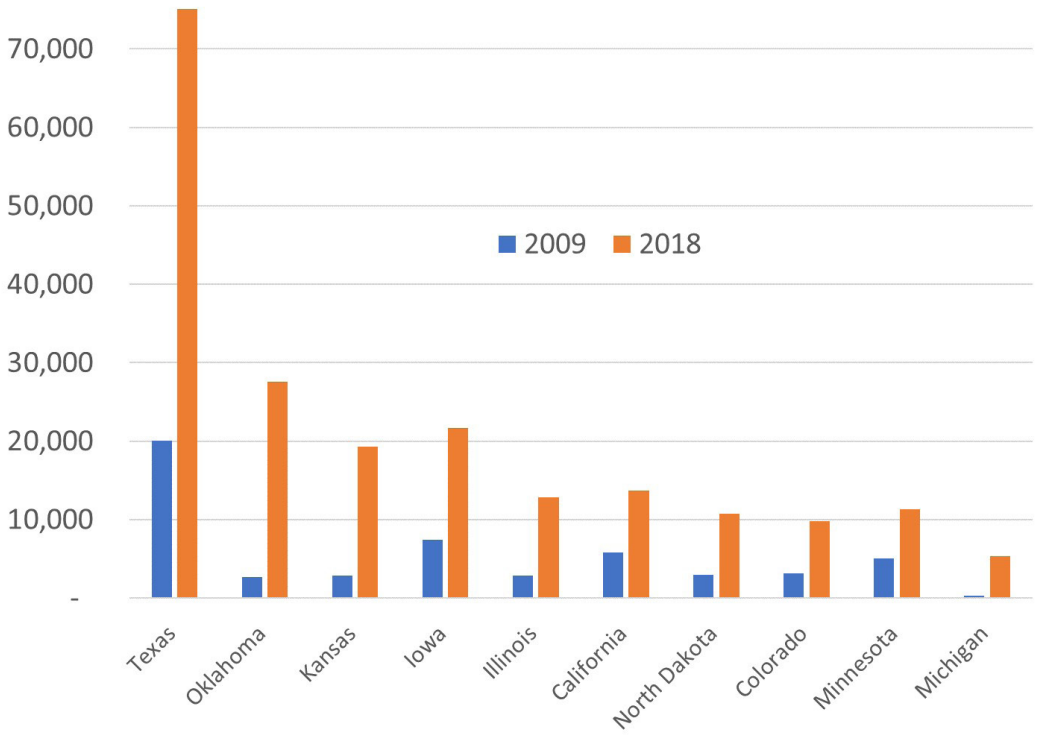
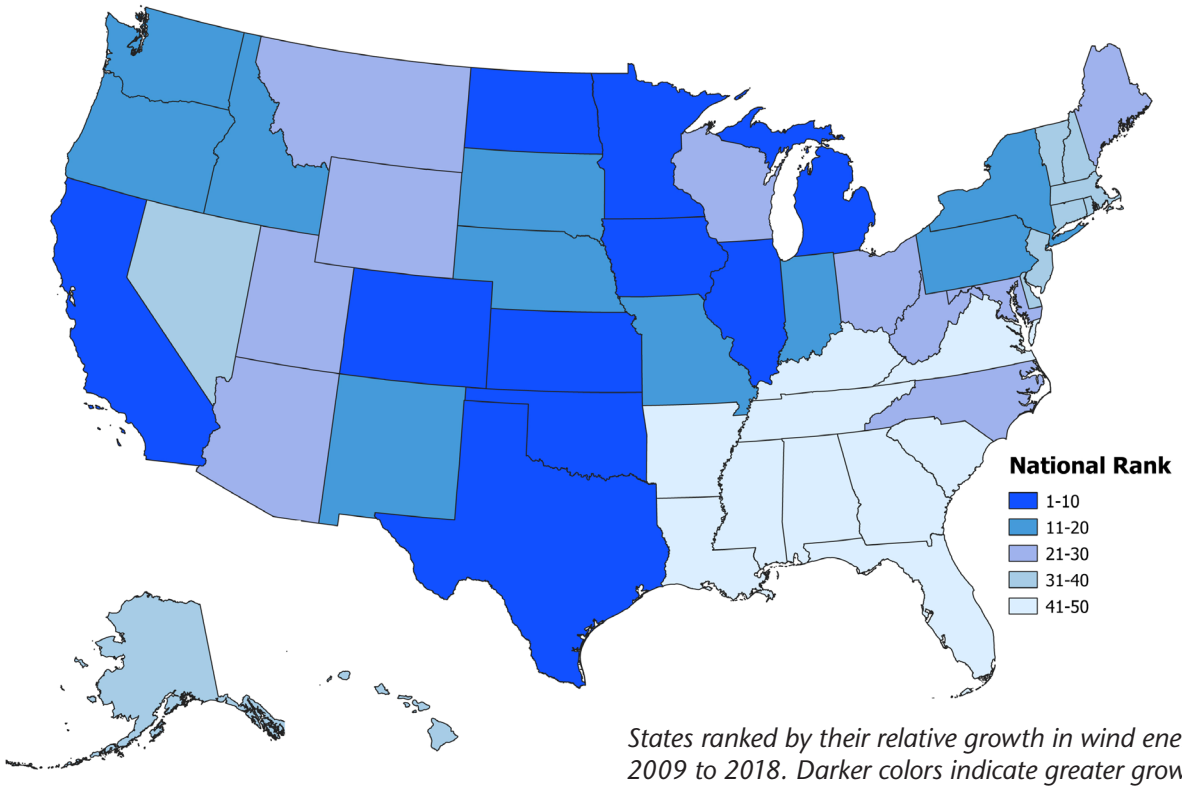


Figure 6. America's Top States for Wind Energy Growth Since 2009



States ranked by their relative growth in wind energy from 2009 to 2018. Darker colors indicate greater growth in wind energy production.

west, there are currently plans to update and expand transmission lines to help export wind energy to states with robust renewable energy requirements.[66]

In Texas alone there are now more than 10,000 wind turbines; during the early morning hours on one day in February 2017, wind power supplied more than half of Texas' electricity demand.[67] While Texas' wind energy growth was triggered by the renewable electricity standard it established in 1999, the recent growth was enhanced by a $7 billion investment in the state grid, which allows for the transmission of wind energy from the state's windiest regions to its biggest cities.[68]

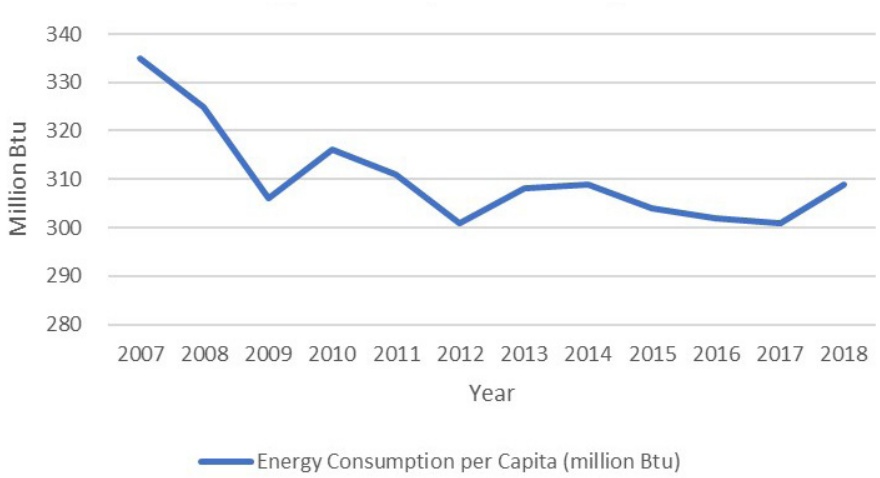
America Continues to Become More Energy Efficient

The task of moving to 100 percent 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.[70] Since then, however, energy use in the United States has stayed roughly the same, despite a growing population and economy.[71] On a per-capita basis, energy consumption in the U.S. fell by almost 8 percent from 2007 to 2018.

