Renewables on the Rise 2018

A Decade of Progress Toward a Clean Energy Future

ENVIRONMENT AMERICA RESEARCH & POLICY CENTER

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Written by:

Gideon Weissman
Frontier Group

Rob Sargent and Bret Fanshaw
Environment America Research & Policy Center

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Contents

Executive Summary

Clean energy is sweeping across America and is poised for further dramatic growth in the years ahead.

Wind turbines and solar panels were novelties 10 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 local hardware store.[1] Electric cars and the use of batteries to store excess electricity on the grid seemed like far-off solutions just a few years ago; now, they are breaking through into the mass market.

Virtually every day, there are new developments that increase our ability to produce renewable energy, use energy more efficiently, and use clean energy technologies to meet a wider range of energy needs – bringing us closer to a future in which we can power our economy with clean, renewable energy.

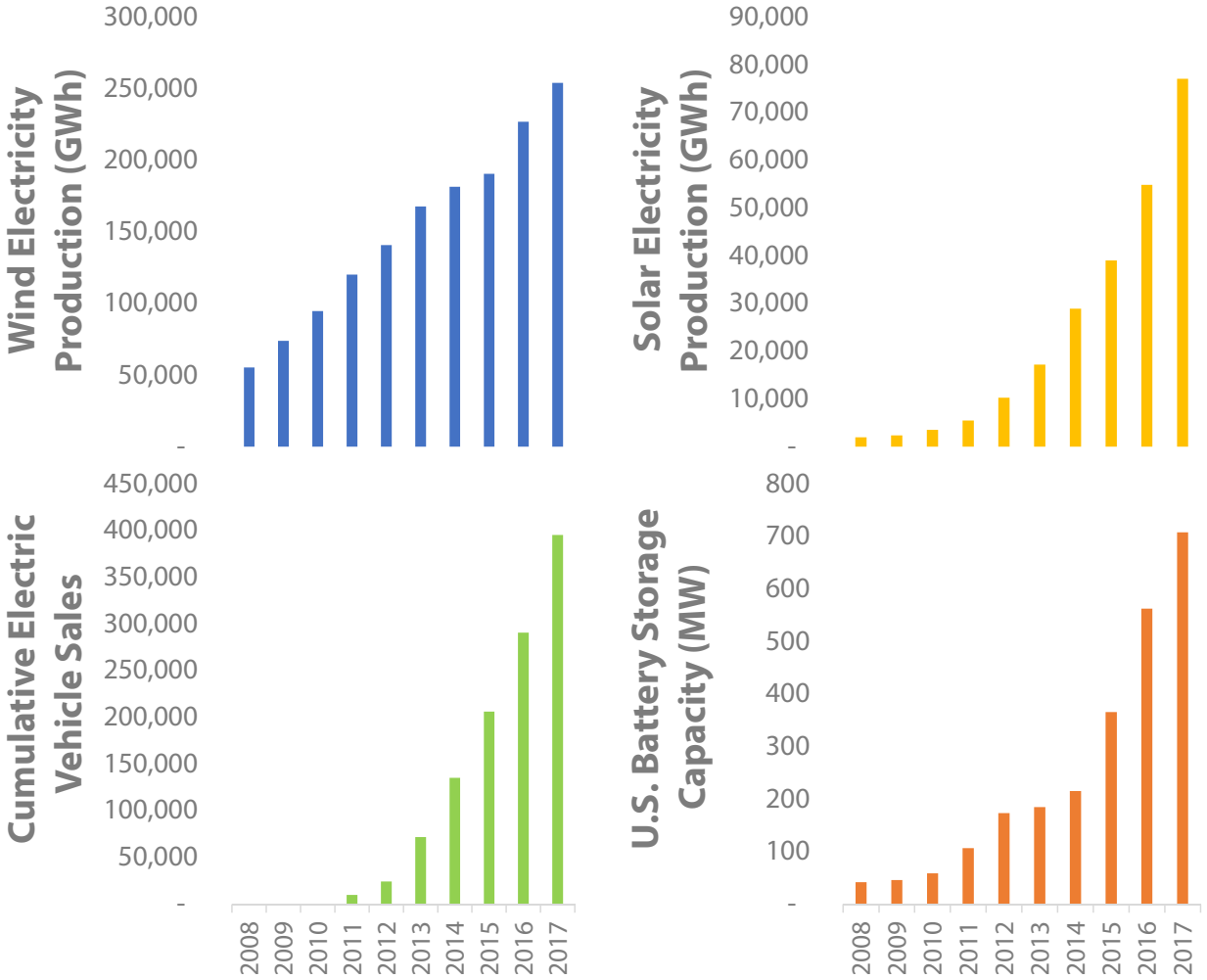
America produces **nearly six times as much renewable electricity** from the sun and the wind as it did in 2008, and in March 2017, for the first time ever, wind and solar produced 10 percent of America's electricity.[2] At the same time, the average American uses nearly **8 percent less energy** than a decade ago, due in great part to improvements in energy efficiency.[3]

The last decade has proven that clean energy technology can power American homes, businesses and industry – and has left America poised to accelerate its shift away from fossil fuels. With renewable energy prices falling and new energy-saving technologies coming on line every day, **America 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:** In 2017, America produced 39 times as much solar power as it did in 2008, and by the end of the first quarter of 2018, America had enough solar capacity to power more than 10 million homes.[4] In 2008, on-site and rooftop solar combined with utility-scale solar power plants produced 0.05 percent of U.S. electricity; in 2017, they produced 2.1 percent of America's power.[5]
- **Wind energy:** America produces 4.6 times as much wind power as it did in 2008, enough to power 24 million homes. In 2008, wind turbines produced 1.5 percent of the nation's electricity; in 2017, they produced 6.9 percent of America's power.[6]
- **Energy efficiency:** Despite a population that has grown by more than 20 million, America uses 1.1 percent less energy than in 2008, in great part due to more energy efficient lighting, appliances and cars.[7] The average American uses 7.7 percent less energy than in 2008, and the nation's energy consumption per unit of GDP has fallen by 14 percent.[8]
- **Electric vehicles:** Building an economy reliant on clean, renewable energy means ending the use of fossil fuels for all activities, including transportation. Over the last decade, 395,000 electric vehicles (EVs) have been sold, passing 100,000 annual sales for the first time in 2017.[9] Electric vehicle sales surged by 24 percent in 2017, fueled by lower prices, better performance and a range of attrac-

Figure ES-1. Clean Energy Technologies Have Seen Dramatic Growth since 2008[14]



tive and affordable new vehicle models.[10] In the first three months of 2018, electric vehicle sales were up an additional 35 percent over 2017.[11]

- **Battery storage:** Expanding the ability to store electricity can help the nation take full advantage of its vast potential for clean, renewable energy. Utility-scale battery energy storage capacity in the U.S. grew 17-fold from 2008 to 2017 (in megawatts), adding half of its total capacity in 2016 and 2017.[12] The recent introduction of home electricity storage systems produced by companies like Tesla and LG Chem could set the stage for further growth in the years to come.[13]

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 in part by the adoption of strong public policies.

- **Solar energy:** California, Arizona, North Carolina, Nevada and Texas saw the greatest total increases in solar energy generation from 2008 to 2017. 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.

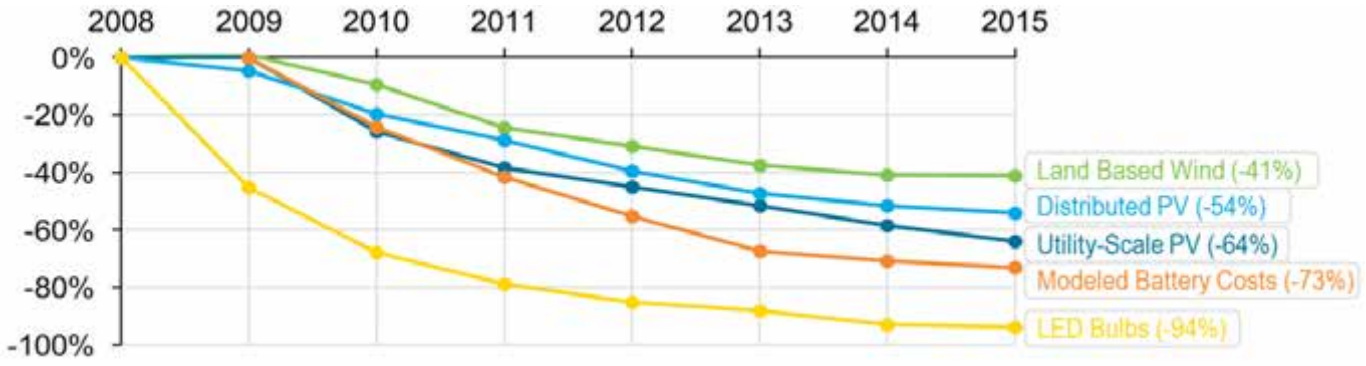
- **Wind energy:** Texas, Oklahoma, Kansas, Iowa and North Dakota saw the greatest total increases in wind energy generation from 2008 to 2017. Texas' policies to upgrade its grid to accommodate more wind power from rural west Texas played an important role in the boom.
- **Energy efficiency:** Massachusetts, Rhode Island, Illinois, Michigan and Washington saw the greatest increases in the share of electricity saved through efficiency measures, according to the American Council for an Energy-Efficient Economy. In 2016, Massachusetts and Rhode Island implemented efficiency measures that saved the equivalent of 3 percent of statewide electricity consumption over the previous year.
- **Electric vehicles:** California, Hawaii, Washington, Georgia and Oregon have seen the most battery electric vehicles sold since 2008, as a percentage of in-state vehicles.[15] Four 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.[16]
- **Battery storage:** California, Illinois, Texas, West Virginia and Ohio led the nation in additions to utility-scale battery energy storage since 2008.[17] Nine of the 10 states that added the most battery storage capacity had zero utility-scale battery capacity in 2008.

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 seeing rapid price declines, and the unsubsidized costs of utility-scale wind and solar energy have fallen to levels that are "cost-competitive with conventional generation technologies under some scenarios" even before accounting for environmental and social benefits, according to the financial firm Lazard's most recent levelized cost of energy survey.[18] From 2009 to 2017, the levelized cost of energy from wind and utility-scale solar fell by 67 percent and 86 percent, respectively.[19]
- Experts predict that prices will continue to fall. A 2016 survey of wind energy experts by the National Renewable Energy Laboratory found that the global price of wind power is expected to fall 24-30 percent by 2030 and 35-41 percent by 2050.[20] Bloomberg New Energy Finance predicts that "[b]y 2025, solar may be cheaper than using coal on average globally," even excluding the costs coal use imposes on public health and the environment.[21]
- Technology advances are also 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.[22] Today, an entire wind farm of 8 MW turbines is generating electricity off the coast of England. According to Ørsted, that company that led the project, a single revolution of the blades on just one turbine can power a home for 29 hours.[23] The average rooftop solar panel installed in 2016 was 25 percent more efficient than in 2008.[24]
- Advanced new products are also helping to reduce energy consumption. Smart, internet-connected appliances and climate control systems, for example, can reduce energy consumption and peak grid demand by enabling users to control equipment remotely or shift its operation to off-peak hours. U.S. smart appliance revenue grew more than eight-fold from 2011 to 2016, from $105 million to $887 million.[25]

The U.S. should work toward meeting all of its energy needs – for electricity, transportation and industry – with clean, renewable energy.

- Repowering America with clean, renewable energy is a key strategy in phasing out carbon pollution by 2050 – a necessary step to prevent



A Department of Energy survey of clean energy prices found that, from 2008 to 2015, the cost of land-based wind power fell by 41 percent; distributed PV by 54 percent; utility-scale PV by 64 percent; batteries by 73 percent; and LED bulbs by 94 percent.[26] Image: U.S. Department of Energy

the worst impacts of global warming. Transitioning to clean, renewable energy will also improve our health by preventing hazardous air pollution and eliminating the hazards of extracting, transporting and processing fossil fuels.

