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THIS LAND WAS YOUR LAND

A Closer Look at 80 by 50

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About the Author

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Bryce has delivered more than 200 invited and keynote lectures to groups of all kinds, ranging from the Marine Corps War College and University of Calgary, to the Sydney Institute and Melbourne's Institute of Public Affairs. He appears regularly on major media outlets, including CNN, Fox News, PBS, NPR, and BBC. Bryce holds a B.F.A. from the University of Texas at Austin.

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Executive Summary

Politicians from federal to local levels have joined in a pledge known as 80 by 50, an effort to cut carbon-dioxide emissions 80% by 2050. The pledges are long on fanfare but short on details. There is, however, a published literature that determines how to achieve so-called deep carbonization, and it involves a massive increase of renewable-energy sources, primarily wind and solar.

This report analyzes the extraordinary amount of land that would be needed to achieve 80 by 50 through wind and solar, the amount of additional high-voltage transmission capacity, and the growing resistance to local wind-energy projects. It also looks at what all this means for the populations of birds and bats, including endangered species.

Key Findings

1. Relying on wind and solar energy to achieve an 80% reduction in carbon-dioxide emissions will require installing energy infrastructure over 287,700 square miles, a surface nearly as large as Texas and West Virginia combined.[1] It also will require adding at least 200,000 miles of new high-voltage transmission lines, roughly double the existing capacity.

2. The U.S. would have to install about 1,900 gigawatts (1 gigawatt is equal to 1 billion watts) of wind capacity—26 times the existing U.S. amount and four times the global wind capacity—if it plans to rely primarily on wind energy to cut greenhouse gas emissions by 80%.

3. Rural communities, acting through more than 100 government entities, have resisted expansion of renewable-energy capacity by moving to reject or restrict wind projects in about two dozen states since January 2015. Solar projects have also faced opposition.

4. Wind turbines kill birds and raptors, including bald and golden eagles. The turbines also are the largest cause of bat mortality, including several bats that are categorized as endangered. Attempting a 26-fold increase in wind-energy capacity may have devastating impacts on bird and bat populations.

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A Closer Look at 80 by 50

I. Introduction

Over the past few years, politicians and environmental groups have declared that the U.S. must make drastic cuts in domestic carbon-dioxide emissions. On July 21, the Democratic Party released its platform, which included a plank to reduce domestic "greenhouse gas emissions more than 80% below 2005 levels by 2050." The platform also says that "America must be running entirely on clean energy by mid-century."[2] In August, Bill McKibben, a prominent American environmentalist, wrote in *The New Republic* that the domestic economy can be run solely on renewable energy, adding that the U.S. should mobilize to fight climate change with the fervor that the Allies used to defeat Hitler in World War II.[3]

While 80 by 50 has many adherents, it is by no means clear how many of them understand that achieving it will require restructuring the domestic electric grid, a major expansion of the country's high-voltage transmission system, and retooling nearly every sector of the U.S. economy. This report focuses on how 80 by 50 will affect land use. It highlights wind and solar energy because many of the environmental groups and climate activists who champion 80 by 50 and other decarbonization scenarios oppose nuclear energy.

McKibben claims in his *New Republic* essay that the all-renewable-energy plan he favors will only require "four-tenths of one percent of America's land mass"—about 15,200 of the country's 3.8 million square miles. This report will show that the actual amount of land required is about 19 times larger.

As renewable-energy projects proliferate, land-use issues have already become increasingly important and controversial. Small communities nationwide have begun to actively oppose projects. Recently, to take just one example, the Board of Selectmen in Stoddard, New Hampshire, voted unanimously in August to oppose a proposed 29-megawatt wind project near their town. In a letter to state officials protesting the project, the board cited concerns about a "significant wildlife area" centered in the town.[4]

Renewable-energy projects routinely ignore the impact on wildlife when figuring decarbonization scenarios. This is a significant omission, given the iconic status of the many bird species that can be affected by the projects. And bats, which are especially at risk from such projects, play a critical environmental role as pollinators and insectivores.

II. What Is Deep Decarbonization?

In recent years, groups such as Greenpeace International, Worldwatch Institute, the International Energy Agency, and the consulting firm McKinsey & Company have published scenarios that show how carbon-dioxide emissions might be reduced by 80% or more. Achieving such cuts will require a dramatic reduction, or perhaps elimination, of the use of coal, oil, and natural gas. The process is known as deep decarbonization.

Published decarbonization scenarios vary widely in their assumptions of key factors such as cost, future energy demand, development of better batteries, and adoption rates for alternative- and electric-vehicle technology. They also differ on the amount of electric generation capacity required.

Consider a decarbonization scenario published in 2015, which says that the "average fleet fuel economy" for a light-duty vehicle in the U.S. will need to be greater than 100 miles per gallon of gas-equivalent in 2050 in order to achieve 80 by 50. It also warns that up to 95% of all the miles driven should shift from gasoline-fueled vehicles to use electric- or hydrogen-powered ones. That's not all: the paper predicts that *total energy demand must decline by about 50%* between now and 2050 to meet the goal.[5]

A 2015 study published in *Wiley Interdisciplinary Reviews: Climate Change* critiques the feasibility of more than a dozen deep decarbonization scenarios and concludes that they all "envision historically unprecedented improvements" in energy efficiency. The paper finds that the scenarios were short on detail when it came to strategies for decarbonizing industry and transportation, "and most give superficial treatment to relevant constraints on energy system transformations."[6]

While a number of details of the decarbonization scenarios differ, perhaps the biggest differentiators are the assumptions regarding the use and deployment of nuclear energy. In the 2015 paper, the authors find that only one of the scenarios relies heavily on nuclear energy to achieve major reductions in carbon dioxide. Some scenarios project only modest growth in nuclear energy, while others project a complete global phaseout of nuclear energy.[7]

The only scenario that relies on a major expansion of nuclear energy was written by Barry W. Brook, professor of environmental sustainability at the University of Tasmania. Brook claims that a global decarbonization effort modeled on France's rapid adoption of nuclear energy during the late 1970s and 1980s could allow the global economy to derive about half its energy needs from nuclear energy by 2060.[8]

While Brook's paper presents a possible decarbonization strategy, some of America's most influential environmental groups are staunchly antinuclear and are working to close down reactors. The Natural Resources Defense Council and Friends of the Earth led the negotiations with Pacific Gas & Electric to shutter Diablo Canyon, California's last nuclear energy plant. PG&E recently announced that it will close down Diablo Canyon by 2025.[9] When the announcement was made, the NRDC claimed in an article on its website that the closure sends a message to other utilities: "You can replace reactors without increasing greenhouse gas output."[10]

The Sierra Club, among the largest environmental groups in the U.S., is "unequivocally opposed to nuclear energy."[11] This environmental group is part of the Alliance for a Green Economy. The Alliance says that it is "imperative" to have a "carbon-free and nuclear-free energy supply."[12] In June, the Sierra Club, along with dozens of other organizations, sent a letter to New York governor Andrew Cuomo, saying that nuclear energy is "dangerous, costly, and dirty" and should not be part of New York's effort to reduce greenhouse-gas emissions.[13]

During his unsuccessful bid for the Democratic Party presidential nomination, Bernie Sanders (D., VT) introduced an all-renewable-energy plan, which he touted as "completely nuclear-free."[14] Sanders's plan was immediately endorsed by the leaders of some of the largest environmental groups in the U.S., including Greenpeace USA, the Sierra Club, and 350.org.[15]

On her campaign website, Hillary Clinton said that, as president, she will act to reduce greenhouse gas emissions by as much as 30% in 2025 relative to 2005 levels. She also wants to see the country cut emissions more than 80% by 2050. Her energy plan doesn't mention nuclear energy.[16] Clinton's omission matches the Democratic Party's platform, which also ignores nuclear energy.