Energy consumption per capita has been on a downward trajectory over the last decade. Even amidst a slight uptick in energy consumption in 2018, the nation still used only 1 percent more energy per

Figure 7. U.S. Per Capita Energy Consumption Has Decreased by 7.8 Percent Since 2007



capita than it did during the depths of the recession in 2009. From 2009 to 2018, energy consumption per unit of GDP fell by more than 11 percent, even as real GDP increased by 22 percent.[72]

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.[73] In 2009, the preliminary average fuel economy of a new, light-duty vehicle was 22.4 miles per gallon.[74] In 2018, the average fuel economy was 25.4 miles per gallon – an improvement of 13 percent.

- According to a survey by the American Council for an Energy-Efficient Economy (ACEEE), electric efficiency programs across the U.S. saved more than twice as much energy in 2017 as in 2009, as states ramped up investments in efficiency.[75] In 2017, these programs saved enough electricity to power more than 2.5 million homes, equivalent to 0.7 percent of all U.S. electricity sales in 2017.

- 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.[76] From 2009 to 2015, the percentage of homes with at least one energy-efficient lightbulb in the house – typically either an LED or CFL bulb – increased from 58 percent to 86 percent.[77] By 2027, the Department of Energy estimates that LEDs could save 348 terawatts of electricity, or equivalent to the annual production of 44 large power plants.[78]

- Utility and state efficiency programs have been able to prevent the usage of millions of therms of natural gas, a greenhouse gas emitting fossil fuel. Although a truly carbon-free society will have to be powered exclusively by renewable sources, making gas appliances and systems more efficient can help avoid more carbon dioxide and methane emissions. In 2016, these efficiency programs saved 340 million therms of natural gas – equivalent to the usage of over 500,000 homes.[79]

- State energy building codes are reducing building energy use; residential and commercial buildings account for 40 percent of U.S. energy consumption.[80] In recent years many states either implemented or updated building energy codes.[81] In 2014, building energy codes saved approximately 1.1 quadrillion Btu.[82] Between 2010 and 2040, the U.S. Department of Energy estimates that model energy codes could save 12.82 quadrillion Btu, or enough to power 89 million homes.[83]

ACEEE's data on energy efficiency also reveals improvements in state-level programs and policies to reduce electricity use. Rhode Island, Massachusetts, Vermont, Michigan and California led the nation in additional electricity efficiency savings in 2017 compared with 2009.[84] Over that period, Rhode Island almost tripled its electricity savings, and in 2017 Rhode Island's electricity savings were equivalent to over 3 percent of the state's total electricity consumption. These savings were thanks to several energy-saving programs in the state. Significant savings have been due to Rhode Island's Comprehensive Energy Conservation, Efficiency and Affordability Act of 2006, which requires utilities to acquire all cost-effective energy efficiency.[85] And, since 2008, Rhode Island has invested millions of dollars in revenue from the Regional Greenhouse Gas Initiative (RGGI, the northeast's carbon cap-and-trade program) in energy efficiency, in programs designed to promote efficient public-sector buildings, and improved efficiency in homes and businesses.[86]

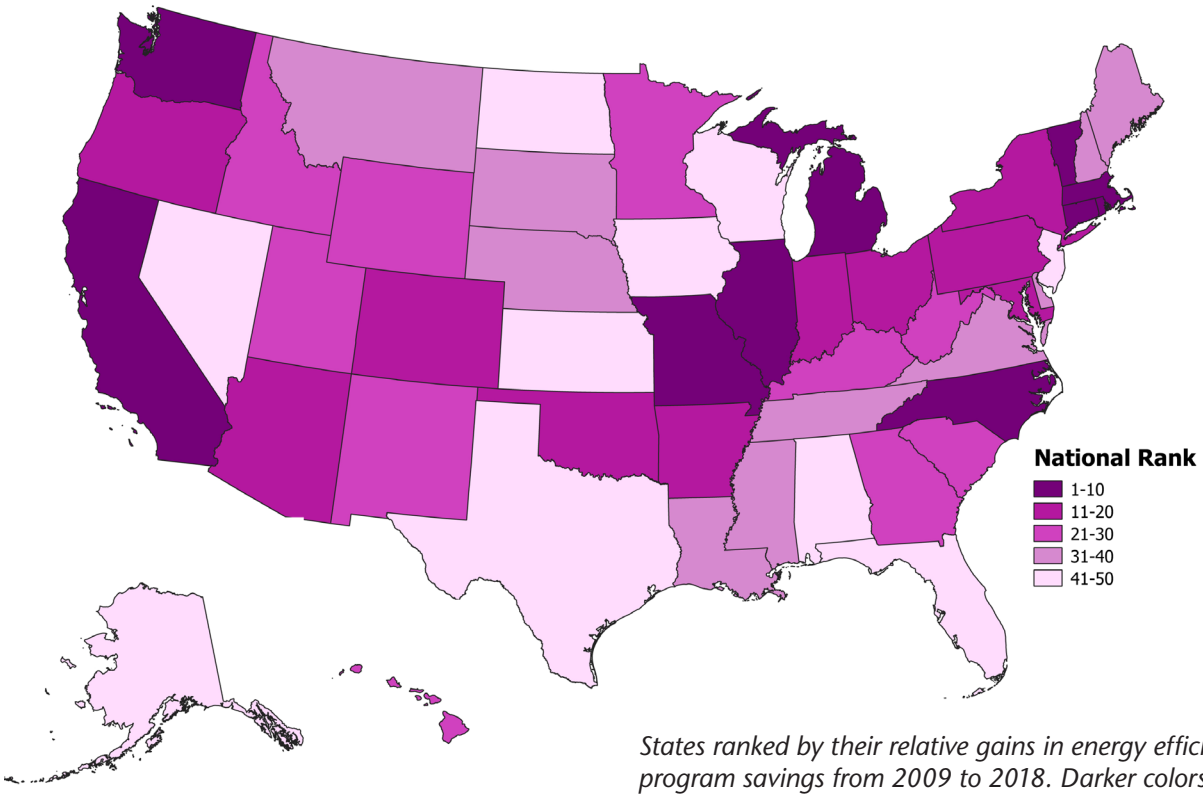
Smart thermostats, like this Nest Diamond Thermostat, can help reduce energy usage in homes. Credit: grant-sewell via Wikimedia, CC BY-SA 2.0

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

Table 3. Most Improved States for Electricity Efficiency[89]
Data reported by ACEEE's 2011 and 2018 State Energy Efficiency Scorecard reports.