- America's renewable energy resources are sufficient 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.[27]
- Between 2008 and 2017, U.S. wind and solar generation grew at an annual rate of 22 percent. If generation were to grow by 14 percent per year, or about two thirds of the past decade's growth rate, wind and solar would produce enough electricity to meet all of our current electricity needs by 2035.
- To accelerate progress, a growing number of businesses, institutions of higher learning, local governments and states are adopting 100 percent renewable energy targets and goals. In 2015, Hawaii became the first state in the country to set a 100 percent renewable energy requirement for its electricity sector, doing so through its renewable energy standard.[28] According to the Sierra Club, 65 cities have committed to 100 percent renewable energy, and another six cities have already achieved it.[29] The organization RE100 has chronicled 100 percent renewable energy commitments from 131 companies, including Bank of America, Google and Anheuser-Busch InBev.[30] And many college and university campuses already get 100 percent of their electricity from clean energy sources.[31]

America has already made incredible progress toward getting its energy from clean, renewable sources. Policymakers at all levels should adopt policies aimed at repowering America with clean, renewable energy.

Introduction

The cost of America's dependence on fossil fuels is steep. Our dependence on oil, gas and coal pollutes our environment, jeopardizes our health, costs us money, and threatens our national security. Burning fossil fuels in our homes, businesses, factories and cars is the leading source of the pollutants that cause global warming, which is already contributing to more intense storms, punishing droughts, and rising seas, and which threatens far greater consequences in the years and decades to come.[32]

Repowering our economy with clean, renewable energy can put our nation on a healthier, more sustainable course. And with rapid improvements in technology, vast clean energy resources, and a willing public, a future powered entirely by clean, renewable energy is increasingly within our reach.

The last decade has seen solar power sweep across the country, becoming a common feature on homes and businesses, as well as in solar farms and community solar gardens. Tens of thousands of wind turbines have popped up on the plains, mountains and coasts of the United States. Advanced energy-saving technologies – from LED light bulbs to "smart" thermostats – have made their way into millions of Americans' homes and businesses.

For America to take full advantage of that momentum, however, local and state governments, businesses, institutions and individuals will need to take the lead. Strong public policies that support renewable energy development will be necessary, as will individual, corporate and governmental commitments to clean, renewable energy.

The American people are ready to move forward. Eight in 10 Americans support expanding wind power, and nine in 10 support expanding solar power – nearly double the support for any other type of energy.[33] Twice as many Americans want energy policy to emphasize conservation as opposed to production.[34] And 20 percent of Americans say their next vehicle will likely be electric.[35]

The experience of the last decade, as documented in this report, shows that rapid adoption of clean energy technologies is possible. By continuing to foster and accelerate the growth of renewable energy and the technologies that can successfully integrate it into our energy system, we can achieve a clean energy future for America.

Clean Energy Technologies Are Booming across America

Since 2008, America has made rapid progress toward powering our economy with clean, renewable energy.

Just a decade 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 efficient 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 39-Fold since 2008

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.[37]

Despite its abundance, tapping into solar energy was seen as too difficult and prohibitively expensive for most people until the early part of the 21st century. By 2008, years of intensive research, along with pioneering pro-solar policies adopted by nations such as Japan and Germany and 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 0.05 percent of America's electricity, or enough electricity to power 180,000 average American homes.[38]

What Is Clean, Renewable Energy?

Not all renewable energy sources have equal benefits for the environment and society. 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, wildlife, community safety and public health, with any impacts that do occur being 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.

By the end of the first quarter of 2018, America had enough solar capacity – including these panels in Minneapolis, Minnesota – to power more than 10 million homes.[36] *Credit: U.S. Department of Energy*

Since 2008, however, solar power has boomed. In 2012, solar power generated enough electricity to power 1 million average U.S. homes. And in 2017, solar power generated more than 2 percent of America's electricity, enough to power more than 7 million average American homes.[39] By the end of the first quarter of 2018, America had enough solar capacity to power more than 10 million homes.[40]

In 2017, the U.S. produced more solar power than ever before, generating 39 times more solar power than in 2008 and 40 percent more than the previous year.

Both rooftop solar and utility-scale solar power are growing rapidly. Distributed solar energy, including panels installed on residential and commercial rooftops, grew 21-fold from 2008 to 2017, while utility-scale generation grew 57-fold.[41]

California stands apart in solar energy additions and overall production of solar energy. California was responsible for 43 percent of the growth in solar energy production nationwide between 2008 and 2017, with the amount of solar electricity produced in the state increasing 23-fold over that time. California's booming solar market has benefited from strong policy support, including the innovative "Million Solar Roofs" program that accelerated state solar growth in the mid-2000s.[43]

The top 10 states for solar energy additions since 2008 include some of America's sunniest states, like Arizona and Nevada, as well as northeastern states such as New Jersey and Massachusetts that have historically provided strong policy support for solar energy. Strong policy has been a critical factor in most of the states with the fastest solar energy development.[44] And federal policies like the solar Investment Tax Credit and programs like the Department of Energy's Sunshot Initiative have helped drive solar growth across the country.

Figure 1. Solar Electricity Production Grew 39-Fold from 2008 to 2017[42]

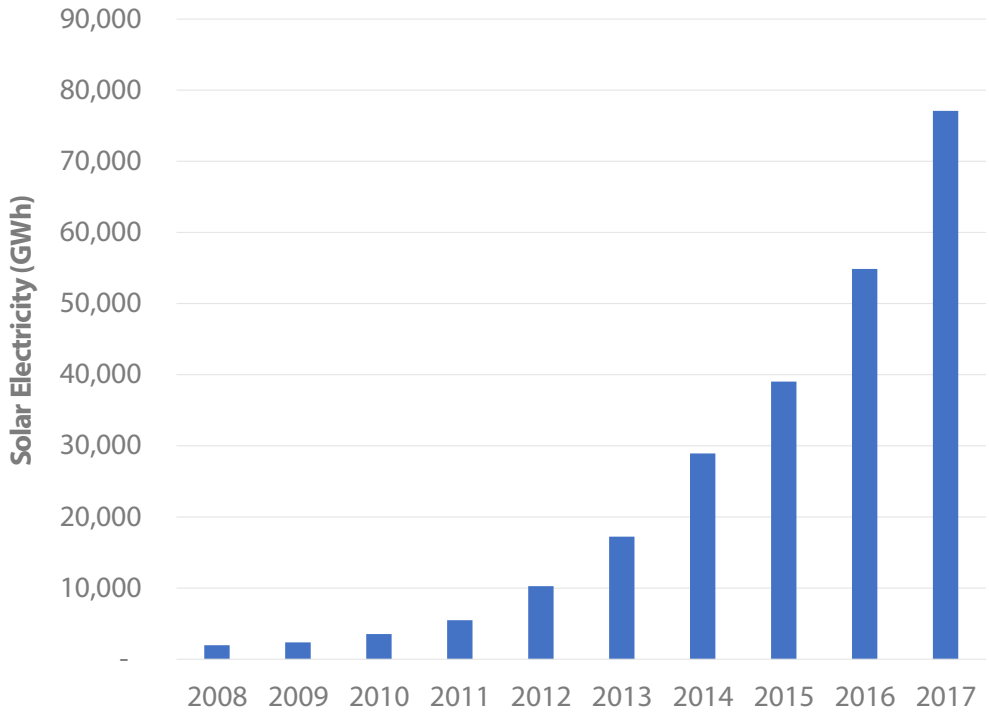


Table 1. Top States for Solar Electricity Growth 2008 to 2017[45]

State	Solar Electricity Production, 2008 (GWh)	Solar Electricity Production, 2017 (GWh)	Increase, 2008-2017 (GWh)	Rank, by Increase
California	1,454	33,733	32,279	1
Arizona	35	6,498	6,463	2
North Carolina	7	5,783	5,776	3
Nevada	178	4,241	4,063	4
Texas	7	2,814	2,807	5
New Jersey	109	2,836	2,727	6
Massachusetts	10	2,554	2,544	7
Georgia	1	2,364	2,363	8
Utah	0	2,262	2,262	9
Colorado	58	1,463	1,405	10

Figure 2. Top States for Increase in Solar Electricity Production, 2008 to 2017[46]

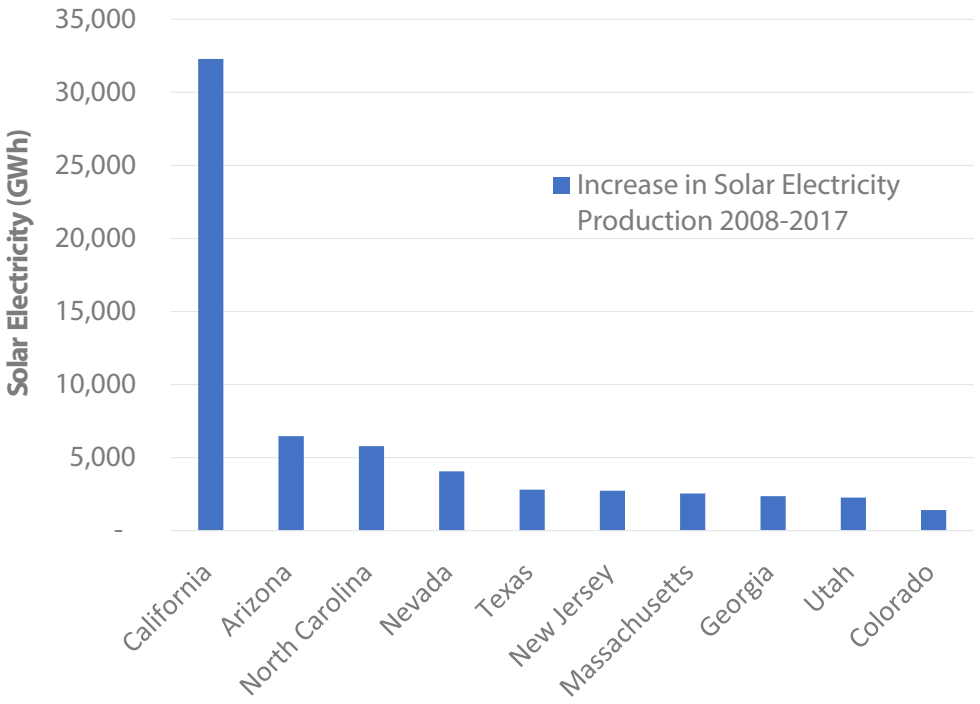
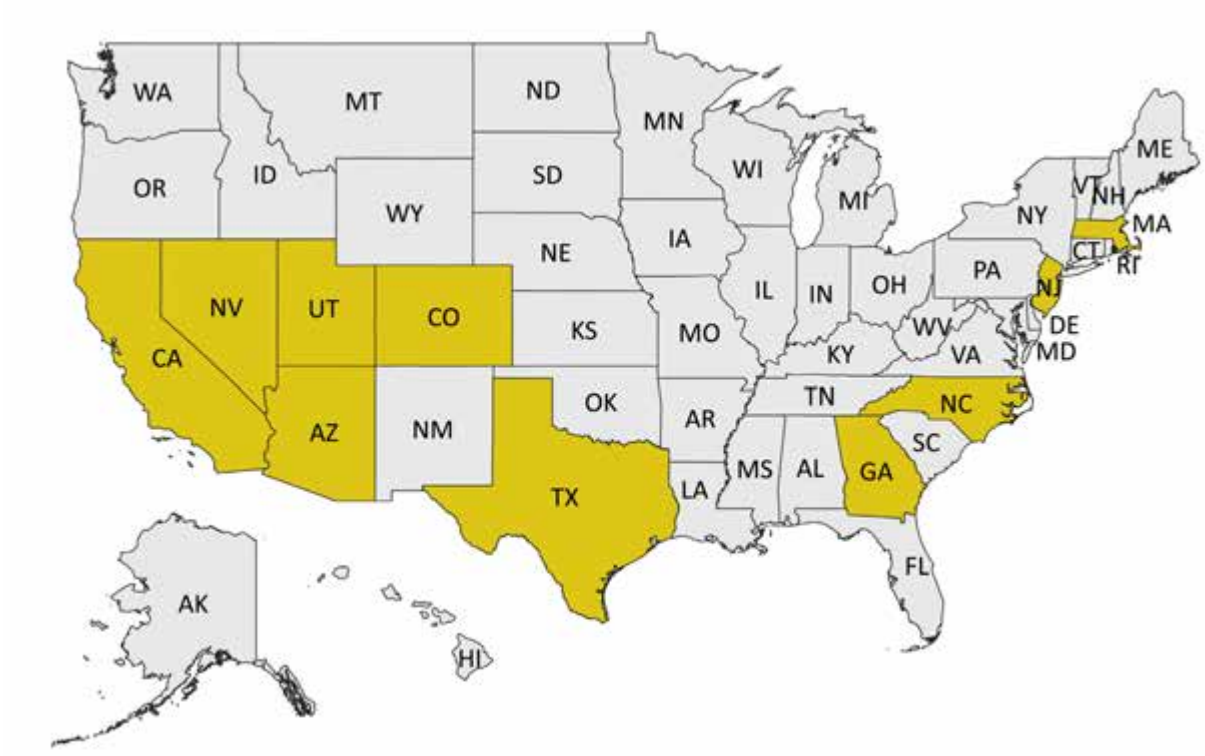