Given the clear lack of political support for nuclear energy, this report will consider wind- and solar-only decarbonization scenarios.

III. Climbing Aboard the Bandwagon

President Obama has repeatedly endorsed 80 by 50.[17] He set that goal for the nation in remarks delivered at the National Academy of Sciences in early 2009.[18] The White House claimed in 2015 that the U.S. can double its rate of decarbonization and that doing so will "keep the United States on the pathway to achieve deep economy-wide reductions of 80% or more by 2050."[19]

New York mayor Bill de Blasio in 2014 declared that the Big Apple also intends to achieve 80 by 50.[20] In 2015, then-governor of Maryland Martin O'Malley issued an executive order endorsing 80 by 50.[21] The 80 by 50 concept has been accepted in significant numbers among academia. Boston-based Second Nature announced in April 2016 that 91 colleges and universities in the U.S. had committed to "carbon neutrality."[22]

A number of U.S. states and cities have adopted goals or mandates to meet, or exceed, an 80% cut in carbon-dioxide emissions by 2050. Last year, the White House published a list of 80 by 50 adherents that included the following cities: Atlanta, Boston, Houston, Los Angeles, Portland, New York, Oakland, Phoenix, Salt Lake City, San Francisco, Seattle, and Washington, D.C. Across the globe, some 135 jurisdictions in 32 countries have signed an "Under 2 MOU (Memorandum of Understanding)," agreeing to "reduce their greenhouse gas emissions 80 to 95%, or limit to 2 metric tons CO2-equivalent per capita, by 2050."

IV. Three 80 by 50 Scenarios

How much renewable-energy capacity is required to reduce carbon-dioxide emissions 80% by 2050? Consider three deep decarbonization scenarios: by the Deep Decarbonization Pathways Project (DDPP); by Mark Z. Jacobson, professor of civil and environmental engineering at Stanford; and by the U.S. Climate Change Technology Program (CCTP).

The DDPP is a collaborative effort of Energy and Environmental Economics, Lawrence Berkeley National Laboratory, and Pacific Northwest National Laboratory. Its scenario estimates that getting to 80 by 50 will require a total of 2,500 gigawatts of renewable-energy capacity. The group didn't break down how that capacity will be split between wind and solar. Therefore, I'll assume that DDPP's capacity will be split evenly between the two types of energy, with 1,250 gigawatts of wind capacity and 1,250 gigawatts of solar.[24]

Stanford's Jacobson claims that the U.S. and other countries don't need hydrocarbons or nuclear energy and that the global economy can be run solely with energy derived from wind, water, and solar, or WWS.[25] Jacobson's work has been cited positively by several mainstream media outlets and endorsed by numerous politicians and environmental groups. The WWS scenario was adopted by Bernie Sanders during his presidential campaign.[26]

Jacobson's WWS scenario shows that a 100% renewable-energy system will require 5,800 gigawatts of electrical generation capacity.[27] To compare, the current U.S. electric generation network has about 1,000 gigawatts of generation capacity, which includes everything from nuclear to solar and natural gas to geothermal.[28] The WWS scenario requires 2,480 gigawatts of wind-energy capacity, including 1,700 gigawatts onshore and 780 gigawatts offshore.[29]

States and cities that have adopted various decarbonization goals or mandates include:[23]

Atlanta
Boston
California
Connecticut
Florida
Hawaii
Houston
Los Angeles
Minnesota
New Hampshire
New Jersey
New York City
Oakland
Oregon
Phoenix
Portland
San Francisco
Seattle
Vermont
Washington, D.C.

It requires 3,200 gigawatts of solar capacity, split among rooftop installations, concentrated solar, and utility-scale solar facilities. It also calls for more than 100 gigawatts of renewable capacity from geothermal, hydroelectric, wave, and tidal devices. (While the current electrical generation network requires 1,000 gigawatts, renewable sources require huge amounts of extra capacity to account for their intermittency and geographic variability.)

The third deep decarbonization scenario comes from the Climate Change Technology Program (CCTP), which issued its report in 2006.[30] The program included participants from more than a dozen federal agencies, including the U.S. Department of Energy and the U.S. Environmental Protection Agency. It provides several metrics for achieving deep decarbonization through renewable energy. Before looking at the CCTP's metrics, pause to remember the scale of the proposed emissions reductions: U.S. annual carbon-dioxide emissions currently total about 5.5 billion tons.[31] To reduce those emissions by 80%, the U.S. must cut 4.4 billion tons of emissions. To split that reduction evenly between wind and solar, each source must cut emissions by 2.2 billion tons.

The CCTP report concludes that a 1-billion-ton reduction through the use of wind energy requires the installation of 650,000 wind turbines, and each turbine must have a capacity of 1.5 megawatts. Therefore, the U.S. needs to install about 1.43 million wind turbines with 1.5 megawatts of capacity in order to reduce emissions by 2.2 billion tons through the use of wind. The total wind-energy capacity needed under the CCTP scenario is 2,145 gigawatts.

According to the CCTP report, to cut 1 billion tons of carbon dioxide with solar energy requires installation of "6 million acres of solar photovoltaics," a type of solar technology. Therefore, using solar energy to cut domestic carbon-dioxide emissions by 2.2 billion tons will mean covering about 13.2 million acres of land with solar panels. At 640 acres per square mile, that works out to about 20,645 square miles of solar panels.

The CCTP report doesn't say how much solar capacity is required; it only calculates the land needed to hold the panels. Still, by using productivity figures from the domestic solar sector, one can estimate how much capacity is required under the CCTP scenario. For solar energy to be a real player in 80 by 50, it must cut emissions by at least 30%, with the remainder coming from wind. According to the EPA, domestic electricity production accounts for 30% of domestic greenhouse gas emissions.[32] In 2015, electricity production totaled 4,300 terawatt-hours.[33] Each gigawatt of U.S. solar capacity now produces about 1.5 terawatt-hours of energy.[34] Therefore, producing 4,300 terawatt-hours of electricity annually from solar will require about 2,866 gigawatts of solar capacity.[35]

Figure 1 shows a summary of the three scenarios. The three decarbonization scenarios require an average of 1,958 and 2,441 gigawatts of solar and wind capacity, respectively.