State	Electricity Saved as % of Retail Sales, 2009	Electricity Saved as % of Retail Sales, 2017	Change (Percentage points)	Rank, by Increase
Rhode Island	1.07%	3.08%	2.01	1
Massachusetts	0.84%	2.57%	1.73	2
Vermont	1.64%	3.33%	1.69	3
Michigan	0.38%	1.48%	1.1	4
California	0.88%	1.97%	1.09	5
Illinois	0.40%	1.34%	0.94	6
Connecticut	0.84%	1.62%	0.78	7
Missouri	0.11%	0.78%	0.67	8
North Carolina	0.04%	0.69%	0.65	9
Washington	0.74%	1.35%	0.61	10

Figure 8. America's Top States for Electricity Efficiency Gains Since 2009



States ranked by their relative gains in energy efficiency program savings from 2009 to 2018. Darker colors indicate greater gains in energy efficiency.

point that they are now a viable heating system in cold climates.[87] To achieve a zero-carbon future, buildings across the nation will be transitioning to an electric source of heat within the next couple decades. Already, states like Maine and Vermont have established ambitious goals that will result in more electric heating systems.[88]

Annual Sales of Electric Vehicles Have Grown to 360,000

Achieving an economy powered by 100 percent 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 sizeable task, given that it that currently powers the overwhelming majority of our vehicles. Although there are several strategies for reducing transportation fossil fuel use – like encouraging public transportation, walking and biking, and promoting compact, walkable forms of development – 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 EVs – including plug-in hybrids – on American roads numbered only in the hundreds.

To date, however, there have been more than a million EVs (including plug-in hybrid vehicles) sold in the U.S.[90] There are over 40 models on the market, ranging from affordable commuter cars to luxury SUVs.[91] In 2018, 361,307 EVs were sold, a nearly 86 percent increase over 2017.[92] In the first seven months of 2019, EV sales were up 14 percent compared with the same time in 2018.[93] Last year, Tesla's Model 3 was the best-selling luxury car in the nation.[94]

Figure 9. Cumulative Electric Vehicle Sales Reached Over 1 Million in 2018[95]

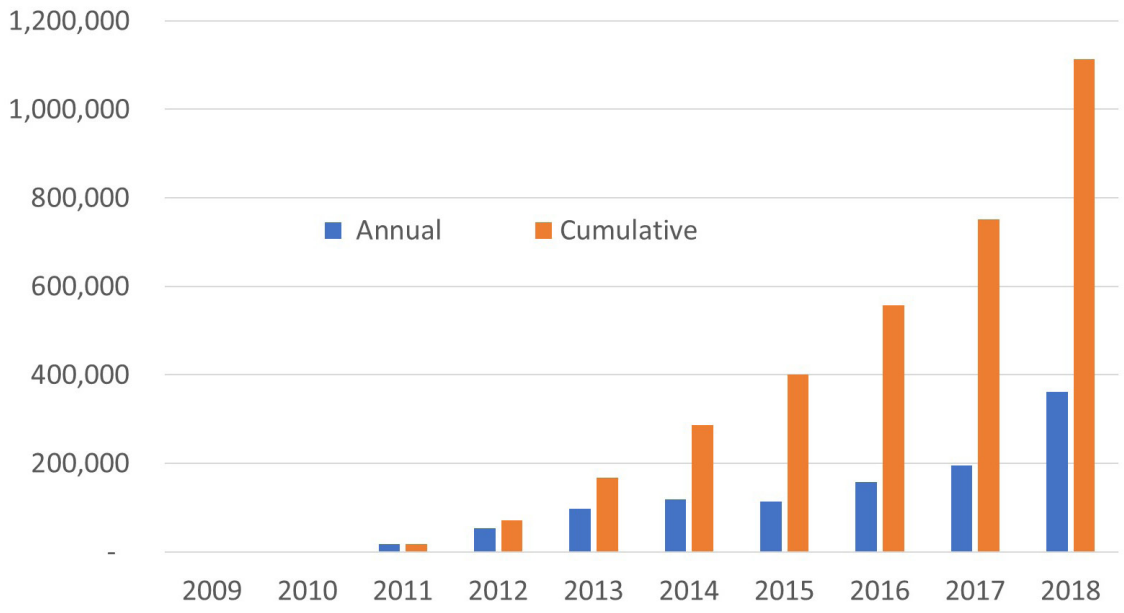


Table 4. Top EV States through 2018[106]

Rank (by EV Sales)	State	EV Sales through 2018	EVs per Thousand Registered Vehicles
1	California	506,608	34.7
2	New York	46,397	10.2
3	Washington	41,459	14.5
4	Florida	40,548	5.3
5	Texas	34,239	4.2
6	Georgia	33,947	9.8
7	New Jersey	25,945	9.3
8	Massachusetts	22,824	10.4
9	Illinois	22,475	4.9
10	Oregon	21,433	14.1

California leads the nation in electric vehicle adoption. Nearly half of all EVs ever sold in the country have been sold in California.[96] Five of the states leading the nation in EV sales – California, New Jersey, New York, Oregon and Massachusetts – have requirements that a certain percentage of each automakers' sales be zero-emission vehicles.[97] Georgia, which ranks sixth for cumulative EV sales, had seen its EV market boom under a tax incentive program. However, since that program was repealed and replaced with a registration fee for EVs, electric vehicle sales dropped by 80 percent.[98] Georgia's experience suggests the importance of policy for the adoption of EVs.

Recent years have also seen the widespread deployment of electric vehicle charging stations across the country. Currently there are more than 66,000 charging ports, located in 22,000 stations across the country, including along major highways.[107]