Figure 3. America's Top 10 States for Growth in Solar Electricity Production Since 2008[47]



Although the U.S. is generating more solar power than ever before, the amount of solar capacity installed in 2017 fell from 2016 – the first time in the era of modern solar panels that growth slowed.[48] The drop-off was likely the result of a number of factors, including strong growth in 2016 due to long-awaited extensions of federal tax credits, and policy changes in some states that reduced the financial benefits to homeowners and businesses of installing rooftop solar panels.[49]

Wind Energy Has Grown Nearly Five-Fold since 2008

Like solar power, energy from the wind is abundant. America has enough wind energy technical potential to supply the nation's electricity needs 13 times over – and over the last decade, America has dramatically increased its use of this vast, emission-free energy resource.[50]

Wind power is not a new technology. 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 2008, America had built up modest capacity for generating electricity from the wind, producing 1.5 percent of the nation's electricity, enough to power more than 3 million homes.[51]

The last decade has seen dramatic growth in wind energy. In January 2016, the 50,000th wind turbine was installed in the U.S. From 2008 through 2017, American wind generation grew nearly five-fold. In 2017, wind turbines produced 6.9 percent of America's electricity, enough to power nearly 24 million homes, an increase of 12 percent over the previous year.[52]

The U.S. is poised for a major offshore wind energy breakthrough. In 2016, America's first utility-scale offshore turbines began spinning off the coast of Rhode Island, where a 30 MW wind farm generates enough electricity to power 17,000 homes.[53] As of February

More than 50,000 wind turbines, including these in Iowa, are now spinning across the U.S. Credit: Dennis Schroeder/NREL

2018, 13 offshore wind projects along the Atlantic seaboard had obtained ocean area leases and were moving toward operation.[54] With a total estimated capacity of 14.2 gigawatts (GW), these proposed projects could power approximately 5.2 million homes.[55]

State and federal policies, including the federal investment and production tax credits, have helped enable 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."[56]

To date, Plains states have led the American wind energy revolution. From 2008 to 2017, Texas, Oklahoma and Kansas led the nation in added wind power. In Texas, wind generation grew four-fold over that time period. In Oklahoma and Kansas wind generation grew 10-fold.

In Texas alone, there are now more than 10,000 wind turbines; during the early morning hours on one day in March 2017, wind power supplied more than half of Texas' electricity demand.[58] Texas' wind energy growth was made possible in part by a $7 billion investment in the state's grid, which allows for the transmission of wind energy from the state's windiest regions to its biggest cities.[59]

Table 2. Top States for Wind Electricity Growth, 2008 to 2017[60]

State	Wind Energy Production, 2008 (GWh)	Wind Energy Production, 2017 (GWh)	Increase, 2008-2017 (GWh)	Rank, by Increase
Texas	16,225	67,092	50,867	1
Oklahoma	2,358	24,404	22,046	2
Kansas	1,759	18,501	16,742	3
Iowa	4,084	20,816	16,732	4
North Dakota	1,693	10,987	9,294	5
Illinois	2,337	11,297	8,960	6
California	5,385	13,971	8,586	7
Minnesota	4,355	10,885	6,530	8
Colorado	3,221	9,567	6,346	9
Nebraska	214	5,237	5,023	10

Figure 4. U.S. Wind Energy Production Grew Nearly Five-Fold from 2008 to 2017[57]

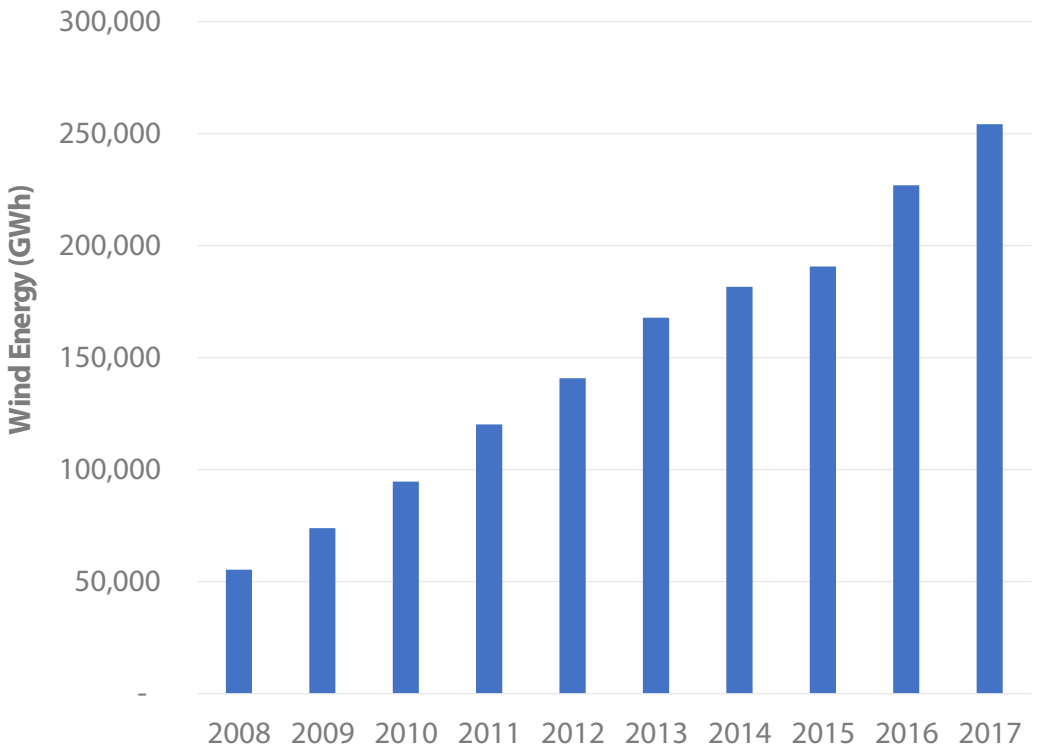


Figure 5. Top States for Increase in Wind Energy Production, 2008 to 2017[61]

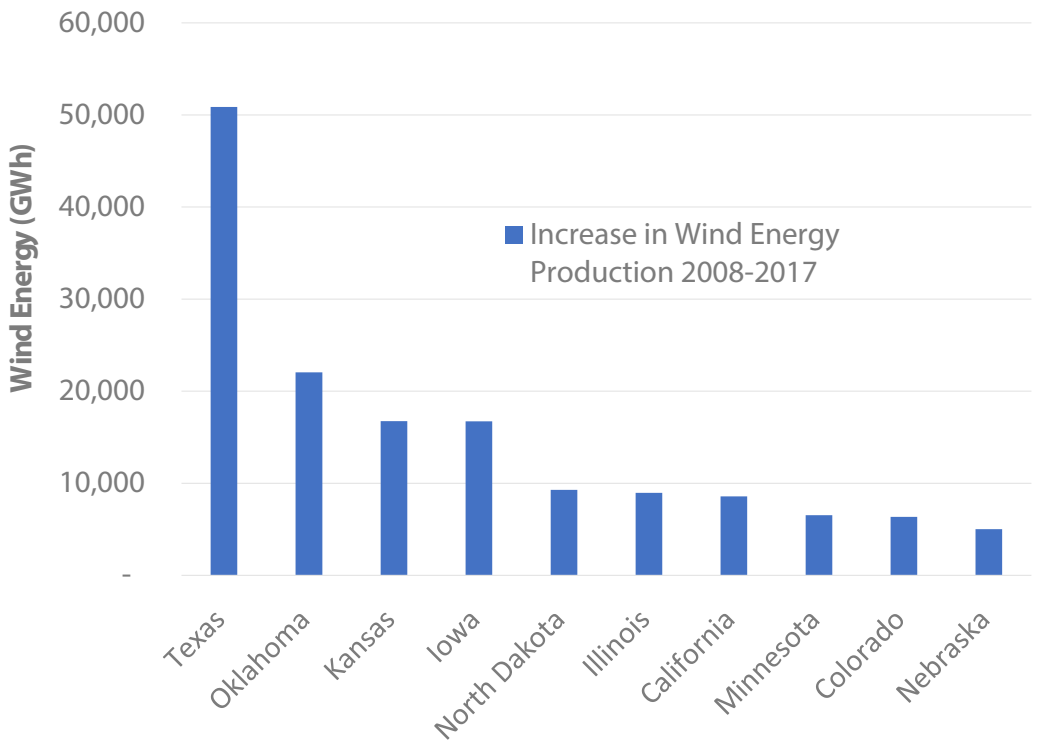
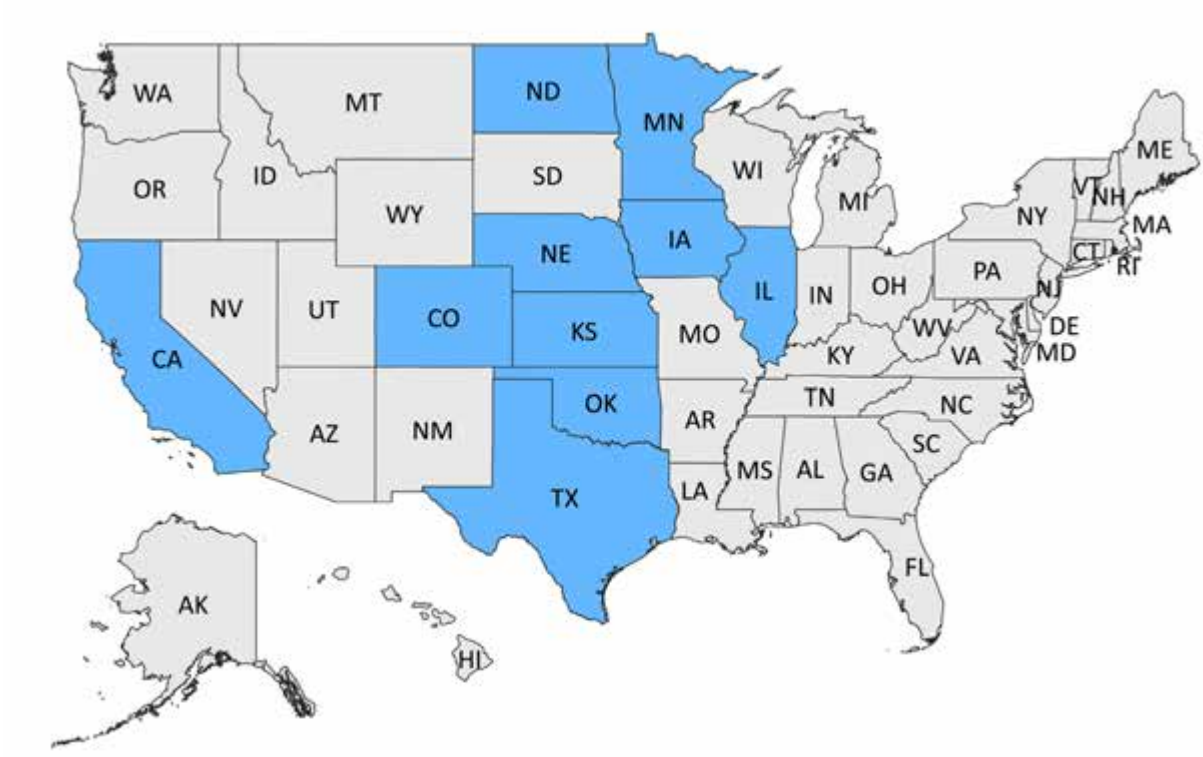