FIGURE 1.

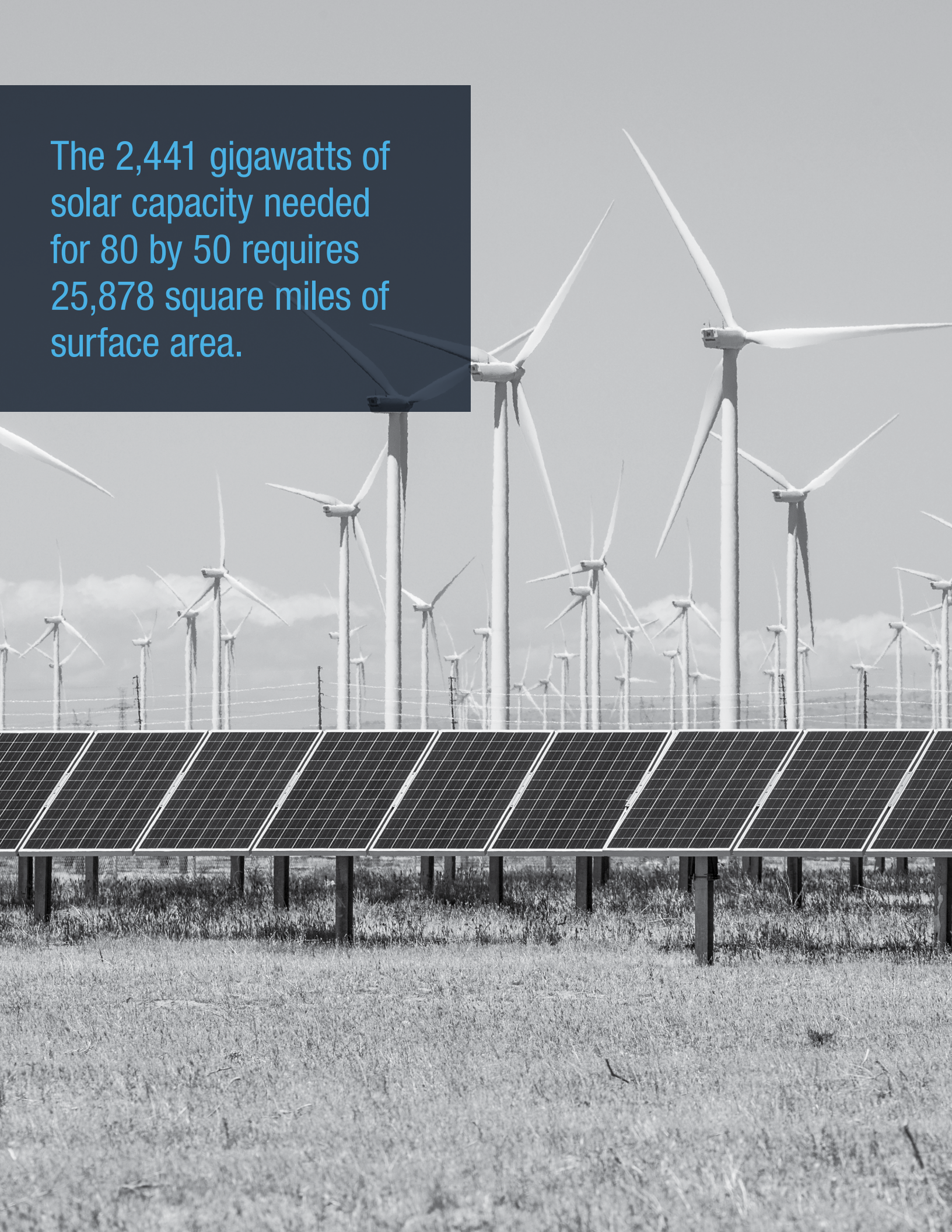
Gigawatts of Renewable-Energy Capacity in Three Decarbonization Scenarios

	Solar	Wind	Total
DDPP	1,250	1,250	2,500
WWS	3,208	2,480	5,688
CCTP	2,866	2,145	5,011
Average	2,441	1,958	4,400

V. The Implications of 80 by 50 for Land Use

Solar

Today's solar-energy projects deploy thermal and photovoltaic energy. While thermal projects can vary widely in scope, they generally use some method of reflectors to concentrate sunlight. The light heats a fluid, which is then used to produce electricity. Photovoltaic systems rely on panels packed with semiconductors that convert the light energy of the sun into electricity. While the solar technologies differ, they have similar footprints. That can be shown by comparing the capacity density, which is the overall project footprint, of solar-thermal projects with that of photovoltaic projects.



The 2,441 gigawatts of solar capacity needed for 80 by 50 requires 25,878 square miles of surface area.

The U.S. currently has about two dozen large solar-thermal projects. They include the Ivanpah Solar Electric Generating System (392 megawatts), Mojave Solar Project (280 megawatts), and Genesis Solar Energy Project (250 megawatts), all three in California.[36] Their total capacity is 922 megawatts; they cover 7,215 acres.[37] That's the equivalent of 31.6 watts per square meter, or 1 gigawatt per 12.2 square miles.[38]

Though solar-thermal projects tend to garner publicity, the Solar Energy Industries Association estimates that 95% of all the large solar projects now in development or under construction use photovoltaic technology.[39] This report examines three large projects to gather capacity density figures for photovoltaic projects: the 579-megawatt Solar Star, 550-megawatt Topaz Solar, and 550-megawatt Desert Sunlight.[40] Like the solar-thermal projects mentioned earlier, these facilities are located in California. The total capacity of the three photovoltaic facilities is 1.7 gigawatts. They cover 11,530 acres. That's equal to 36.4 watts per square meter, or 1 GW per 10.6 square miles.[41]

To be clear, the photovoltaic capacity that might be deployed in pursuit of 80 by 50 will be split among different types of projects. Some will be large, utility-scale facilities. Others will be smaller, such as rooftop installations on commercial and residential buildings. Rooftop systems will not require setting aside additional land.

Photovoltaic projects have a higher density than solar-thermal facilities because they require less land. Consequently, these calculations assume that each gigawatt of solar capacity requires 10.6 square miles of surface area.