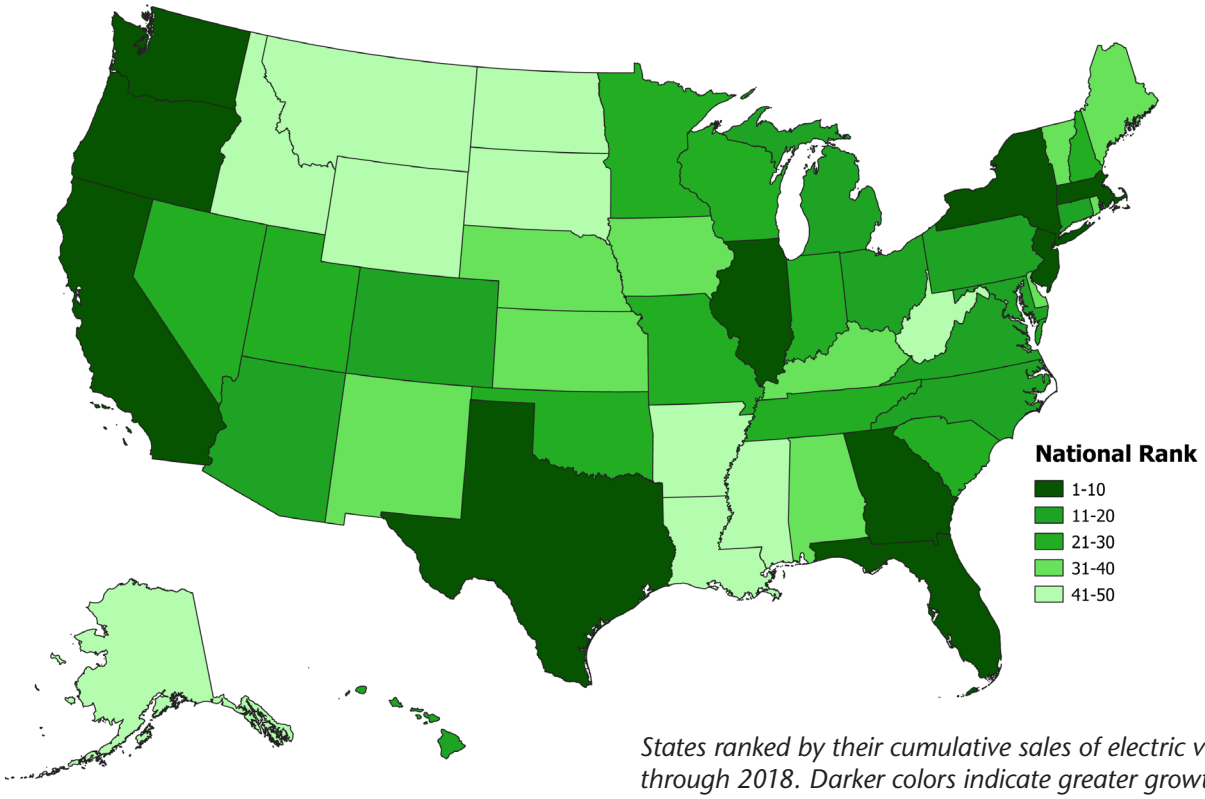
An electric vehicle charging station stands next to solar panels in Iowa. Credit: Jonathan Sundby.

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 also aggravate asthma and other respiratory illnesses.[99] A recent report by U.S. PIRG Education Fund found that 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.[100] Furthermore, electric buses can also save transit agencies money. While electric transit buses costs around $200,000 more than diesel buses, lifetime fuel and maintenance savings of electric transit buses are around $400,000.[101]

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 within its fleet.[102] Three years later, hundreds of electric buses were running across the country and 9 percent of all transit agencies had an electric bus in service or ordered.[103] King County Metro Transit, which serves Seattle and the surrounding areas, has a plan to acquire 120 electric buses by the end of 2020 and to electrify its entire fleet by 2040.[104] The state of California has made a similar commitment, setting a goal to make its 12,000 transit buses fully electric by 2040.[105]

Figure 10. America's Top States for Electric Vehicle Sales Through 2018



States ranked by their cumulative sales of electric vehicles through 2018. Darker colors indicate greater growth in electric vehicle sales.

Table 5. Charging Stations as of May, 2019[108]

State	Number of Stations	Rank
California	5,128	1
New York	1,241	2
Florida	1,189	3
Texas	1,136	4
Washington	877	5
Georgia	783	6
Colorado	706	7
Massachusetts	602	8
Maryland	599	9
Oregon	596	10

Battery Energy Storage Has Grown 18-Fold Since 2009

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 they need it. 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.[109]

Energy storage technologies can also help to enable a 100 percent renewable energy future. Energy storage technologies like batteries can smooth the deployment of renewable energy by storing excess energy for later use. For example, when the sun shines during the day, excess energy can be stored for use at night. As states begin committing to robust renewable energy standards and carbon-free futures, energy storage can help facilitate these transitions.[110]

Battery storage being installed at Fort Carson, Colorado. Credit: Scott Clark via U.S. Army Corps of Engineers, CC BY-1.0

Energy storage has not yet seen a boom comparable to wind or solar power, but there are signs that such a boom may soon be on the way.

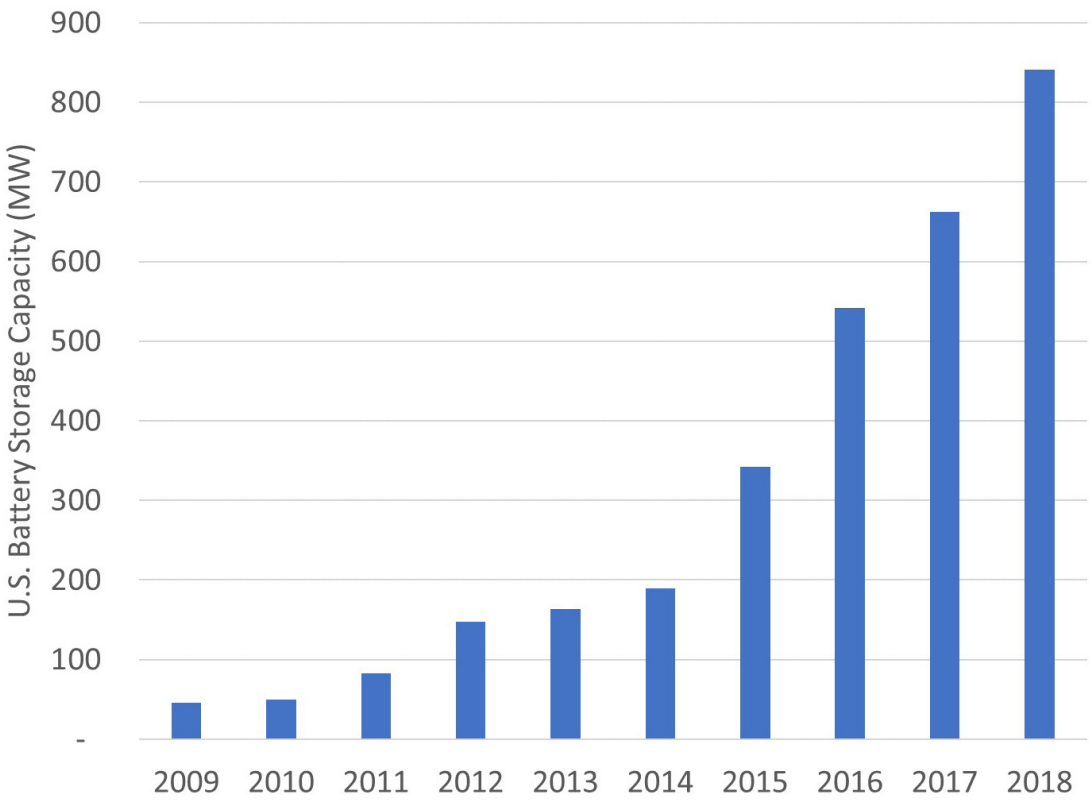
By 2018, the U.S. had over 20 GW of installed, utility-scale energy storage capacity.[111] Most storage that existed before 2009 was in the form of large-scale hydroelectric pumped storage systems. In these systems, water is pumped to a higher elevation during periods of surplus generation and allowed to flow back down through a hydroelectric generator when electricity is later needed.