Figure 6. America's Top 10 States for Wind Energy Growth Since 2008[62]



U.S. Energy Consumption Has Dropped by 1.1 Percent since 2008

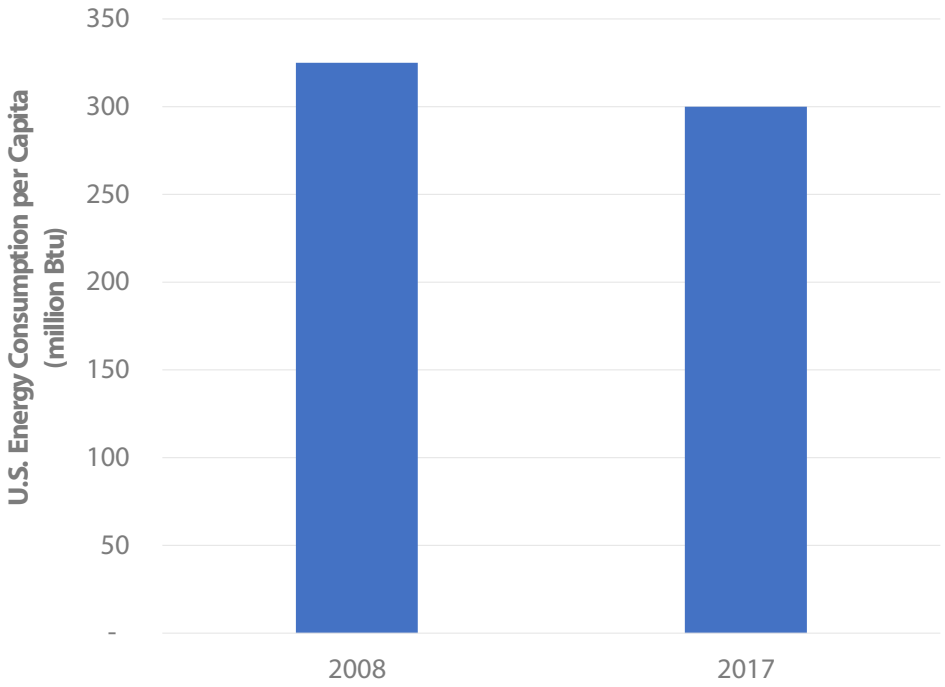
The task of moving to clean, renewable energy can be made dramatically cheaper and easier by reducing the amount of energy wasted in inefficient buildings, cars and equipment. Increased efficiency means getting the same comfort, work and entertainment with less energy. Reduced energy demand also lessens the task of replacing fossil fuel infrastructure with new energy supply.

Between 1950 and 2008, total energy use in the United States nearly tripled.[63] From 2008 to 2017, however, energy use in the United States fell by 1.1 percent, despite a growing population and economy.[64] Today, America uses less energy than it did in 2000, when the country had 44 million fewer people.[65]

On a per-capita basis, energy consumption in the U.S. dropped by 7.7 percent between 2008 and 2017, while

"Smart," internet-connected thermostats and other appliances are helping homes and businesses reduce energy consumption. Credit: Werner Slocum/NREL

Figure 7. U.S. per Capita Energy Consumption Dropped by 8 Percent from 2008 to 2017[67]



energy consumption per unit of GDP fell by 14 percent, even as real GDP increased by more than 15 percent.[66]

Energy consumption can vary from year to year 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., while growing the market for energy efficiency devices and services.

- Federal fuel economy standards have led to more efficient vehicles.[68] In 2008, the average fuel economy of a new vehicle was 21.0 miles per gallon, no better than 20 years earlier.[69] In 2017, the average fuel economy was 25.2 miles per gallon – an improvement of 20 percent.[70]
- According to a survey by the American Council for an Energy-Efficient Economy (ACEEE), electric efficiency programs across the U.S. saved 2.4 times as much energy in 2016 as in 2008, as states ramped up their investments in energy efficiency.[71] In 2016, these programs saved enough electricity to power 2.4 million homes, equivalent to 0.7 percent of all U.S. electricity sales in 2016.
- Dozens of state energy efficiency policies, along with the federal Energy Independence and Security Act of 2007, have driven adoption of efficient appliances and lighting technologies such as light emitting diodes (LEDs).[72] From 2014 to 2016, the number of LED products installed in the U.S. quadrupled to 874 million units, and by 2016 LEDs accounted for 12.6 percent of all lighting installations.[73] In 2016, LED lighting provided 469 trillion Btu of source energy savings, equivalent to the total energy used by 5.2 million homes.[74]
- State energy building codes are reducing building energy use. Residential and commercial buildings account for 40 percent of U.S. energy consumption.[75] In recent years many states either implemented or updated building codes.[76] In 2014, building energy codes saved approximately 1.1 quadrillion Btu, equivalent to the total energy used by 12 million homes.[77]

ACEEE's data on electricity efficiency also reveals improvements in state-level electricity efficiency programs and policies. Massachusetts, Rhode Island, Illinois, Michigan and Washington led the nation in additional electricity efficiency savings in 2016 compared with 2008 (a 2017 analysis is not yet available).[78]

Over that time period, Rhode Island more than tripled its electricity savings, and in 2016 Rhode Island's electricity savings were equivalent to nearly 3 percent of the state's total electricity consumption. These savings were thanks to a number of energy saving programs in the state. Significant savings have been driven by Rhode Island's Comprehensive Energy Conservation, Efficiency and Affordability Act of 2006, which requires utilities to acquire all cost-effective energy efficiency.[79] And, since 2008, Rhode Island has invested millions of dollars in revenue from the Regional Greenhouse Gas Initiative (RGGI, the Northeast's cap-and-trade program) in programs to promote energy efficiency by supporting the construction of efficient public-sector buildings, encouraging the adoption of LED streetlights, and providing financial incentives for consumer efficiency.[80]

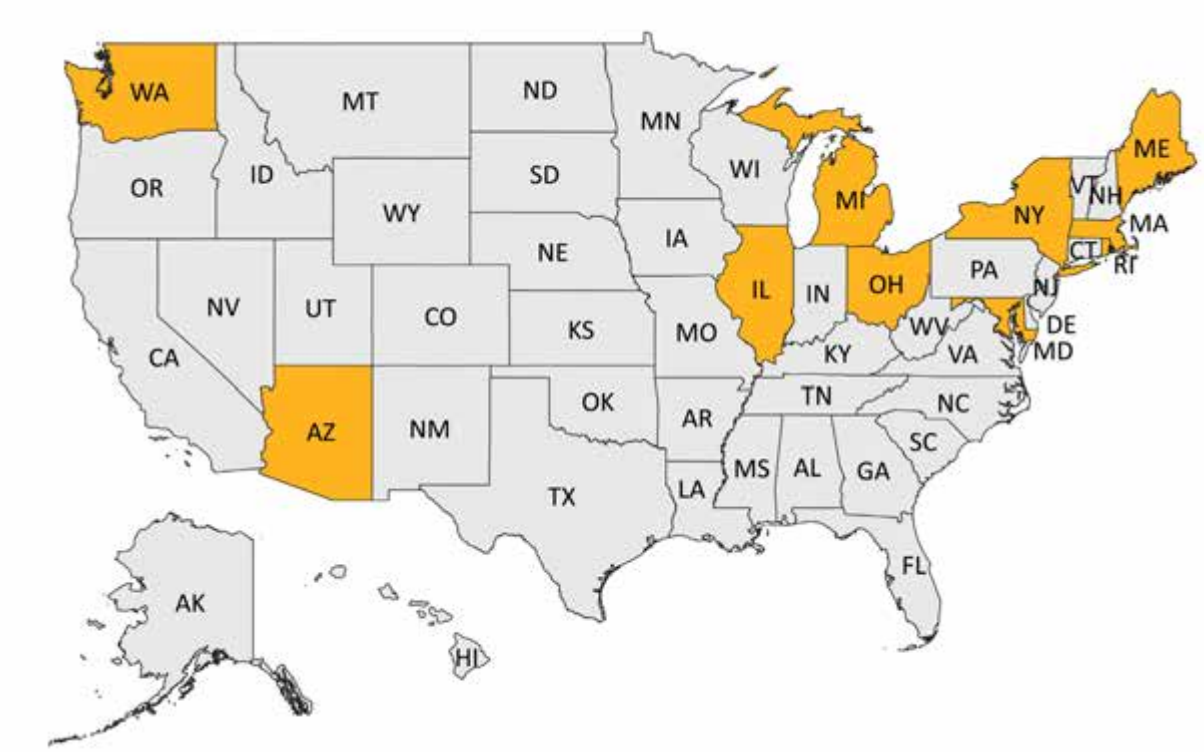
Three states that rank in the top five for biggest improvement in electric efficiency gains – Michigan, Illinois and Ohio – had zero energy efficiency savings in 2008 from state or utility programs. Ohio energy savings resulted in part from its clean energy law, which originally passed in 2008 but was then put on hold by a legislative freeze in 2014. In January 2017, Ohio's clean energy law once again took effect after Governor John Kasich vetoed a continuation of the freeze.[81] Under the law, which was somewhat weakened from the original, utilities must meet annual 1 percent energy reduction targets through 2020, increasing to 2 percent annually in 2021.[82] Michigan, which was recognized as a "most-improved" state in ACEEE's 2016 efficiency rankings, has made significant improvements in recent years to its building efficiency standards.[83]

Table 3. Most Improved States for Electricity Efficiency[84]

Data reported by ACEEE's State Energy Efficiency Scorecard reports.

State	Electricity Saved as % of Retail Sales, 2008	Electricity Saved as % of Retail Sales, 2016	Change (Percentage points)	Rank, by Increase
Massachusetts	0.69%	3.00%	2.31	1
Rhode Island	0.77%	2.85%	2.08	2
Illinois	0.00%	1.23%	1.23	3
Michigan	0.01%	1.17%	1.16	4
Washington	0.61%	1.54%	0.93	5
Arizona	0.53%	1.42%	0.89	6
Ohio	0.03%	0.87%	0.84	7
Maryland	0.13%	0.91%	0.78	8
New York	0.33%	1.09%	0.76	9
Maine	0.64%	1.38%	0.74	10

Figure 8. America's Top 10 States for Electricity Efficiency Gains Since 2008[85]



Annual Sales of Electric Vehicles Have Grown to 104,000

Achieving an economy powered by 100 percent renewable energy means ending the use of fossil fuels for all activities, not just electricity. That means ending the use of petroleum for transportation – a sizable task, given that it that currently powers the overwhelming majority of our vehicles. Although there are many strategies for reducing transportation fossil fuel use – such as encouraging public transportation, walking and biking, and limiting sprawl – as long as Americans continue driving cars and trucks, adopting electric vehicles is a necessity.