The 2,441 gigawatts of solar capacity needed for 80 by 50 requires 25,878 square miles of surface area. **(See Figure 2.)**

Wind

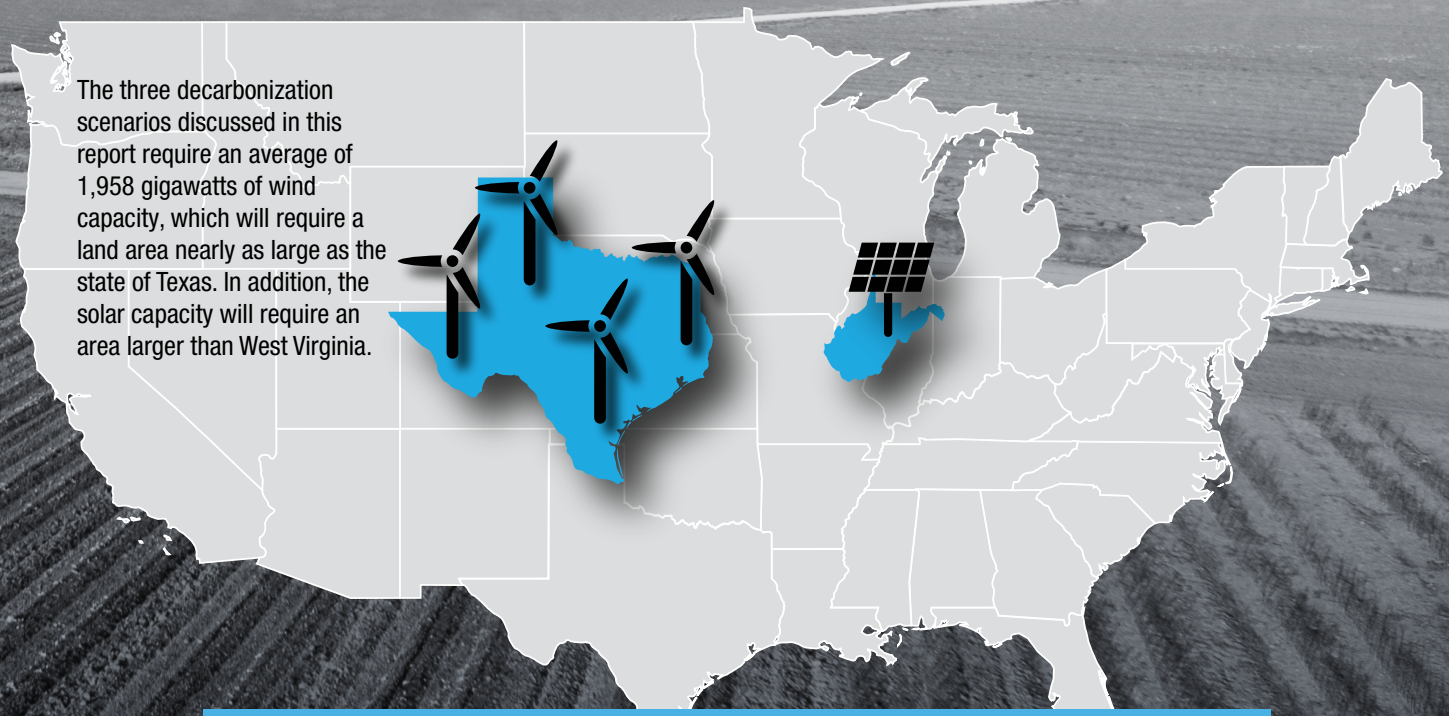
While solar energy uses two different technologies, wind energy relies on a single technology: turbines that stand up to 600 feet high and use large blades to convert the kinetic energy of the wind into electricity. Wind energy's land-use requirements have been well documented.

The U.S. Department of Energy (DOE) issued its Wind Vision Report in 2015 and found that "the average plant boundary for a land-based wind plant is 0.34 square kilometers per megawatt." Applying basic math, one sees that the capacity density of wind-energy projects is 2.94 watts per square meter, or 1 gigawatt per 131.3 square miles.[42] (The report provided a similar capacity density for offshore wind projects.)[43] In 2009, the National Renewable Energy Laboratory (NREL), which is part of the DOE, published similar numbers. In "Land-Use Requirements of Modern Wind Power Plants in the United States," the NREL finds that the "average area requirements" for wind energy are 34.5 hectares per megawatt of wind capacity, or 2.89 watts per square meter.[44] Still earlier, in 1993, researchers at the Pacific Northwest National Laboratory (PNNL) (also part of the DOE) arrived at a similar number. The PNNL determined that the areal power density, which is the amount of energy flow that can be captured from a given area in the best U.S. locations—coastal Oregon, the Dakotas, and the Great Plains—was 1.3 watts per square meter.[45] Since wind-energy facilities operate at roughly a third of their maximum rated capacity (known as their capacity factor), the PNNL figure implies a capacity density of about 3.9 watts per square meter.

Amanda S. Adams, a geoscientist at the University of North Carolina at Charlotte, and David W. Keith, an applied physicist at Harvard, corroborated these wind-energy estimates in a 2013 report published in *Environmental Research Letters*. In their study, "Are Global Wind Power Resource Estimates Overstated?" Adams and Keith point out that several estimates "have assumed that wind power production of 2 to 4 watts per square meter can be sustained over large areas." But in their analysis, Adams and Keith noted that wind turbines reduce the output of other turbines if they are placed too closely together, a problem known as "wind shadow."[46] They conclude that "it will be difficult to attain large-scale wind power production with a power density of much greater than 1.2 watts per square meter, contradicting the assumptions in common estimates of global wind power capacity." Moreover, for very large wind projects, power density "is limited to about 1 watt per square meter."[47] As we now see, wind-energy facilities operate at roughly a third of their design capacity. This means that a power density of 1 watt per square meter implies a capacity density of about 3 watts per square meter.

Vaclav Smil, a geographer at the University of Manitoba, has written extensively about the limitations of

The 1,958 gigawatts of wind capacity needed for 80 by 50 will require 257,129 square miles of surface area.



The three decarbonization scenarios discussed in this report require an average of 1,958 gigawatts of wind capacity, which will require a land area nearly as large as the state of Texas. In addition, the solar capacity will require an area larger than West Virginia.

The Land Requirements of Wind and Solar Energy in 80 by 50 Scenarios

renewable energy. In 2010, he wrote a "power density primer" in which he laid out the amount of energy that can be harnessed from various sources. Smil found that wind energy's power density ranges from 0.5 to 1.5 watts per square meter.[48] Taking the midpoint of those estimates provides a power density of 1 watt per square meter. Smil's figures imply a capacity density of 3 watts per square meter.

Finally, I have collected published data on more than 50 onshore wind projects in the U.S. and other countries. The total generation capacity for those projects—some already built and some only proposed—exceeds 13 gigawatts. The average capacity density for those projects is 2.97 watts per square meter. (See **Appendix A.**) That is essentially the same as the figure provided in the DOE's 2015 Wind Vision report.

Given the agreement of these sources that wind energy's average area requirement is about 3 watts per square meter, or 1 gigawatt per 131.3 square miles, one can calculate the footprint of wind energy in an all-renewable decarbonization scenario that aims to reduce emissions by 80% by 2050.

The 1,958 gigawatts of wind capacity needed for 80 by 50 will require 257,129 square miles of surface area.

VI. High-Voltage Transmission

A major expansion of renewable-energy generation will not only require a vast amount of space; it will also require a significant increase in high-voltage transmission capacity. New transmission lines will be necessary because the largest solar- and wind-energy resources are located far from urban areas, where electricity demand is highest.