Since 2009, however, one sector of energy storage has seen dramatic progress: battery storage. Much of the energy storage added since 2009 has been in the form of battery storage, which increased 18-fold in terms of capacity through 2018.[112] 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 the first-ever widespread installations of home and business-scale energy storage – sometimes paired with solar energy.[113]

Experts predict that improving batteries will propel rapid growth in energy storage in the coming years. Bloomberg's New Energy Finance predicts that the cost of utility-scale lithium-ion batteries will fall by 52 percent between 2018 and 2030, and that the U.S. will exceed 100 GW of installed battery storage capacity by 2040 – a more than 100-fold increase over today's capacity.[114]

At the state level, California, Illinois, Texas, West Virginia and Hawaii led the nation in battery storage additions from 2009 to 2018. Out of the top ten states for growth in battery storage, six are part of the PJM regional grid. PJM (the regional transmission organization that operates the electric grid in much of the Mid-Atlantic and Midwest) increased battery storage as a response to a decision by the Federal Energy

Figure 11. America's Utility-Scale Battery Storage Capacity Grew 18-fold from 2009 to 2018[115]



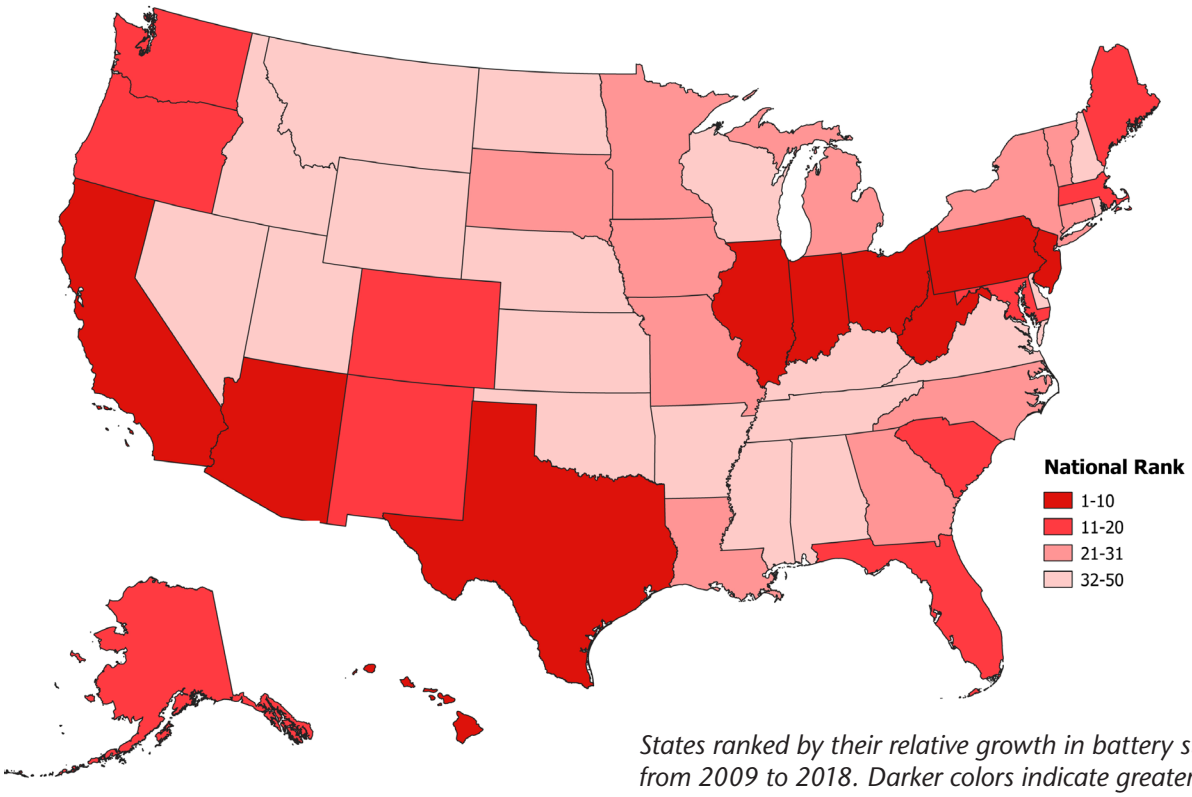
Regulatory Commission (FERC) to increase compensation for grid additions that allow for rapid changes in electricity production.[116] PJM was the first transmission organization to adjust its policies to reflect the FERC rule after it was passed in 2011, leading to massive growth in battery storage during the first half of this decade. In 2017, PJM changed its wholesale market rules in a way that reduced the competitiveness of battery storage.[117] Since then, Illinois, Indiana, Ohio and Pennsylvania have not seen any increase in their battery storage capacity. The outlier within the PJM is New Jersey, which increased its storage by over 20 MW in 2018.[118] In contrast with these other states, New Jersey has set ambitious goals for energy storage.[119] The experience of battery storage within the PJM, especially the difference between New Jersey and other PJM states, reflects the importance of public policy for incentivizing growth within this young industry.

California led the nation in battery storage, installing 231 MW of capacity from 2009 to 2018. By the end of 2018, California accounted for over a quarter of the nation's total battery storage capacity.[120] 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, for which energy storage was used to minimize grid disruptions.[121]

Table 6. States That Added Most Battery Storage 2009 – 2018[122]

State	Battery Storage Capacity, 2009 (MW)	Battery Storage Capacity, 2018 (MW)	Increase, 2009-2018	Rank, by Increase
California	0	231.3	231.3	1
Illinois	0	112.7	112.7	2
Texas	0	94.3	94.3	3
West Virginia	2	65.5	63.5	4
Hawaii	0	63	63	5
Arizona	0	32	32	6
Ohio	2	33	31	7
Pennsylvania	0	30.4	30.4	8
New Jersey	0	22.8	22.8	9
Indiana	2	22	20	10

Figure 12. America's Top States for Battery Storage Additions Since 2009



States ranked by their relative growth in battery storage from 2009 to 2018. Darker colors indicate greater growth in battery storage capacity.

Four States Now Generate 40 Percent (or More) of Their Electricity with Wind and Solar Energy

With falling energy use, and expanding wind and solar generation, renewable energy now accounts for a significant percentage of U.S. electricity use.

In 2018, wind and solar power produced 10 percent of all U.S. electricity generation, almost five times the percentage they produced in 2009.[123] In March 2017, for the first time, wind and solar power produced 10 percent of all U.S. electricity for an entire month.[124]

In 2018, 21 states generated enough wind and solar energy to supply more than 10 percent of the electricity they consumed.[125] Four states – North Dakota, Kansas, Oklahoma and Iowa – generated enough wind and solar power to supply at least 40 percent of their electricity needs. North Dakota generated sufficient wind and solar electricity to supply over half, 54 percent, of its electricity needs.

Table 7. Top 10 States by Wind and Solar Generation as Percentage of Electricity Consumption[126]

State	Wind and Solar Generation as Percentage of Electricity Consumption (2018)	Rank
North Dakota	54%	1
Kansas	47%	2
Oklahoma	44%	3
Iowa	43%	4
New Mexico	32%	5
Wyoming	25%	6
South Dakota	22%	7
Maine	22%	8
California	21%	9
Colorado	21%	10

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.