The first modern all-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.[86]

Over the last decade, EVs have become a sizable presence on American roads. Since 2008, 395,000 EVs have been sold.[87] In 2017, EV sales broke past 100,000 annual sales for the first time, with 104,000 sold.[88] There are more than 20 models on the market, ranging from affordable commuter cars to ultra-fast luxury supercars.[89] And automakers Volvo, Daimler AG (parent company of Mercedes-Benz), Volkswagen and General Motors have all announced plans to incorporate at least some form of electrification into their entire vehicle line-ups in the years ahead.[90]

California leads the nation in electric vehicle adoption. Since 2011, nearly half of all EVs sold in the country have been sold in California.[92] Four of the states that lead the nation in EV sales (ranked by EVs per registered vehicle) – California, Oregon, Vermont and Massachusetts – have requirements that a certain percentage of each automakers' sales be

In 2017, annual sales of electric vehicles passed 100,000 for the first time. Credit: Dennis Schroeder/NREL

Table 4. Top EV States through 2017 (Ranked by EVs per Registered Vehicle)[95]

State	EV Sales through 2017	EVs per Thousand Registered Vehicles	Rank (per Registered Vehicle)	Rank (Cumulative Sales)
California	182,805	12.6	1	1
Hawaii	5,310	10.4	2	13
Washington	19,800	6.9	3	3
Georgia	23,658	6.8	4	2
Oregon	9,210	6.3	5	7
Colorado	7,444	4.2	6	9
Vermont	664	2.9	7	31
Utah	2,639	2.8	8	22
Arizona	6,030	2.6	9	11
Massachusetts	5,411	2.4	10	12

Figure 9. Annual Electric Vehicle Sales Passed 100,000 in 2017[91]

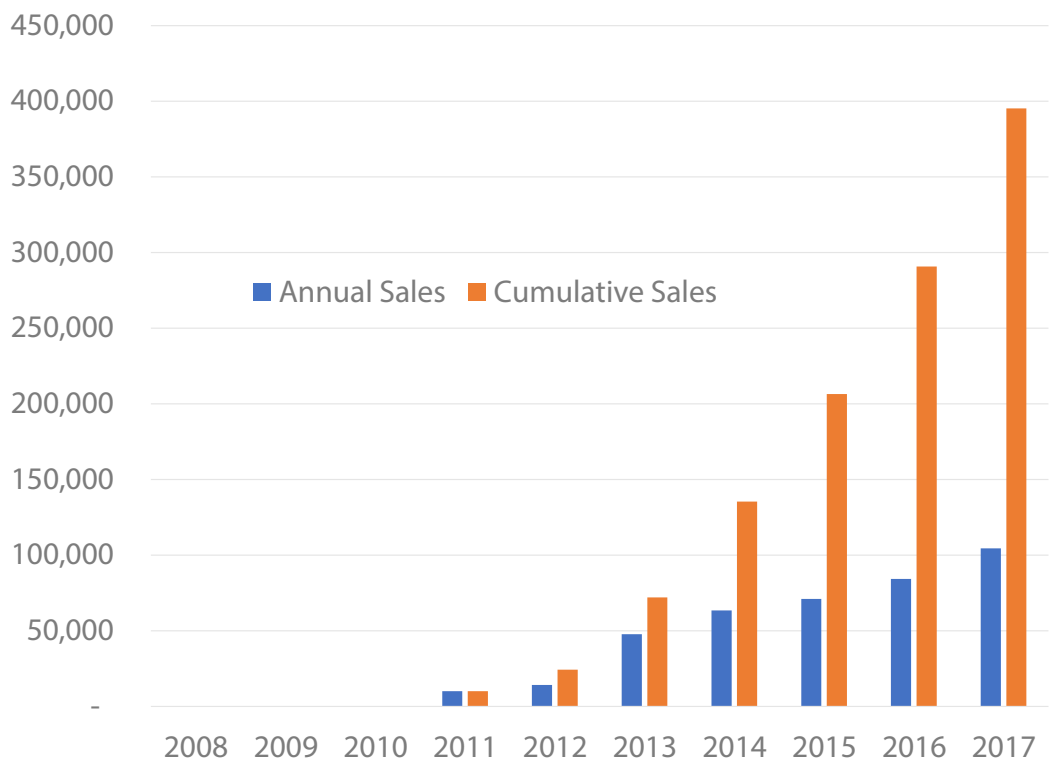


Figure 10. America's Top 10 States for Electric Vehicle Sales per Registered Vehicles through 2017[96]

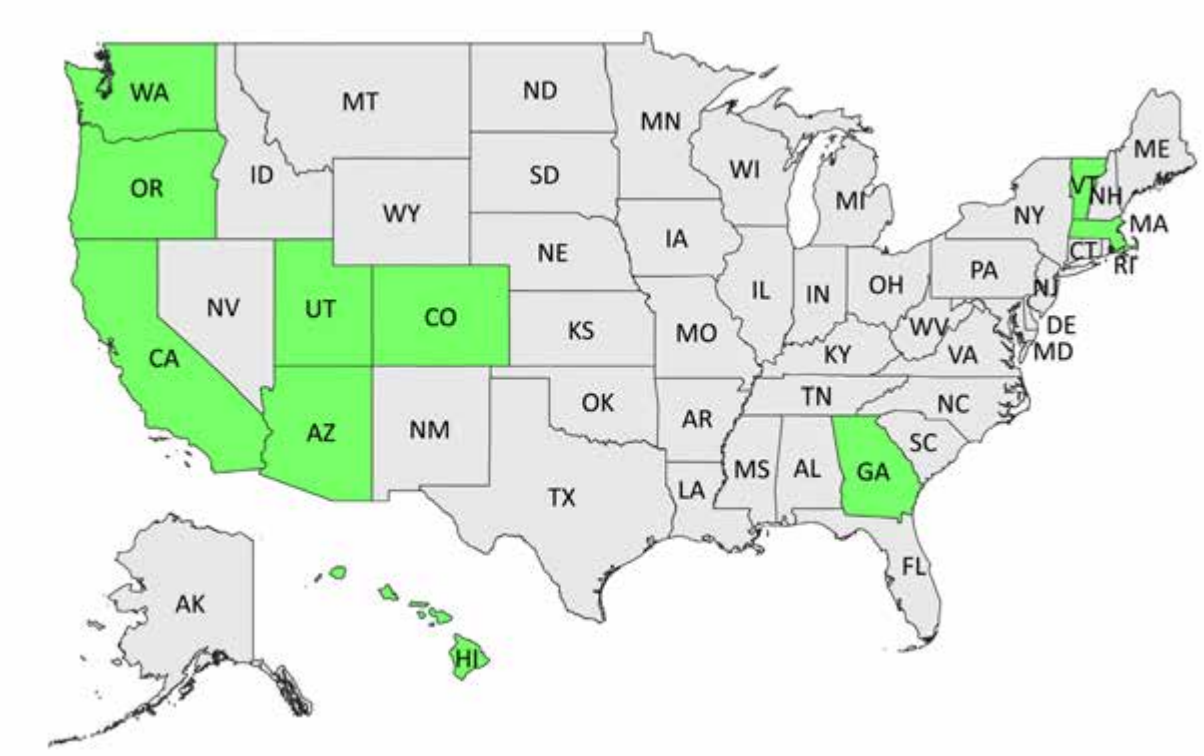
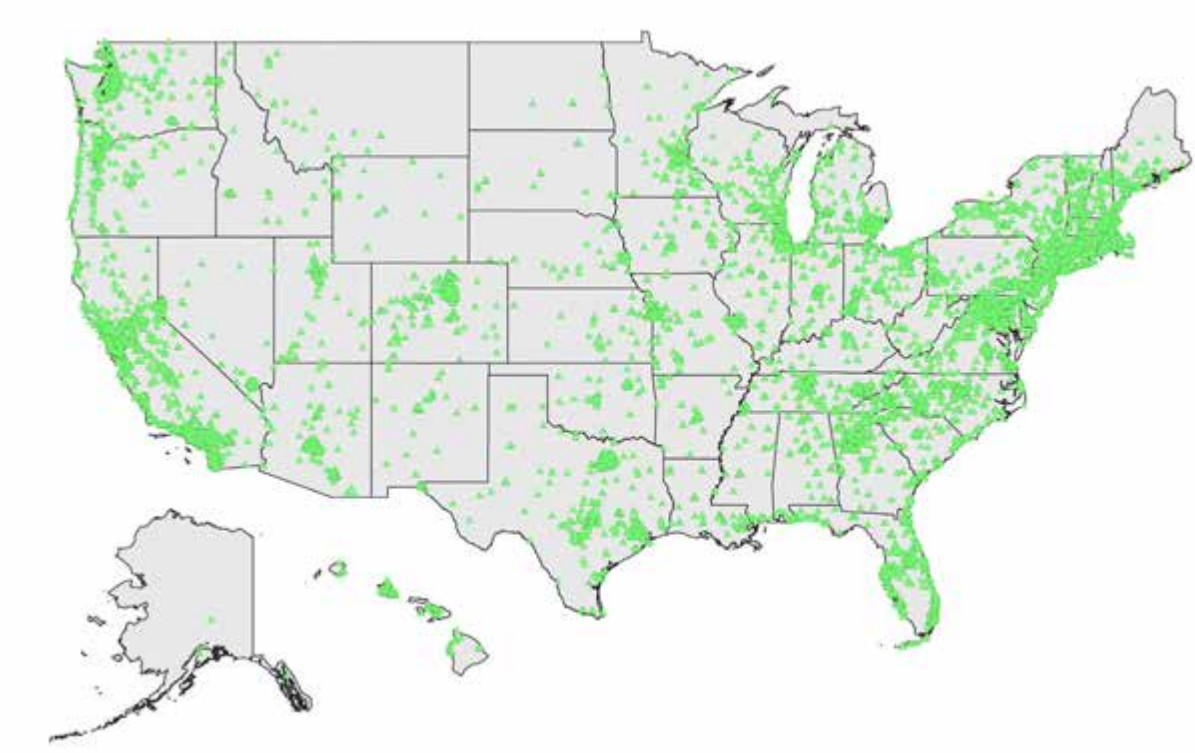


Figure 11. Public EV Charging Stations in the United States[98]



zero-emission vehicles.[93] Georgia, which ranks fourth for EV sales per registered vehicle (and second for cumulative EV sales since 2008), had seen its EV market boom under a tax incentive program. When that program was repealed and replaced with a registration fee for EVs, electric vehicle sales dropped by 80 percent.[94] Georgia's experience suggests the importance of strong and consistent policy support for the adoption of EVs.

Recent years have also seen the widespread deployment of electric vehicle charging stations across the country. From 2008 to 2017, the number of public charging stations tracked by the U.S. Department of Energy increased from barely 100 to more than 17,000, with stations appearing throughout the country, particularly along major highways.[97] Thousands more have been installed in private garages of homes and businesses.

Table 5. Top States for Electric Vehicle Charging Stations[99]

State	Public Charging Stations (as of 26 April 2018)	Rank
California	4,320	1
Florida	1,007	2
Texas	978	3
New York	954	4
Washington	737	5
Georgia	651	6
Colorado	569	7
Massachusetts	537	8
Maryland	503	9
North Carolina	499	10

Battery-Powered Energy Storage Has Grown 17-Fold since 2008

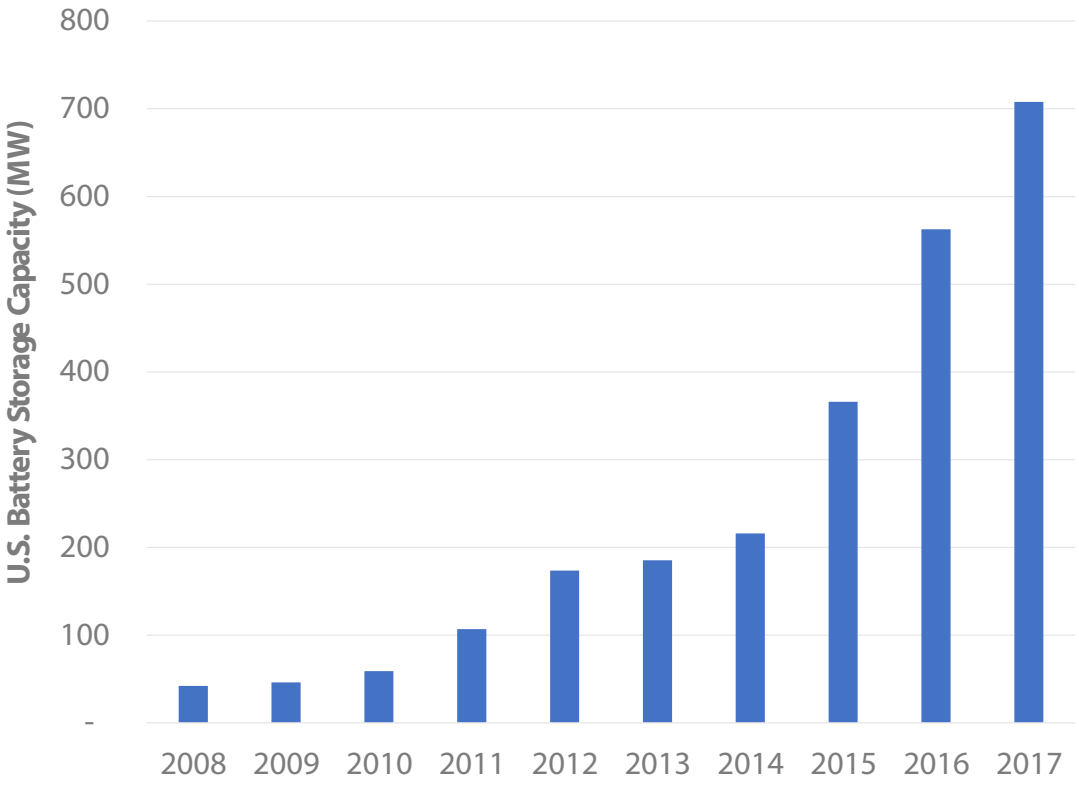
America has vast resources of clean, renewable energy, but taking full advantage of that potential requires an energy system that can accommodate daily and seasonal variations in the availability of energy sources such as solar and wind power. There are many strategies that can be used to integrate renewable 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 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, or shift demand to times of higher generation. In the long run, overbuilding wind and solar energy might allow for adequate generation even on days when there is less sun and wind.[100]

Energy storage technologies can also help enable a future in which the vast majority of our energy comes from renewable sources. Energy storage technologies include batteries, flywheels that store rotational energy, and hydroelectric pumped storage systems that pump water to a higher elevation and later allow the water to flow back downhill through turbines to generate electricity.