High-voltage transmission lines are expensive. They can cost as much as $4 million per mile. They can also be controversial.[49] Rural residents across the U.S. have engaged in lengthy fights to stop construction of transmission lines through their regions. Monmouth County, New Jersey, is an example. Hundreds of residents there have come out in opposition to a 10-mile, 230-kilovolt transmission line.[50]

In Illinois, a group of residents sued to stop construction of the Grain Belt Express, a 780-mile transmission line designed to carry wind energy from Kansas to Missouri, Illinois, and Indiana.[51] The project has faced regulatory problems in Missouri.[52] In 2015, the Missouri Public Service Commission blocked the Grain Belt Express after concluding that the cost to the state's landowners exceeded its benefits.[53]

A group of Arkansas landowners sued in federal court in August 2016 to block the 720-mile Plains & Eastern Clean Line. It is a high-voltage transmission project intended to carry wind-generated electricity from the Oklahoma Panhandle to customers in Arkansas, Tennessee, and other states. The landowners claim that the project uses "federal eminent domain to condemn private property for the benefit of a private, for-profit company."[54]

New York is an example of the need for major increases in transmission capacity to accommodate renewables. The administration of Governor Andrew Cuomo is pushing the state's utilities to obtain 50% of its electricity from renewable sources by 2030. The New York Independent System Operator, the nonprofit agency that manages the state's grid, issued comments in July 2016 on the proposed increase in renewable production. The agency pointed

FIGURE 2.

Total Land-Use Requirements of Three Decarbonization Scenarios

	Solar surface area required (square miles)	Wind surface area required (square miles)	High-voltage transmission (square miles)	Total surface area required (square miles)
DDPP	13,250	164,125	–	–
WWS	34,005	325,624	–	–
CCTP	30,380	281,639	–	–
Average	**25,878**	**257,129**	**4,735**	**287,742**

Note: For consistency, the solar-related land-use figures for CCTP relied on the capacity-density figures that were calculated in this report.

out that about 90% of the new renewable-energy generation needed to meet the target will be located in upstate New York. Given the distance between the upstate generation sources and the population centers located in the southern and eastern parts of the state, the grid operator concluded that "nearly 1,000 miles of new bulk power transmission" will be needed over the next decade and a half.[55]

More than 3,000 miles of high-voltage transmission lines are now awaiting approval from state and federal authorities. The vast majority of that transmission (about 2,700 miles) is being built to accommodate new wind-energy capacity.[56] One of the biggest projects, the $3 billion, 730-mile TransWest Express, is designed to carry wind energy from the proposed Chokecherry–Sierra Madre wind project in Wyoming to Las Vegas.[57]

How much new transmission capacity would be required in an 80 by 50 scenario? In 2012, the NREL estimated that if the U.S. attempted to derive 90% of its electricity from renewable sources, it would have to double the country's high-voltage transmission capacity. The NREL report also said that achieving such a high percentage of renewable electricity would require thousands of miles of interconnections among the country's regional grids.[58] The U.S. currently has about 200,000 miles of high-voltage transmission capacity.[59] The NREL's findings imply that, to achieve 80 by 50, the U.S. would need to double that capacity, to about 400,000 miles.

But the NREL report focused only on the electric sector, which accounts for about 30% of U.S. greenhouse gas emissions. NREL estimated that obtaining 90% of the country's electricity with renewables would require doubling high-voltage transmission capacity. Therefore, it's reasonable to assume that attempting an 80% reduction in total greenhouse gas emissions, not just those from electricity production, would require much more than just doubling high-voltage transmission capacity.

Even doubling current capacity will prove challenging. Some of that new capacity could be added to existing utility easements. But installing 200,000 miles of new high-voltage transmission capacity will involve obtaining or condemning large amounts of land. Data from large electric utilities show that rights of way vary in width from 75 feet to 200 feet. This paper assumes that all 200,000 miles of new high-voltage transmission will require a right of way that is 125 feet wide.

The additional high-voltage transmission capacity needed for 80 by 50 using wind and solar energy will require obtaining or condemning about 4,735 square miles of land.[60]

VII. Growing Rural Opposition

Over the past decade, wind-energy capacity in the U.S. has grown about eight-fold, from about 9.2 gigawatts in 2005 to nearly 75 gigawatts in 2015. But not without controversy, as suburban and rural landowners from Maine to California have pushed back against the prospect of wind turbines as high as 600 feet in their neighborhoods.

Since January 2015, according to media reports, more than 100 government entities in some two dozen states have moved to reject or restrict the development of wind-energy projects. In 2015, more than 60 governmental entities in 22 states moved to reject or restrict wind-energy developments with a total capacity of some 3.1 gigawatts. During the first six months of 2016, more than 40 government entities in 18 states took similar steps regarding facilities with a total capacity of more than 2.4 gigawatts. (See **Appendix B**.) Some examples of efforts to restrict wind-energy development include:

- June 2016: In Pennsylvania, the Lehighton Water Authority rejected a proposal to install three wind turbines on its property. The turbines were planned as part of a 100-megawatt wind project proposed for the Pocono Mountains.[61]

- May 2016: In New York, the Town Board of Yates unanimously approved a six-month moratorium on wind-energy projects in the town.[62] Currently, the towns of Yates and Somerset, as well as three New York counties—Erie, Orleans, and Niagara—all oppose a 200-megawatt project called Lighthouse Wind.[63] The Niagara USA Chamber of Commerce also opposes the project.[64]

- July 2015: In California, the Los Angeles County Board of Supervisors voted unanimously in favor of an ordinance banning large wind turbines in the county's unincorporated areas.[65] During a hearing on the measure, Supervisor Michael D. Antonovich said, "Wind turbines create visual blight." He also said that the skyscraper-size turbines would "contradict the county's rural dark-skies ordinance, which aims to

protect dark skies in areas like Antelope Valley and the Santa Monica Mountains."[66]

Given widespread and growing opposition to the wind-energy projects now being proposed, it is nearly certain that attempts at a terawatt-scale expansion of wind capacity will be met with increasing resistance.

Solar projects also face resistance. In Vermont, more than three dozen towns have signed the Rutland Town Solar Resolution, which seeks more local control over the development of solar projects.[67] Town officials in Rutland began petitioning state authorities in 2015. They had spent a year drafting standards for new solar-energy projects, only to see those standards ignored by state regulators when it came time to approve a solar project in the town.[68] In 2014, New Haven, Vermont, rejected two proposed solar projects, which had a combined capacity of 7.1 megawatts.