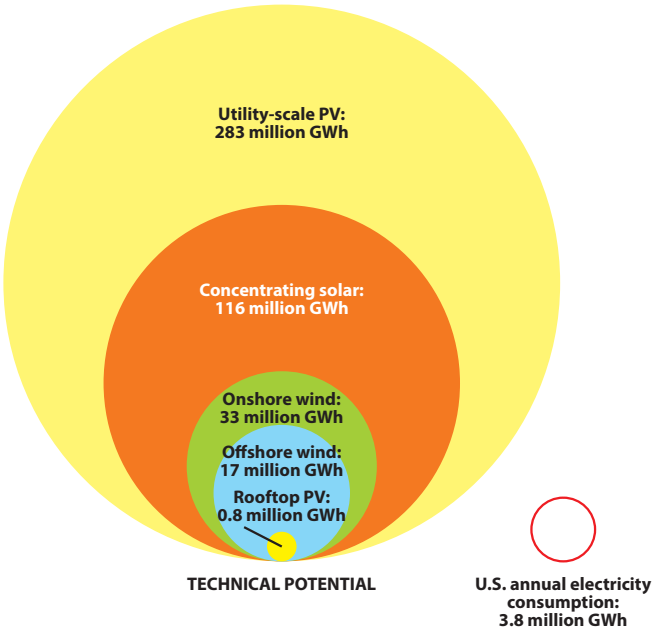
Fortunately, the United States has more than enough renewable energy potential to support all of our energy needs. According to the National Renewable Energy Laboratory, the United States has the technical potential to meet its current electricity needs more than 100 times over with solar energy and more than ten times over with wind energy.[127] Every state in the country has enough solar energy potential to supply all of its electricity needs.[128]

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 – the critical period for preventing the worst impacts of global warming.

Figure 13. Comparison of Renewable Energy Technical Potential and Current Consumption (Data: NREL)[131]



If the nation were to install as much renewable energy every year as we did in 2018, by 2050 American would be producing enough electricity to meet only 43 percent of today's electricity demand.[129] This figure does not account for replacing fossil fuels that we use directly in our homes, businesses, factories and vehicles.

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 2009 and 2018, U.S. wind and solar generation grew at an annual rate of 19 percent.[130] If renewable generation were to continue to grow by 15 percent per year, or slightly less than its current rate of growth, wind and solar would produce enough electricity to meet all of our current electricity needs by 2035.

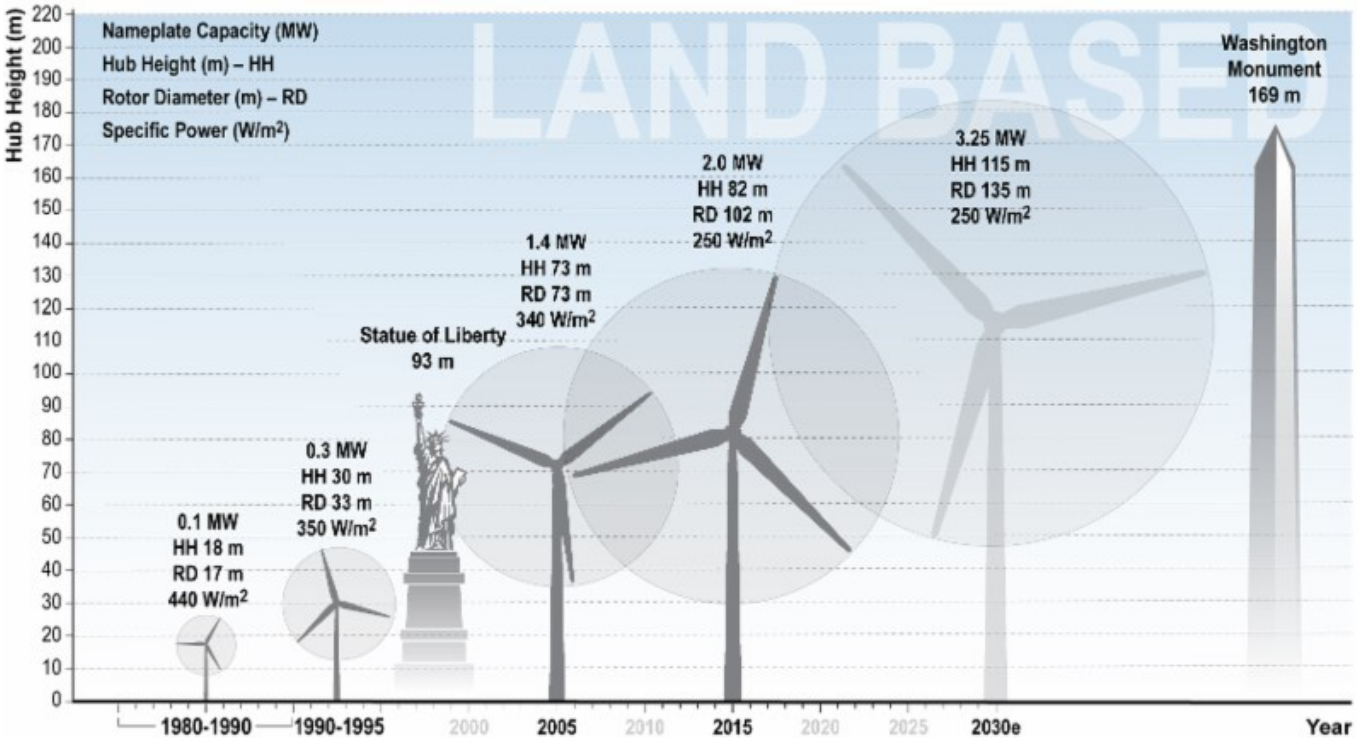
Technology Is Improving

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.

Modern wind turbines are almost 50 percent taller and have blades that are more than double the length of turbines made in the late 1990s, enabling the average wind turbine installed today to have capacity more than double that of the average wind turbine installed in the year 2000.[132] In 2007, the highest-capacity wind turbine in the world was 6 MW, with only one such test prototype actually in operation.[133] Today, an entire wind farm of 8 MW turbines is generating electricity off the coast of England. According to DONG (now Orsted) Energy, which led the project, a single revolution of the blades on just one turbine can power a home for 29 hours.[134]

This summer, GE expects to deploy the prototype of its massive "Haliade-X" wind turbine, which has a capacity of 12 MW – enough to supply annual electricity for nearly 6,500 American homes.[135] By 2030,

Figure 14. Average Wind Turbine Size and Capacity Is on the Rise



From 2005 to 2015, average U.S. land-based wind turbine capacity increased from 1.4 MW to 2.0 MW, and is projected to increase to 3.25 MW by 2030. Similar growth has been observed, and projected, for offshore wind turbines. Credit: Lawrence Berkeley National Laboratory

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."[136]

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, where the ocean is too deep to allow the installation of traditional seafloor-mounted turbines.[137] 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.[138]

Recent years have also seen rapid progress in solar energy technology. The average residential solar panel installed in 2017 was around 20 percent more efficient than one installed in 2009.[139] Efficiency improvements are reducing the cost of utility-scale projects by allowing developers to purchase less land, or fewer modules, to achieve desired project capacity; or to boost the amount of capacity possible on existing land.[140]

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 American Council for an Energy-Efficient Economy calls "intelligent efficiency" – a new 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 percent of thermostat sales by the end of 2018.[141] Industry research suggests that smart thermostat sales will grow at an annual rate of over 20 percent in the coming years and predicts that by 2022, the US will be home to 14.5 million units.[142]