Because of their flexibility, batteries will likely play a particularly important function for a renewable grid. Batteries come in many sizes and types and can be deployed in many places. Batteries can be deployed at large scale by utilities and at small scale by homeowners, and serve a wide range of functions. Battery storage systems can be designed to store large quantities of energy (measured as energy capacity in megawatt-hours) or to rapidly release energy into the grid (measured as power capacity in megawatts) to balance energy supply and demand and smooth transitions between different types of generation sources like wind and solar.[101]

By storing energy generated by wind turbines and solar panels, batteries can ease the transition to a clean, renewable grid. Credit: NREL

Figure 12. America's Utility-Scale Battery Storage Capacity Grew 17-Fold from 2008 to 2017[106]



Most energy storage that existed prior to 2008 was in the form of large-scale hydroelectric pumped storage systems. Since 2008, however, battery storage has seen dramatic growth. Recent price declines and technology improvements – driven in part by the rise of electric vehicles and advances in consumer electronics – have made batteries a viable and flexible option for expanding energy storage capacity. In 2018, for example, a bid to build a solar plus storage peaking power plant in Arizona beat out competing bids for new natural gas plants.[102]

Between 2008 and 2017, the U.S. added 666 MW of utility-scale battery energy storage, for a total of 708 MW – a 17-fold increase in battery storage power capacity.[103] In terms of energy capacity (the total amount of energy that can be stored in batteries), growth has been even more dramatic, growing from 11 MWh to 619 MWh between 2008 and 2016, a 56-fold increase. (Data on energy capacity are not yet available for 2017).[104]

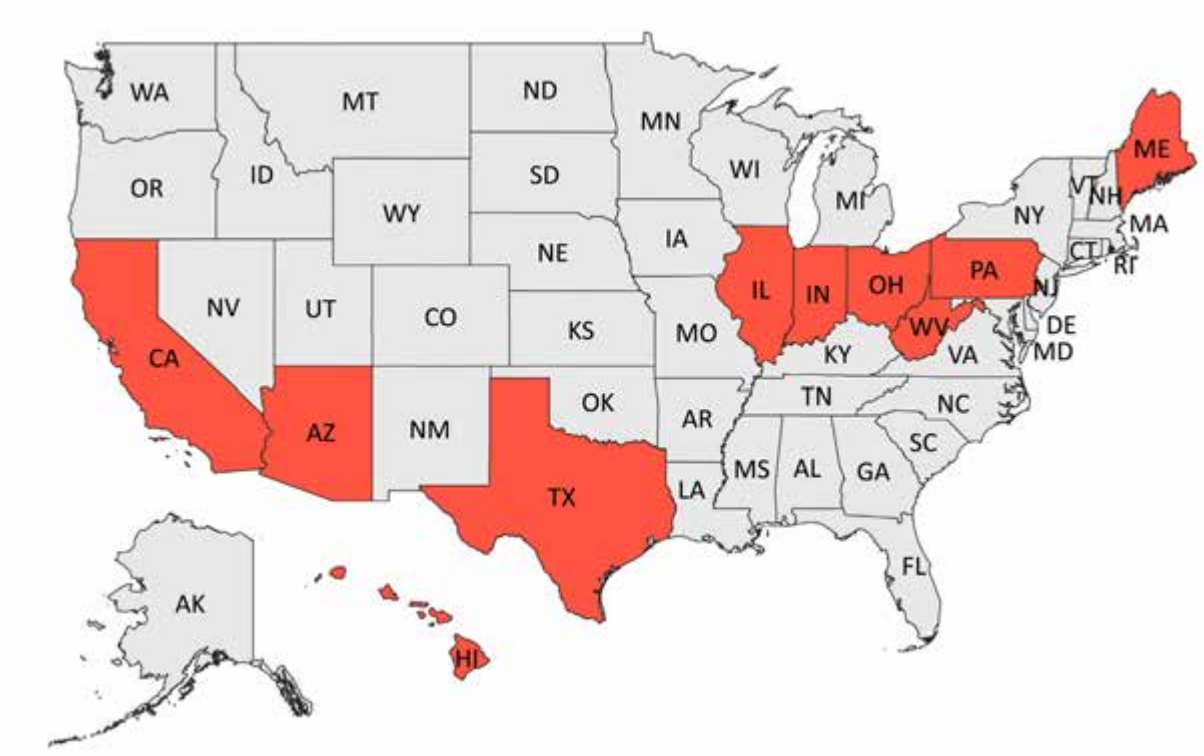
Experts predict that improved technology and declining prices will propel rapid growth in energy storage in the coming years. GTM Research, for example, projects that annual U.S. energy storage additions will reach 1.7 GW by 2020 – nearly three times the total energy storage additions from 2008 to 2017.[105]

At the state level, California, Illinois, Texas, West Virginia and Ohio led the nation in energy storage additions from 2008 to 2017. Nine of the top 10 states for battery storage addition had no battery capacity in 2008. Five of the top 10 states are part of the PJM regional grid. PJM (the regional transmission organization that operates the electric grid in much of the

Table 6. States That Added the Most Energy Storage 2008 – 2017[109]

State	Battery Storage Capacity, 2008 (MW)	Battery Storage Capacity, 2017 (MW)	Increase, 2008-2017	Rank, by Increase
California	0	161.5	161.5	1
Illinois	0	112.4	112.4	2
Texas	0	82.9	82.9	3
West Virginia	0	65.5	65.5	4
Ohio	2	53.0	51.0	5
Arizona	0	40.0	40.0	6
Hawaii	0	39.5	39.5	7
Pennsylvania	0	30.4	30.4	8
Indiana	0	22.0	22.0	9
Maine	0	16.7	16.7	10

Figure 13. America's Top 10 States for Battery Storage Additions since 2008[110]



Mid-Atlantic and Midwest) increased battery storage as a response to a decision by the Federal Energy Regulatory Commission to increase compensation for grid additions that allow for rapid changes in electricity production.[107]

California led the nation in installation of new battery energy storage, installing 162 MW from 2008 to 2017.

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, when California used the additional energy storage to minimize grid disruptions from outages at natural gas power plants.[108]

Nine States Now Generate 20 Percent or More of Their Electricity with Wind and Solar Power

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

In 2017, 19 states generated enough wind and solar energy to supply more than 10 percent of their electricity needs.[111] Nine states generated wind and solar power equivalent to at least 20 percent of electricity consumption, and three states – North Dakota, Iowa and Oklahoma – generated wind and solar power equivalent to at least 40 percent of state electricity consumption. North Dakota generated enough wind and solar electricity to supply 58 percent of its electricity needs.

Table 7. Top 10 States by Wind and Solar Generation as Percentage of Electricity Consumption[112]

State	Wind and Solar Generation as Percentage of Electricity Consumption (2017)	2017 Rank
North Dakota	58%	1
Iowa	43%	2
Oklahoma	41%	3
Wyoming	26%	4
South Dakota	26%	5
New Mexico	25%	6
Kansas	22%	7
Colorado	20%	8
Maine	20%	9
Hawaii	19%	10

The U.S. Can and Must Accelerate Clean Energy Progress

In order 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.

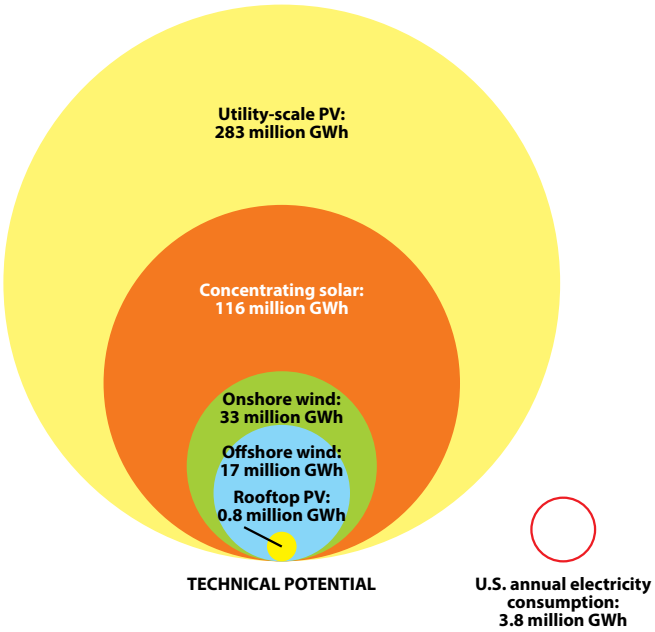
Fortunately, the United States has more than enough renewable energy potential to support all of our energy needs. According to the National Renewable Energy Laboratory, the United States has the technical potential to produce more than 100 times as much solar electricity and more than 10 times as much electricity from wind as the nation consumes each year.[113] Every state in the country has enough solar energy potential to supply all of its electricity needs.[114]

Transitioning to an economy powered by clean, renewable fuels 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 time period for preventing the worst impacts of global warming.