VIII. Deep Carbonization Versus Wildlife

California's Ivanpah is the world's largest solar-thermal project. A 2015 report estimates that the 377-megawatt facility killed more than 3,500 birds during its first year of operation. It is one of a handful of such facilities that use thousands of mirrors to create intense heat that is then used to run boilers and create electricity.[69] In all, during its first year, the Ivanpah facility killed hundreds of birds from 83 species, as well as 32 bats.[70]

Large-scale solar facilities are running into opposition from conservation groups because of their potential effect on desert ecosystems. The opposition has been particularly intense in California, where conservationists are concerned about habitat for the desert tortoise, a long-lived, slow-reproducing reptile, as well as the Mojave fringe-toed lizard and other animals.[71] In August, San Bernardino County officials rejected a solar-energy project proposed for the Mojave Desert, citing concerns about bighorn sheep populations.[72]

While solar projects have had an impact on wildlife, wind-energy projects have been far deadlier. A peer-reviewed study in the *Wildlife Society Bulletin* in 2013 estimates that U.S. wind turbines killed about 888,000 bats and 573,000 birds in 2012. The bird kills include some 83,000 raptors.[73]

Top raptor biologists at the U.S. Fish and Wildlife Service, in a 2013 paper in the *Journal of Raptor Research*, reported that the number of eagles being killed by wind turbines has increased dramatically, going from two in 2007 to 24 in 2011. During that period, wind turbines killed 85 eagles, including six bald eagles. That figure, according to Joel Pagel, the report's lead author, was "an absolute minimum."[74]

The Pagel study shows that adding more U.S. wind capacity contributes to eagle kills. In 2007, the U.S. had about 17 gigawatts of installed capacity. By 2011, that figure nearly tripled, to about 47 gigawatts.[75] Over that period, the number of documented eagle kills increased by a factor of 12. Pagel's study was published a few months after the Fish and Wildlife Service issued a report concluding that "there are no conservation measures that have been scientifically shown to reduce eagle disturbance and blade-strike mortality at wind projects."[76]

Federal law protects nearly all domestic species of birds under the Migratory Bird Treaty Act. Under the 1918 law, it is a federal crime to kill more than 1,000 different bird species. Yet the federal government has shown reluctance to prosecute wind-energy companies in connection with bird deaths. The government has also been reluctant to prosecute wind-energy companies under the Bald and Golden Eagle Protection Act.

The U.S. Fish and Wildlife Service in mid-2016 proposed an extension on the length of permits for accidental eagle kills currently permitted for the wind industry and other entities. The proposal would extend the permit from the current five years to 30 years. The changes would allow wind-energy producers to kill or injure as many as 4,200 bald eagles every year. The agency estimates that there are about 72,434 bald eagles in the continental U.S.

Wind turbines are also deadly to bats. Bat Conservation International says that bats are now "being killed in alarming numbers at many wind energy facilities around the world." As many as 1.3 million bats may have been killed by wind turbines in 2012 alone, and wind-energy projects are negatively affecting 23 of the 45 bat species found in the U.S. and Canada, according to the group.[77]

The U.S. Geological Survey (USGS) has concluded that the "widespread deployment of industrial wind

turbines is having unprecedented adverse effects on certain species of bats that roost in trees and migrate." An article on the USGS website explains: "Bats are beneficial consumers of agricultural insect pests and migratory species of bats provide free pest-control services across ecosystems and international borders." It continues: "Bats are being found beneath wind turbines all over the world. Bat fatalities have now been documented at most wind facilities in the U.S. and Canada and it is estimated that tens to hundreds of thousands die at wind turbines in North America each year."[78]

Two USGS scientists, Thomas J. O'Shea and Paul M. Cryan, are the lead authors of a January 2016 paper in *Mammal Review*. They determined that wind turbines are now the largest cause of mass bat mortality and exceed the toll taken by white-nose syndrome, a fungal disease that afflicts bats.[79] Cryan told *Scientific American* in June that the wind industry's toll on bat populations could have long-term negative effects. "Bats are long-lived and very slow reproducers," he said. "Their populations rely on very high adult survival rates. That means their populations recover from big losses very slowly."[80]

The deleterious effect of wind turbines on bat populations was further confirmed in July 2016, when Bird Studies Canada, a conservation group, released a report on wind energy. According to the study, "across Canada, bat fatalities were reported more often than birds, accounting for 75% of all carcasses found." The report estimates that wind turbines in Ontario alone killed about 42,656 bats between May 1 and October 31, 2015, and each wind turbine had killed about 18 bats over that time frame.[81] The bat fatalities in Ontario included several species of rare or endangered bats, such as the little brown bat and northern long-eared bat. The report also finds that wind turbines in Ontario killed 462 raptors over the six-month period.[82]

Separately, wind turbines are causing greater than expected mortality to bats in Hawaii. The now-bankrupt company SunEdison asked the state for permission in 2015 to increase the number of endangered Hawaiian hoary bats that can be accidentally killed by the company's wind turbines.[83]

While bats are not as popular among the general public as eagles, they play an important role in ecosystems as pollinators and insectivores. In Texas alone, economists have estimated that bats save the state more than $1 billion annually in spending on pesticides.[84]

It's not clear how much wind-energy capacity will be added to the U.S. grid over the coming decades, but deep carbonization means that many more birds and bats will be killed by wind turbines. In 2012, the wind industry was estimated to be killing 888,000 bats and 573,000 birds. That year, the U.S. had about 60 gigawatts of installed wind capacity.[85] Thus, each gigawatt of wind capacity killed about 14,800 bats and 9,550 birds, of which some 1,383 were raptors.

If the U.S. increases its wind capacity to 1,958 gigawatts, wind turbines potentially could kill as many as 28.9 million bats yearly. Bird kills could be as high as 18.7 million yearly, of which some 2.7 million would be raptors.

Of course, these numbers are only theoretical. Still, bat and bird species may not be able to sustain mortality impacts of that magnitude without seeing significant declines in their overall populations.

IX. Conclusion

The U.S. will need about 1,958 gigawatts of wind capacity if it hopes to reduce its emissions by 80% by 2050. *Global* wind capacity currently stands at about 435 gigawatts.[86] In other words, 80 by 50 means that the U.S. will have to install four to five times as much wind capacity as now exists on the planet. Adding 1,883 gigawatts of new wind—on average, about 55 gigawatts of new wind capacity each year—will be difficult to achieve, considering that during the nation's record year for wind-energy deployment in 2012, the U.S. installed about 13 gigawatts.[87]

Similar challenges are likely if the U.S. attempts to ramp up solar capacity from the current level of 26 gigawatts to the 2,441 gigawatts outlined in this report. Such an increase would be 92 times the amount of current U.S. solar capacity and 10 times more than current global solar capacity.[88]

While the industrial challenges inherent in an extreme energy makeover are clear, the fundamental problem with an all-renewable decarbonization scenario is land use. For decades, environmental groups have championed small footprints from urban living to farming. But now, in the name of

climate change, some of America's most prominent environmental groups and climate-change activists are promoting a policy that will result in massive energy sprawl.

Setting aside a surface area the size of Texas and West Virginia for the sole purpose of decarbonization will surely result in even greater resistance from rural residents who see little benefit but plenty of costs, including the despoliation of their viewsheds and waterfronts. Add in the need for hundreds of thousands of miles of new high-voltage transmission lines, and the potential friction of the all-renewable 80 by 50 effort is clear.