Industrial operations are embracing intelligent efficiency.[143] 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 past couple years.[144] 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 Net-Zero Energy Coalition found more than 6,000 net-zero energy buildings in the U.S. and Canada in 2017, almost a 50 percent increase from 2016.[145]

Improvements in battery technology are enabling both improvements in energy storage and long-range electric vehicles. The median range for an EV grew from 73 to 125 miles between 2011 and 2018 – a 71 percent increase.[146] 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.[147] Advances in range are due to improved battery technology, advances in aerodynamics and reductions in rolling resistance.[148] Meanwhile, auto companies continue to invest resources in improving battery technology; Toyota recently announced that it would invest almost $14 billion into the development of solid-state battery technology, which has the potential to dramatically increase range and cut charging times from several hours to minutes.[149] 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.[150]

Prices Are Falling

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

A National Renewable Energy Laboratory (NREL) survey of clean energy prices found that, from 2010 to 2018, the cost of distributed PV fell by 71 percent and utility-scale PV by 80-82 percent.[151] 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 percent during the same period.[152]

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."[153] In Idaho, for example, a record-breaking solar contract was signed in 2019, promising to deliver energy for 2.18 cents per kilowatt-hour.[154]

Energy-saving LED light bulbs cost more than $40 apiece as recently as 2010; today, they cost a few dollars at the local hardware store.[155] A recent analysis by the Consumer Federation of America found that a single LED light bulb can save $59 to $95 over a ten-year period – if a household has 20 bulbs, this can translate to savings of between $1,100 and nearly $2,000.[156]

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 percent by 2030 from 2017 cost levels.[157] Bloomberg New Energy Finance 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 percent by 2050.[158] It also estimates that by 2030, energy storage costs will fall by 52 percent.[159]

Putting it All Together

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.

With many potential pathways and rapid changes in technology, it is difficult to foresee the precise path by which America will achieve 100 percent renewable energy. Researchers from a wide variety of academic and governmental institutions have put forward a variety of scenarios by which America can power all, or nearly all, of our electricity system – and even our entire economy – with renewable energy.[160] 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.

Achieving a future powered by clean, renewable energy will require bold commitments and equally bold action. The benefits are immense. The potential is clear. The time to begin is now.

Conclusion and Recommendations

American clean energy is growing at an incredible pace. Over just nine years – from 2009 to 2018 – America saw solar energy grow 40-fold, wind energy triple, electric vehicles surge to over a million total sales, and energy storage emerge as a viable new solution to enable the transition to renewable energy.

To transition to a clean, renewable energy system by 2050, however, the U.S. must dramatically accelerate its clean energy progress.

Many public and private institutions have already set their sights on a 100 percent renewable energy future. State renewable energy programs have become vastly more ambitious over the past five years.[161] In 2015, Hawaii started this trend by establishing a goal to use 100 percent clean energy by 2045.[162] Since then, California, New Mexico, Washington, Maine, New York and Puerto Rico and the District of Columbia have all made similar commitments.[163] In the past 18 months, many other states, including Connecticut, Maryland, Massachusetts, Nevada, New Jersey, have adopted significant increases in their renewable electricity standards.[164]

Local governments are also acting. According to the Sierra Club, 127 cities have committed to 100 percent renewable energy, and six cities have already achieved it.[165] The city of Greensburg, Kansas, produces more than enough energy to power every single one of its homes, businesses and municipal buildings.[166] The organization RE100 has collected 100 percent renewable energy commitments from 191 companies, including IKEA, Google, and Anheuser-Busch InBev.[167]

In order to break our dependence on fossil fuels and achieve a renewable energy future, leaders of cities, states, companies and institutions should:

- Set ambitious goals to meet all of their energy needs with renewable energy.
- Prioritize energy savings. Conserving energy and using it more efficiently can ease the transition from dirty fuels to clean, renewable energy.
- Work to ensure the rapid deployment of renewable energy. Policymakers should require utilities to ramp up renewable energy generation over time, work to make clean energy technologies accessible to and affordable for consumers, and encourage adoption of clean energy at all scales, from small rooftops to large wind and solar farms.
- Support the development of emerging technologies critical to the development of a fully renewable energy system, including offshore wind power, smart grid improvements, and electrification of heating and transportation.
- Set limits on carbon and greenhouse gas emissions that will shift us away from fossil fuels.

Appendix

Table A1. Clean Energy Progress by State

State	Increase in Solar Electricity Generation, 2009 - 2018 (GWh)[168]	Increase in Wind Electricity Generation, 2009 - 2018 (GWh)[169]	Increase in Electricity Efficiency Savings, 2009 - 2017 (percentage point increase in savings as share of electricity consumption)[170]	Number of Electric Vehicles Sold through 2018[171]	Increase in Battery Storage Capacity 2009 - 2018 (MW)[172]
Alabama	397	0	-0.02	2,487	0
Alaska	3	140	-0.01	534	4
Arizona	7,413	556	0.55	18,129	32
Arkansas	227	0	0.55	1,194	0
California	38,395	7,810	1.09	506,608	231
Colorado	1,583	6,655	0.38	19,738	5
Connecticut	586	13	0.78	10,916	2
Delaware	168	5	0.11	1,895	0
Florida	2,880	0	-0.07	40,548	14
Georgia	2,438	0	0.20	33,947	1
Hawaii	1,205	292	0.33	9,539	63
Idaho	576	2,248	0.14	1,459	0
Illinois	151	9,992	0.94	22,475	113
Indiana	480	4,194	0.37	6,047	20
Iowa	146	14,264	-0.07	2,799	1
Kansas	36	16,432	0.00	2,621	0
Kentucky	85	0	0.35	2,186	0
Louisiana	229	0	0.05	1,803	1
Maine	68	2,113	0.02	2,456	17
Maryland	1,294	550	0.53	17,900	13
Massachusetts	3,175	232	1.73	22,824	9
Michigan	240	5,030	1.10	18,434	1
Minnesota	1,383	6,293	0.31	8,845	1

Table A1. Clean Energy Progress by State

State	Increase in Solar Electricity Generation, 2009 - 2018 (GWh)[168]	Increase in Wind Electricity Generation, 2009 - 2018 (GWh)[169]	Increase in Electricity Efficiency Savings, 2009 - 2017 (percentage point increase in savings as share of electricity consumption)[170]	Number of Electric Vehicles Sold through 2018[171]	Increase in Battery Storage Capacity 2009 - 2018 (MW)[172]
Mississippi	341	0	0.13	649	0
Missouri	342	2,442	0.67	6,676	2
Montana	56	1,360	0.11	1,033	0
Nebraska	42	4,795	0.02	1,816	0
Nevada	4,946	368	-0.68	6,296	0
New Hampshire	107	372	0.07	3,375	0
New Jersey	3,038	2	-0.11	25,945	23
New Mexico	1,549	4,621	0.25	2,100	4
New York	1,864	2,117	0.49	46,397	1
North Carolina	7,198	543	0.65	13,054	1
North Dakota	-	7,766	-0.01	291	0
Ohio	300	1,758	0.60	12,820	31
Oklahoma	77	24,895	0.37	4,918	0
Oregon	779	3,667	0.60	21,433	5
Pennsylvania	499	2,540	0.36	18,248	30
Rhode Island	132	163	2.01	1,966	0
South Carolina	857	0	0.32	3,447	4
South Dakota	3	2,345	0.05	424	1
Tennessee	254	0	0.06	6,684	0
Texas	4,051	55,727	-0.02	34,239	94
Utah	2,574	695	0.20	6,767	0
Vermont	271	381	1.69	3,307	3
Virginia	980	0	0.09	16,505	0
Washington	153	3,784	0.61	41,459	4
West Virginia	10	1,037	0.22	746	64
Wisconsin	116	907	-0.22	8,271	0
Wyoming	7	1,961	0.24	269	0