Figure 14. Comparison of Renewable Energy Technical Potential and Current Consumption (Data: NREL)[115]



If the nation were to install as much renewable energy every year as we did in 2017, by 2050 America would be producing enough electricity to meet only 53 percent of today's electricity demand. That 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 potential to repower our electricity system, and

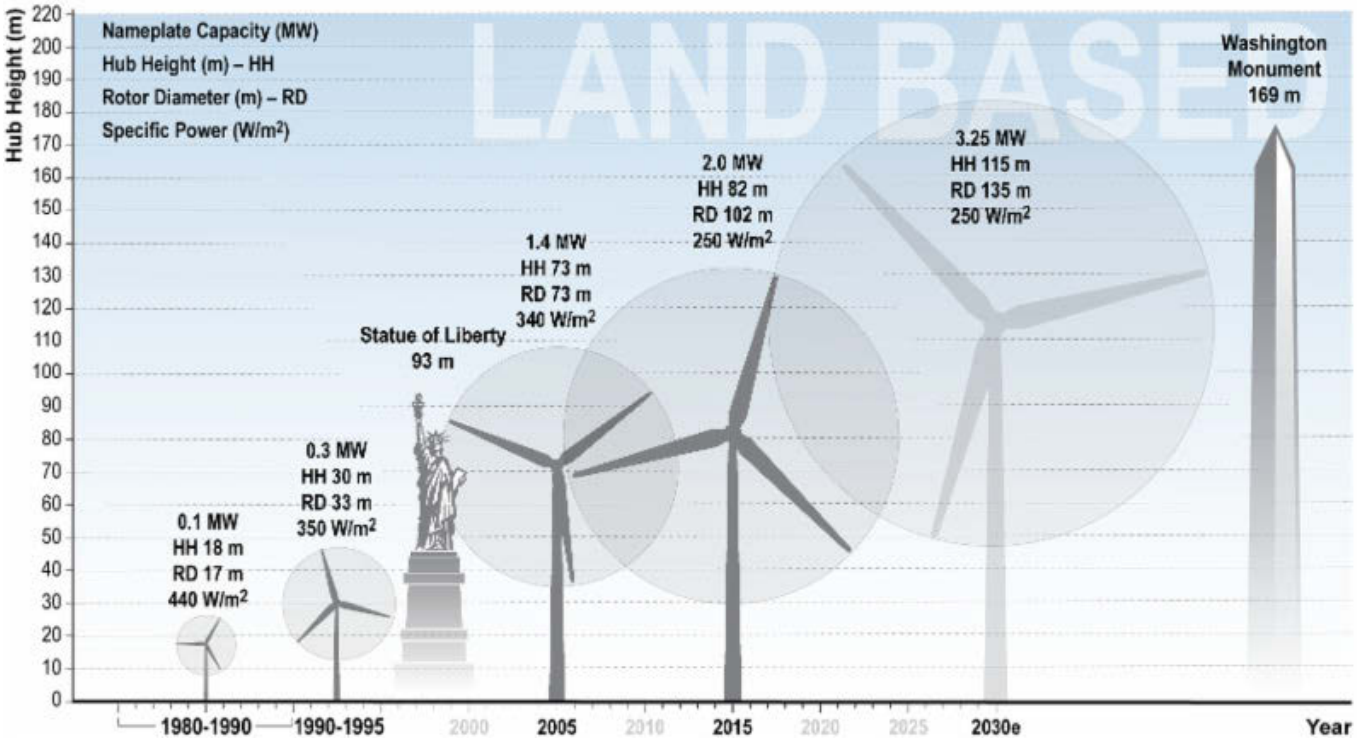
eventually our entire economy, begins to come into view. Between 2008 and 2017, U.S. wind and solar generation grew at an annual rate of 22 percent. If generation were to grow by 14 percent per year, or about two thirds of the current growth rate, wind and solar would produce enough electricity to meet 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 twice as long as those used in turbines made 15 years ago, enabling the average wind turbine installed today to have capacity more than double that of the average wind turbine installed in the year 2000.[116] In 2007, the highest-capacity wind turbine in the world was 6 MW, with only one such test prototype actually in operation.[117] Today, an entire wind farm of 8 MW turbines is generating electricity off the coast of England. According to Ørsted, the company that led the project, a single revolution of the blades on just one turbine can power a home for 29 hours.[118]

Wind manufacturers already have plans to develop 10 MW offshore prototypes by 2020.[119] In March 2018, General Electric introduced a 12 MW turbine, able to generate 67 GWh annually, meaning that just 100 of the turbines could match the generation of the entire U.S. wind industry from 2001.[120] By 2030, experts suggest that that scale of wind turbine will be commonplace, and typical turbines could have "a swept area more than five times the size of a football field."[121]



From 2005 to 2015, the average capacity of a U.S. land-based wind turbine increased from 1.4 MW to 2.0 MW, and average turbine capacity 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

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 far too deep to allow the installation of traditional seafloor-mounted turbines.[122] Data from the National Renewable Energy Laboratory shows that the West Coast has the potential to generate more than 10 times as much electricity from the wind as it uses in a given year.[123]

Recent years have also seen rapid progress in solar energy technology. The average rooftop solar panel installed in 2016 was 25 percent more efficient than the average panel installed in 2008.[124] For utility-scale solar energy, efficiency improvements are reducing costs by allowing developers to purchase less land, or fewer modules, to achieve desired project capacity.[125]

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, internet-connected appliances and climate control systems for example, can reduce energy consumption and peak grid demand by allowing users to control equipment remotely or shift its operation to off-peak hours. U.S smart appliance revenue grew more than eight-fold from 2011 to 2016, from $105 million to $887 million.[126]

Industrial operations are also embracing intelligent efficiency.[127] In 2016, the U.S. market for industrial energy management systems – systems that allow monitoring and adjustment of energy use in industrial settings – reached $4.7 billion, an increase of 48 percent over 2011.[128] Efficiency technologies and advances in building design, combined with on-site renewable energy, are enabling the spread of net-zero energy buildings, which generate at least as much energy as they consume over the course of a year. A survey by the Net-Zero Energy Coalition found more than 4,000 net-zero energy buildings in the U.S. and Canada in 2016, an increase of more than 20 percent from 2015.[129]

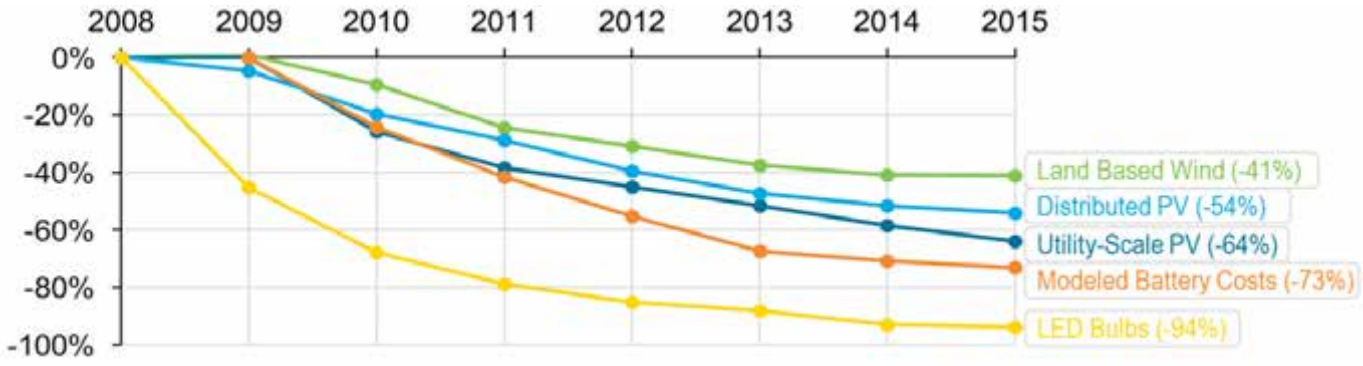
Improvements in battery technology are enabling both advances in energy storage and the production of longer-range electric vehicles. From 2013 to 2017, the range of the base model Tesla Model S grew from 208 to 249 miles per charge, while the range of a Nissan Leaf grew from 75 to 107 miles per charge.[130] The 2018 Leaf offers a range of 150 miles, and an extended range model of Tesla's Model S offers a range of 351 miles.[131] The 2018 Chevrolet Bolt offers a range of 238 miles.[132]

Prices Are Falling

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

From 2009 to 2017, the levelized cost of energy from wind and utility-scale solar fell by 67 percent and 86 percent, respectively, according to financial firm Lazard.[133] (Levelized cost of energy allows for "apples to apples" comparisons of energy costs, and is the lifetime cost of the technology divided by lifetime energy production, levelized to remove the effects of inflation.) In 2017, Bloomberg New Energy Finance reported that lithium-ion battery packs were selling for an average price of $209 per kilowatt-hour, down 24 percent from 2016 and approximately 80 percent from 2010.[134] Falling battery prices enable cheaper electric vehicles and cheaper energy storage.

These and other recent price declines have made many clean energy technologies price competitive when compared to conventional fossil-fuel technology. Lazard, which conducts an annual levelized cost of energy survey, now reports that the unsubsidized cost of utility-scale wind and solar energy have fallen to levels that are "cost-competitive with conventional generation technologies under some scenarios."[136] In the United Arab Emirates in 2016, for example, a



A Department of Energy survey of clean energy prices found that, from 2008 to 2015, the cost of land-based wind power fell by 41 percent; distributed PV by 54 percent; utility-scale PV by 64 percent; batteries by 73 percent; and LED bulbs by 94 percent.[135] Image: U.S. Department of Energy

record-breaking solar contract was signed promising to deliver energy for 2.42 cents per kilowatt-hour, or half the average global cost of coal power.[137] In many areas in the U.S., wind energy is already cheaper than fossil fuel generation.[138] And in response to a request for proposals for new energy capacity by Xcel Energy in Colorado in 2018, bids for wind plus storage projects were cheaper than coal for the first time.[139]

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.[140] An analysis by the Consumer Federation of America found that a household with 20 light bulbs can expect to save approximately $1,000 in a decade by switching from incandescent bulbs to LEDs.[141]

As adoption increases and technology improves, prices are expected to continue to fall. A survey of wind experts by the National Renewable Energy Laboratory found that the price of wind power is expected to fall 24-30 percent by 2030 and 35-41 percent by 2050.[142] And Bloomberg New Energy Finance predicts that the average utility-scale solar energy system "will cost 73 cents a watt by 2025," a 36 percent price drop from today, and that "[b]y 2025, solar may be cheaper than using coal on average globally."[143]

Putting it All Together

America has virtually limitless potential to produce energy from the wind and sun, and many opportunities to use energy smarter and more efficiently. 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 our energy system relies almost entirely on clean, renewable sources – 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 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.[144] 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

Clean energy is growing at an incredible pace. Over just nine years – from 2008 to 2017 – America saw solar energy grow 39-fold, wind energy grow nearly five-fold, total energy consumption drop by 1 percent, and battery-powered electric vehicles and energy storage emerge as viable new solutions to enable the transition to renewable energy.

Yet while renewable energy is booming, achieving the rapid growth necessary to take on America's environmental and public health challenges is no certainty. In 2017 the U.S. added less solar capacity than in 2016.[145] Some states have scaled back support for renewable energy, and the Trump administration has undertaken efforts to keep aging fossil fuel plants in operation.[146]

Fortunately, states, communities and businesses have a variety of tools at their disposal to accelerate the transition to a renewable future. In 2015, Hawaii became the first state in the country to set a 100 percent renewable energy mandate for its electricity sector, doing so through its renewable energy standard.[147] According to the Sierra Club, 65 cities have committed to 100 percent renewable energy, and another six cities have already achieved it.[148] The city of Greensburg, Kansas, has a wind farm that produces enough energy to power every single one of its homes, businesses and municipal buildings.[149] The organization RE100 has chronicled commitments from 131 companies to source 100 percent of their electricity consumption from renewable sources, including Bank of America, Google and Anheuser-Busch InBev.[150] And a number college and university campuses already get 100 percent of their electricity from clean energy sources.[151]

The U.S. is seeing rapid renewable energy growth. To continue and accelerate the pace of change, community leaders and policymakers should:

- Set goals to meet all energy needs across all sectors with renewable energy by 2050.
- Prioritize energy savings. Conserving energy and using it more efficiently can ease the transition from dirty fuels to clean, renewable energy. Policies to increase energy savings include:
  - Zero net energy requirements for new buildings.
  - Energy efficiency standards for appliances.
  - Financial or other assistance for weatherization and building energy efficiency retrofits.
  - Vehicle efficiency (mile per gallon) standards.
  - Statewide energy efficiency standards that require utilities to hit annual energy savings targets.
- 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. Policies to hasten renewable energy deployment include:
  - State renewable energy standards to require that a significant and growing share of that state's electricity comes from the wind and sun.

- Technology-specific targets and mandates for offshore wind power and energy storage.
- Net metering or value of solar tariffs that will guarantee owners of solar power systems a fair return for the electricity they produce and supply to the grid. "Virtual" or "community" net metering policies can also encourage shared, community solar gardens.
- Requirements for new buildings to include solar panels and electric vehicle charging infrastructure, and programs to encourage clean energy installations and building retrofits.

- 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. Policies to support technology development include:
  - Funding for clean energy research.
  - Funding and technical assistance for clean energy demonstration projects, including energy storage installations, microgrids, community solar, and smart electric vehicle charging stations.
  - Policies to create a smarter grid that will work with variable generation, including funding for new transmission and distribution infrastructure, and support for grid managers to plan and prepare for the integration of clean energy technologies.
  - Support for the installation of electric heating systems and other technologies that replace on-site combustion of fossil fuels.
- Set limits on greenhouse gas emissions that will shift us away from fossil fuels. Policies include:
  - Cap and invest policies, like the Northeast Regional Greenhouse Gas Initiative.
  - Carbon pricing, with revenues invested in clean energy solutions.