In addition to the impact on people and land, a massive expansion of wind and solar capacity will have a huge negative effect on wildlife, including iconic species like the bald and golden eagle as well as numerous species of rare and endangered bats. If large-scale cuts in carbon-dioxide emissions are to be pursued, the only energy sources with relatively small footprints that can provide large volumes of low- or zero-carbon energy at reasonable cost are natural gas and nuclear.

APPENDIX A.

Capacity Density Data for Onshore Wind Projects*

Project	Location	Capacity in Megawatts	Project Area	Area covered in m^2	Capacity Density (W/m^2)
Roscoe Wind	TX	781.5	100,000 ac	400,000,000	1.95
Waubra	Australia	192	173 km^2	173,000,000	1.11
Langford Wind	TX	150	35,000 ac	141,640,000	1.06
Los Vientos	TX	200	30,000 ac	121,400,000	1.65
Flat Ridge 1	KS	50	5,000 ac	20,200,000	2.48
Flat Ridge 2	KS	410	66,000 ac	267,000,000	1.54
Chokecherry and Sierra Madre	WY	3,000	219,707 ac	889,154,229	3.37
Capital Wind Farm	Australia	141	35 km^2	35,000,000	4.03
Snowtown Wind Farm	Australia	99	12,000 ha	120,000,000	0.83
Ripley Wind Power Project	Canada	76	3,600 ha	36,000,000	2.11
Erie Shores Wind Farm	Canada	99	5,260 ha	52,600,000	1.88
Greenwich Wind Farm	Canada	99	10,000 ac	40,468,000	2.45
Kingsbridge I Wind Project	Canada	40	1,000 ha	10,000,000	4.00
Melancthon I Wind Plant	Canada	67.5	2,500 ha	15,000,000	4.50
Sherbino 1 Wind Project	TX	150	10,000 ac	40,468,000	3.71
Sherbino 2 Wind Project	TX	150	20,000 ac	80,900,000	1.85
Mehoopany Wind Farm	PA	144	9,000 ac	36,421,000	3.95
Pine Tree Wind	CA	120	8,000 ac	32,375,000	3.71
Stark County	ND	150	39,000 ac	157,833,000	0.95
Pleasant Ridge	IL	250	58,300 ac	235,931,000	1.06
Golden West	CO	250	25,000 ac	101,100,000	2.47
Mills Branch Wind	MD	100	5,000 ac	20,200,000	4.95
Chapman Ranch	TX	200	20,000 ac	80,900,000	2.47
Ocotillo Wind	CA	265	12,500 ac	50,587,000	5.24
Shepherd Flat	OR	845	32,100 ac	129,908,000	6.50
Notrees Wind	TX	153	17,000 ac	68,799,000	2.22

Capacity Density Data for Onshore Wind Projects

Midway Farms	TX	160	16,000 ac	64,752,000	2.47
Horse Hollow	TX	735	47,000 ac	190,209,000	3.86
Hallam Wind	NE	124	11,000 ac	44,517,000	2.79
Shirley Wind	WI	20	500 ac	2,023,000	9.89
Butler County	NE	200	33,000 ac	133,550,000	1.50
Cottonwood Wind	NE	89.5	9,000 ac	36,400,000	2.46
Steele Flats	NE	74.8	10,500 ac	43,700,000	1.71
Perquimans County	NC	300	15,000 ac	60,700,000	4.94
Boone County	IL	200	12,000 ac	48,560,000	4.12
Amazon Wind	NC	208	22,000 ac	89,000,000	2.34
Origin Wind	OK	150	18,000 ac	72,840,000	2.06
Lighthouse Wind	NY	201	20,000 ac	80,940,000	2.48
Black Oak	NY	16.1	1,000 ac	4,047,000	3.98
Blue Sky Green Field	WI	145	10,600 ac	42,890,000	3.38
Shiloh Wind	CA	150	6,800 ac	27,519,600	5.45
Smoky Hills	KS	250	20,000 ac	80,940,000	3.09
Pioneer Prairie II	IA	102.3	10,000 ac	40,468,000	2.53
Searchlight	NV	200	18,949 ac	76,686,603	2.61
Thumb Wind Park	MI	110	15,000 ac	60,705,000	1.81
Spring Valley Wind	NV	151.8	7,680 ac	31,080,960	4.88
Rush Creek	CO	600	90,000 ac	364,230,000	1.65
Enchanis	OR	104	10,500 ac	42,493,500	2.45
Scioto	OH	225	17,000 ac	68,799,000	3.27
Gratiot	MI	212.8	30,000 ac	121,410,000	1.75
Echo Wind Park	MI	112	16,000 ac	64,752,000	1.73
Total		**13,023.3**		**5,250,096,892**	**2.97**

Results: 50 projects with total capacity of 13 GW. Average capacity density: 2.97 W/m^2

*Excel file with links to project data at robertbryce.com

APPENDIX B.

Government Entities That Moved to Reject or Restrict Wind Projects in 2015*

Date	State	Entity	Government	Notes	Capacity (MW)
2/10/15	AL	Cleburne County	County	Cleburne County Commission passed regulations on setbacks and noise, including 2,500 feet from adjacent property and a 40-decibel limit. Regulations were passed after sustained opposition to a proposed wind project on Turkey Heaven Mountain. Project is for up to 30 turbines, therefore, estimated capacity is 60 megawatts.	60
7/14/15	CA	LA County	County	Board of Supervisors voted unanimously to ban wind turbines in county's unincorporated areas.	
8/2/15	IA	Buchanan County	County	Buchanan County Zoning and Planning Commission denied a permit for Optimum Renewables' 3-turbine wind project.	
8/26/15	IA	Black Hawk County	County	County Board of Adjustment voted 5-0 to reject a special permit and setback variance for a 3-turbine wind project. The project had previously been turned down in Fayette and Buchanan counties.	6
11/25/15	IA	Fayette County	County	County supervisors imposed a 6-month moratorium on new wind projects.	
7/17/15	IL	Livingston County	County	Livingston County Board denies Invenergy's application for a permit for a wind project.	250
11/18/15	IL	Boone County	County	Boone County Board voted 9-3 to require all wind turbines be a minimum of 2,640 feet from a property line.	200
7/6/15	IN	Wells County	Wells County Area Plan Commission	The Area Plan Commission recommended that no large wind turbines be allowed in Wells County.	
9/11/15	IN	Rush County	County	Ended negotiations with wind developer.	180
10/22/15	KS	Douglas County	County	County commissioners extend a moratorium on new wind projects for an additional six months so the county can develop better regulations.	
12/1/15	MA	Bourne	Town	Board of Selectmen unanimously approved health officials' request to seek legal action to stop a four-turbine wind project in South Plymouth due to concerns about adverse health effects.	8
11/14/15	MD	Allegany County	County	The Board of Zoning Appeals voted unanimously to deny variances for a 17-turbine wind project on Dan's Mountain.	47
3/24/15	MD	Kent County	County	County commissioners reject a 49-turbine project being pushed by Apex Clean Energy.	100
11/17/15	ME	Freedom	Town	A 40-page ordinance enacts numerous regulations on wind turbines.	
6/9/15	ME	Dixfield	Town	Town voters approve a new ordinance on wind turbines that sets limits on noise, setback (4,000 feet from any occupied building), and flicker.	
6/19/15	ME	Department of Inland Fisheries and Wildlife	State	Department of Inland Fisheries and Wildlife announced it would oppose the Weaver Wind project based on its potential impact on birds and bats. Two months later, SunEdison, the developer of the project, withdrew its application for the project, which had been pending at the Maine Department of Environmental Protection.	76
12/3/15	ME	Maine Supreme Court	State	The court ruled that the state environmental appeals board acted within its power in denying SunEdison's proposed 16-turbine Bowers Mountain wind farm. The court agreed that the project would have "an unreasonable adverse effect on the scenic character" of several lakes that have been deemed scenic resources of the state.	48
9/18/15	ME	Fort Fairfield	Town	Passed restrictive law with a one-mile setback.	
11/11/15	MI	Huron County	County	County Commissioners approve an ordinance setting stricter rules on turbines.	
6/26/15	MI	Mason County	County	After lawsuits, an ordinance enacts restrictions.	
6/23/15	MI	Moore	Township	Weak ordinance passed by township was challenged by residents and heads to a referendum vote in MI. For now the project is stalled. Moore is one of four townships that will have turbines.	
6/19/15	MI	Bengal	Township	Passed restrictive zoning under police powers authority. The courts initially overruled the ordinance. The township is still deciding its next steps.	64
6/19/15	MI	Essex	Township	Passed restrictive zoning under police powers authority. The courts initially overruled the ordinance saying that only the planning board could pass laws governing land use. The ordinance was revised to focus on noise.	