Table A2. Solar Generation by State[173]

State	2009 Solar Electricity Generation (GWh)	2018 Solar Electricity Generation (GWh)	Growth (GWh)	Rank (Growth from 2009-2018)
Alabama	0	397	397	24
Alaska	0	3	3	48
Arizona	64	7,477	7,413	2
Arkansas	0	227	227	32
California	1,602	39,997	38,395	1
Colorado	91	1,674	1,583	12
Connecticut	25	611	586	20
Delaware	5	173	168	33
Florida	24	2,904	2,880	8
Georgia	1	2,439	2,438	10
Hawaii	33	1,238	1,205	16
Idaho	0	576	576	21
Illinois	4	155	151	35
Indiana	0	480	480	23
Iowa	0	146	146	36
Kansas	0	36	36	45
Kentucky	0	85	85	40
Louisiana	0	229	229	31
Maine	0	68	68	42
Maryland	4	1,298	1,294	15
Massachusetts	19	3,194	3,175	6
Michigan	1	241	240	30
Minnesota	2	1,385	1,383	14
Mississippi	0	341	341	26
Missouri	0	342	342	25
Montana	2	58	56	43
Nebraska	0	42	42	44
Nevada	198	5,144	4,946	4
New Hampshire	1	108	107	39
New Jersey	181	3,219	3,038	7
New Mexico	4	1,553	1,549	13
New York	35	1,899	1,864	11
North Carolina	11	7,209	7,198	3
North Dakota	0	0	0	50
Ohio	2	302	300	27
Oklahoma	0	77	77	41
Oregon	22	801	779	19
Pennsylvania	11	510	499	22
Rhode Island	3	135	132	37
South Carolina	1	858	857	18
South Dakota	0	3	3	48
Tennessee	1	255	254	29
Texas	12	4,063	4,051	5
Utah	1	2,575	2,574	9
Vermont	2	273	271	28
Virginia	1	981	980	17
Washington	2	155	153	34
West Virginia	0	10	10	46
Wisconsin	6	122	116	38
Wyoming	0	7	7	47
United States	**2,369**	**96,075**	**93,706**	**N/A**

Table A3. Wind Generation by State[174]

State	Wind generation 2009 (GWh)	Wind generation 2018 (GWh)	Growth (GWh)	Rank (Growth from 2009-2018)
Alabama	0	0	0	41
Alaska	7	147	140	37
Arizona	30	586	556	28
Arkansas	0	0	0	41
California	5,840	13,650	7,810	6
Colorado	3,164	9,819	6,655	8
Connecticut	0	13	13	38
Delaware	0	5	5	39
Florida	0	0	0	41
Georgia	0	0	0	41
Hawaii	251	543	292	34
Idaho	313	2,561	2,248	19
Illinois	2,820	12,812	9,992	5
Indiana	1,403	5,597	4,194	13
Iowa	7,421	21,685	14,264	4
Kansas	2,863	19,295	16,432	3
Kentucky	0	0	0	41
Louisiana	0	0	0	41
Maine	299	2,412	2,113	21
Maryland	0	550	550	29
Massachusetts	6	238	232	35
Michigan	300	5,330	5,030	10
Minnesota	5,053	11,346	6,293	9
Mississippi	0	0	0	41
Missouri	499	2,941	2,442	17
Montana	821	2,181	1,360	24
Nebraska	383	5,178	4,795	11
Nevada	0	368	368	33
New Hampshire	62	434	372	32
New Jersey	21	23	2	40
New Mexico	1,547	6,168	4,621	12
New York	2,266	4,383	2,117	20
North Carolina	0	543	543	30
North Dakota	2,998	10,764	7,766	7
Ohio	14	1,772	1,758	23
Oklahoma	2,698	27,593	24,895	2
Oregon	3,470	7,137	3,667	15
Pennsylvania	1,075	3,615	2,540	16
Rhode Island	0	163	163	36
South Carolina	0	0	0	41
South Dakota	421	2,766	2,345	18
Tennessee	52	52	0	41
Texas	20,026	75,753	55,727	1
Utah	160	855	695	27
Vermont	12	393	381	31
Virginia	0	0	0	41
Washington	3,572	7,356	3,784	14
West Virginia	742	1,779	1,037	25
Wisconsin	1,052	1,959	907	26
Wyoming	2,226	4,187	1,961	22
United States	**73,886**	**274,952**	**201,066**	**N/A**

Table A4. Wind and Solar Generation as Percentage of State Electricity Consumption by State[175]

State	Total Wind and Solar Generation 2018 (GWh)	Wind and Solar Generation as Percentage of State Electricity Consumption	Rank (Percentage of Consumption)
Alabama	397	0%	47
Alaska	150	2%	37
Arizona	8,063	10%	21
Arkansas	227	0%	46
California	53,647	21%	9
Colorado	11,493	21%	10
Connecticut	624	2%	38
Delaware	178	2%	40
Florida	2,904	1%	42
Georgia	2,439	2%	39
Hawaii	1,781	19%	12
Idaho	3,137	13%	18
Illinois	12,967	9%	22
Indiana	6,077	6%	25
Iowa	21,831	43%	4
Kansas	19,331	47%	2
Kentucky	85	0%	50
Louisiana	229	0%	49
Maine	2,480	22%	8
Maryland	1,848	3%	34
Massachusetts	3,432	7%	24
Michigan	5,571	5%	27
Minnesota	12,731	19%	13
Mississippi	341	1%	45
Missouri	3,283	4%	32
Montana	2,239	15%	16
Nebraska	5,220	17%	14
Nevada	5,512	15%	17
New Hampshire	542	5%	29
New Jersey	3,242	4%	30
New Mexico	7,721	32%	5
New York	6,282	4%	31
North Carolina	7,752	6%	26
North Dakota	10,764	54%	1
Ohio	2,074	1%	41
Oklahoma	27,670	44%	3
Oregon	7,938	17%	15
Pennsylvania	4,125	3%	36
Rhode Island	298	4%	33
South Carolina	858	1%	43
South Dakota	2,769	22%	7
Tennessee	307	0%	48
Texas	79,816	20%	11
Utah	3,430	11%	20
Vermont	666	12%	19
Virginia	981	1%	44
Washington	7,511	8%	23
West Virginia	1,789	5%	28
Wisconsin	2,081	3%	35
Wyoming	4,194	25%	6
United States	**371,099**	**10%**	**N/A**

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