Appendix

Table A1. Clean Energy Progress by State (National Rank in Parentheses)

State	Increase in Solar Electricity Generation, 2008 - 2017 (GWh)[152]	Increase in Wind Electricity Generation, 2008 - 2017 (GWh)[153]	Increase in Electricity Efficiency Savings, 2008 – 2016 (percentage point increase in savings as share of electricity consumption)[154]	Number of Electric Vehicles Sold through 2017[155]	Increase in Battery Storage Capacity 2008 - 2017 (MW)[156]
Alabama	211 (28)	None	0.04 (38)	594 (33)	None
Alaska	2 (49)	164 (36)	0 (40)	136 (47)	3 (14)
Arizona	6,463 (2)	588 (28)	0.89 (6)	6,030 (11)	40 (6)
Arkansas	40 (42)	None	0.57 (12)	222 (44)	None
California	32,279 (1)	8,586 (7)	0.4 (19)	182,805 (1)	161.5 (1)
Colorado	1,405 (10)	6,346 (9)	0.5 (16)	7,444 (9)	1 (20)
Connecticut	448 (19)	None	0.39 (21)	2,896 (21)	1.6 (18)
Delaware	149 (31)	5 (38)	0.01 (39)	354 (40)	None
Florida	1,159 (13)	None	-0.04 (42)	13,583 (4)	None
Georgia	2,363 (8)	None	0.22 (29)	23,658 (2)	1 (20)
Hawaii	1,148 (14)	403 (32)	-0.65 (50)	5,310 (13)	39.5 (7)
Idaho	510 (17)	2,246 (20)	0.37 (23)	316 (42)	None
Illinois	109 (33)	8,960 (6)	1.23 (3)	8,193 (8)	112.4 (2)
Indiana	389 (22)	4,504 (12)	0.41 (18)	1,545 (27)	22 (9)
Iowa	98 (35)	16,732 (4)	0.3 (26)	478 (36)	None
Kansas	21 (45)	16,742 (3)	-0.04 (43)	692 (30)	None
Kentucky	46 (40)	None	0.45 (17)	462 (37)	None
Louisiana	208 (29)	None	0.1 (33)	494 (35)	None
Maine	51 (39)	2,090 (21)	0.74 (10)	334 (41)	16.7 (10)
Maryland	1,065 (15)	511 (29)	0.78 (8)	4,490 (14)	13 (11)
Massachusetts	2,544 (7)	217 (35)	2.31 (1)	5,411 (12)	3 (14)
Michigan	165 (30)	4,931 (11)	1.16 (4)	2,095 (25)	None
Minnesota	784 (16)	6,530 (8)	0.52 (14)	2,247 (23)	1.1 (19)
Mississippi	99 (34)	None	0.24 (28)	141 (45)	None
Missouri	263 (23)	1,746 (22)	0.37 (22)	2,037 (26)	1 (20)
Montana	32 (43)	1,557 (23)	0.04 (37)	269 (43)	None
Nebraska	23 (44)	5,023 (10)	0.17 (31)	382 (39)	None
Nevada	4,063 (4)	361 (33)	-0.51 (49)	2,156 (24)	None

Table A1 cont'd. Clean Energy Progress by State (National Rank in Parentheses)

State	Increase in Solar Electricity Generation, 2008 - 2017 (GWh)[152]	Increase in Wind Electricity Generation, 2008 - 2017 (GWh)[153]	Increase in Electricity Efficiency Savings, 2008 – 2016 (percentage point increase in savings as share of electricity consumption)[154]	Number of Electric Vehicles Sold through 2017[155]	Increase in Battery Storage Capacity 2008 - 2017 (MW)[156]
New Hampshire	87 (36)	404 (31)	-0.06 (45)	634 (32)	None
New Jersey	2,727 (6)	None	-0.06 (44)	6,219 (10)	1 (20)
New Mexico	1,312 (12)	2,899 (17)	0.32 (25)	546 (34)	2.6 (16)
New York	1,370 (11)	2,693 (18)	0.76 (9)	9,346 (6)	None
North Carolina	5,776 (3)	471 (30)	0.56 (13)	4,018 (17)	1 (20)
North Dakota	-50	9,294 (5)	-0.2 (48)	51 (50)	None
Ohio	259 (24)	1,548 (24)	0.84 (7)	3,139 (19)	51 (5)
Oklahoma	44 (41)	22,046 (2)	0.39 (20)	1,327 (28)	None
Oregon	406 (21)	3,931 (13)	0.51 (15)	9,210 (7)	5 (13)
Pennsylvania	451 (18)	2,650 (19)	0.73 (11)	4,278 (15)	30.4 (8)
Rhode Island	71 (38)	153 (37)	2.08 (2)	418 (38)	None
South Carolina	246 (25)	None	0.35 (24)	885 (29)	None
South Dakota	3 (48)	3,009 (16)	0.13 (32)	79 (48)	None
Tennessee	236 (27)	None	0.1 (33)	2,966 (20)	None
Texas	2,807 (5)	50,867 (1)	-0.02 (41)	12,455 (5)	82.9 (3)
Utah	2,262 (9)	911 (27)	0.09 (36)	2,639 (22)	None
Vermont	238 (26)	269 (34)	-0.07 (46)	664 (31)	2 (17)
Virginia	441 (20)	None	0.09 (35)	4,241 (16)	None
Washington	115 (32)	3,824 (14)	0.93 (5)	19,800 (3)	7.6 (12)
West Virginia	8 (46)	1,215 (25)	0.18 (30)	138 (46)	65.5 (4)
Wisconsin	83 (37)	1,042 (26)	-0.17 (47)	3,428 (18)	None
Wyoming	5 (47)	3,435 (15)	0.28 (27)	64 (49)	None

Table A2. Solar Generation Change by State[157]

State	Solar Generation, 2008 (GWh)	Solar Generation, 2017 (GWh)	Times by Which Solar Generation Increased, 2008-2017
Alabama	-	211	N/A
Alaska	-	2	N/A
Arizona	35	6,498	184.5
Arkansas	-	40	N/A
California	1,454	33,733	23.2
Colorado	58	1,463	25.1
Connecticut	15	463	31.9
Delaware	3	152	55.5
Florida	4	1,163	286.5
Georgia	1	2,364	3882.5
Hawaii	17	1,165	68.3
Idaho	-	510	N/A
Illinois	4	113	26.5
Indiana	-	389	N/A
Iowa	-	98	N/A
Kansas	-	21	N/A
Kentucky	-	46	N/A
Louisiana	-	208	N/A
Maine	-	51	N/A
Maryland	2	1,067	500.7
Massachusetts	10	2,554	246.7
Michigan	-	165	N/A
Minnesota	1	785	552.5
Mississippi	-	99	N/A
Missouri	-	263	N/A

State	Solar Generation, 2008 (GWh)	Solar Generation, 2017 (GWh)	Times by Which Solar Generation Increased, 2008-2017
Montana	3	35	12.8
Nebraska	-	23	N/A
Nevada	178	4,241	23.8
New Hampshire	-	87	N/A
New Jersey	109	2,836	26.1
New Mexico	1	1,313	995.3
New York	25	1,395	55
North Carolina	7	5,783	876.7
North Dakota	-	-	N/A
Ohio	1	260	183
Oklahoma	-	44	N/A
Oregon	13	419	32.5
Pennsylvania	2	453	262.6
Rhode Island	3	74	23.5
South Carolina	-	246	N/A
South Dakota	-	3	N/A
Tennessee	1	237	233.5
Texas	7	2,814	385.1
Utah	-	2,262	N/A
Vermont	1	239	168.2
Virginia	1	442	544.4
Washington	1	116	228.6
West Virginia	-	8	N/A
Wisconsin	4	87	23.8
Wyoming	-	5	N/A

Table A3. Wind Generation Percentage Change by State[158]

State	Wind Generation, 2008 (GWh)	Wind Generation, 2017 (GWh)	Times by Which Wind Generation Increased, 2008-2017
Alabama	-	-	N/A
Alaska	-	164	N/A
Arizona	-	588	N/A
Arkansas	-	-	N/A
California	5,385	13,971	2.6
Colorado	3,221	9,567	3
Connecticut	-	-	N/A
Delaware	-	5	N/A
Florida	-	-	N/A
Georgia	-	-	N/A
Hawaii	240	643	2.7
Idaho	207	2,453	11.9
Illinois	2,337	11,297	4.8
Indiana	238	4,742	19.9
Iowa	4,084	20,816	5.1
Kansas	1,759	18,501	10.5
Kentucky	-	-	N/A
Louisiana	-	-	N/A
Maine	132	2,222	16.8
Maryland	-	511	N/A
Massachusetts	4	221	55.3
Michigan	141	5,072	36
Minnesota	4,355	10,885	2.5
Mississippi	-	-	N/A
Missouri	203	1,949	9.6

State	Wind Generation, 2008 (GWh)	Wind Generation, 2017 (GWh)	Times by Which Wind Generation Increased, 2008-2017
Montana	593	2,150	3.6
Nebraska	214	5,237	24.5
Nevada	-	361	N/A
New Hampshire	10	414	41.4
New Jersey	21	20	1
New Mexico	1,643	4,542	2.8
New York	1,251	3,944	3.2
North Carolina	-	471	N/A
North Dakota	1,693	10,987	6.5
Ohio	15	1,563	104.2
Oklahoma	2,358	24,404	10.3
Oregon	2,575	6,506	2.5
Pennsylvania	729	3,379	4.6
Rhode Island	-	153	N/A
South Carolina	-	-	N/A
South Dakota	145	3,154	21.8
Tennessee	50	30	0.6
Texas	16,225	67,092	4.1
Utah	24	935	39
Vermont	10	279	27.9
Virginia	-	-	N/A
Washington	3,657	7,481	2
West Virginia	392	1,607	4.1
Wisconsin	487	1,529	3.1
Wyoming	963	4,398	4.6

Table A4. Wind and Solar Generation as Percentage of State Electricity Consumption by State[159]

State	Total Wind and Solar Generation 2017 (GWh)	Wind and Solar Generation as Percentage of State Electricity Consumption	Rank (Percentage of Consumption)
Alabama	211	0.2%	46
Alaska	166	2.7%	35
Arizona	7,086	9.1%	21
Arkansas	40	0.1%	49
California	47,704	18.7%	11
Colorado	11,030	20.1%	8
Connecticut	463	1.7%	39
Delaware	157	1.4%	40
Florida	1,163	0.5%	42
Georgia	2,364	1.8%	38
Hawaii	1,808	19.4%	10
Idaho	2,963	12.5%	18
Illinois	11,410	8.4%	22
Indiana	5,131	5.4%	24
Iowa	20,914	43.2%	2
Kansas	18,522	21.7%	7
Kentucky	46	0.1%	50
Louisiana	208	0.2%	47
Maine	2,273	19.9%	9
Maryland	1,578	2.7%	36
Massachusetts	2,775	4.6%	29
Michigan	5,237	5.2%	25
Minnesota	11,670	17.9%	13
Mississippi	99	0.2%	48
Missouri	2,212	2.9%	33
Montana	2,185	15.1%	15
Nebraska	5,260	17.5%	14
Nevada	4,602	12.6%	17
New Hampshire	501	4.7%	28
New Jersey	2,856	3.9%	30
New Mexico	5,855	25.3%	6
New York	5,339	3.7%	31
North Carolina	6,254	4.8%	27
North Dakota	10,987	58.3%	1
Ohio	1,823	1.3%	41
Oklahoma	24,448	41.0%	3
Oregon	6,925	14.4%	16
Pennsylvania	3,832	2.7%	34
Rhode Island	227	3.1%	32
South Carolina	246	0.3%	43
South Dakota	3,157	25.7%	5
Tennessee	267	0.3%	45
Texas	69,906	18.0%	12
Utah	3,197	10.6%	19
Vermont	518	9.6%	20
Virginia	442	0.3%	44
Washington	7,597	8.4%	23
West Virginia	1,615	5.1%	26
Wisconsin	1,616	2.3%	37
Wyoming	4,403	26.3%	4

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