6/19/15	MI	Dallas	Township	Passed restrictive zoning under police powers authority. The courts initially overruled the ordinance (see Essex). The township has since passed interim zoning that restricts tower height to 380 feet.	
5/6/15	MI	Meade	Township	Referendum vote voided a decision by the town board to create a wind-overlay district.	100
3/16/15	MI	Ogden	Township	Town board passed 6-month moratorium.	
7/17/15	MO	Clinton County	County	The county Planning and Zoning Commission denies a request by NextEra Energy to put up meteorological testing towers in the Northern part of the county.	200
10/1/15	NC	Bald Head Island	Governing board	Bald Head Island governing board adopted a resolution opposing wind turbines located within 24 nautical miles of shore. The resolution says "wind turbines located within the Bald Head Island viewshed would transform our community's natural and historic vista of open ocean to a view of massive industrial machinery...Such a change would represent for us the most destructive commitment of ocean resources that we have ever heard proposed in North Carolina – one that could irreversibly damage the natural environment and resources that we cherish and that drive our economy."	
10/5/15	NC	Perquimans County	County	County commissioners imposed a four-month moratorium on a wind project after a surge in local opposition.	300
6/30/15	ND	Williams County	County	County Planning and Zoning Commission voted 4-1 to deny a permit for a proposed wind project.	150
5/5/15	ND	Stark County	County	County commissioners rejected a permit for a NextEra project with 87 turbines.	150
12/30/15	ND	Stark County	County	County commissioners voted unanimously to impose a two-year moratorium on applications for new wind projects.	
9/17/15	NE	Linwood	Township	Residents voted overwhelmingly in favor of regulations restricting high-voltage power lines on township property, as well as noise limits on turbines, and minimum setbacks of 1640 feet from township roads and private property not associated with the wind project.	200
9/8/15	NE	Franklin	Township	Township residents voted against allowing wind-energy development.	
9/8/15	NE	Savannah	Township	Township residents voted against allowing wind-energy development.	
9/8/15	NE	Skull Creek	Township	Township residents voted against allowing wind-energy development.	
9/16/15	NE	Oak Creek	Township	Township residents voted against allowing wind-energy development.	
9/8/15	NE	Richardson	Township	Township residents voted against allowing wind-energy development.	
11/10/15	NE	Lancaster County	County	County commissioners approved noise and setback regulations aimed at halting the Hallam Wind project.	74
3/16/15	NH	Alexandria	Town	Town voted against the Spruce Ridge Wind Project in Grafton County. Passed various local laws to restrict wind-energy projects.	60
3/16/15	NH	Dorchester	Town	Town voted against the Spruce Ridge Wind Project in Grafton County. Passed various local laws to restrict wind-energy projects.	
3/16/15	NH	Grafton	Town	Town voted against the Spruce Ridge Wind Project in Grafton County. Passed various local laws to restrict wind-energy projects.	
3/16/15	NH	Groton	Town	Passed restrictive law. This ordiance passed overwhelmingly after town has had to deal with the turbines.	
3/16/15	NH	Orange	Town	Passed various laws to restrict wind-energy projects.	
3/13/15	NH	Danbury	Town	Passed various local laws to restrict wind-energy projects.	
12/3/15	NH	Site Evaluation Committee	State	The Site Evaluation Committee passed final rules on the siting of energy projects that include strict rules on wind-energy projects.	
11/6/15	NV	Federal Judiciary	U.S. District Cout	U.S. District Court halted an 87-turbine wind project after determining that a Bureau of Land Management (BLM) environmental study of the project, to be built in the Mojave Desert, had gaps. The project aims to install 87 turbines on 18,949 acres of BLM land. Total capacity: 200 MW	87
11/2/15	NV	Searchlight	U.S. District Court	Judge Miranda Du vacated the federal permits for construction of the Searchlight Wind Project in Southern Nevada. Judge Du found that environmental analyses prepared by the BLM and U.S. Fish & Wildlife Service inadequately evaluated the dangers that the industrial-scale wind project would pose to desert wildlife.	200
6/9/15	NY	Burke	Town	Town Board approves a local law on setbacks from wind turbines.	
7/13/15	NY	Catlin	Town	Officials approve regulations on setbacks, noise, and compensation in case of reduced property values.	

8/30/15	NY	Niagara County	County	The county Legislature has gone on record as opposing the Lighthouse wind project.	
12/3/15	NY	Niagara County Board of Health	County	The Board of Health votes to ask Albany for a full environmental review of the Lighthouse wind project.	
7/8/15	NY	Somerset	Town	Town board voted to oppose the proposed Lighthouse wind project.	200
7/28/15	NY	Henderson	Town	Town officials went on record as opposing Hudson Energy's proposed wind project on Galoo Island.	102
12/16/15	NY	Orleans County	County	Orleans County legislators voted to oppose the Lighthouse Wind project that is proposed near Yates and Somerset. Legislators voted to oppose the project which they said would "place commercial wind turbines within this quaint, beautiful Town of Yates."	
12/17/15	NY	Erie County	County	The legislature of Erie County adopted a resolution opposing the "construction of wind turbines" in the flight path of the Niagara Falls Airforce Reserve Station. The resolution specifically names Apex Energy and is clearly aimed at Lighthouse Wind.	
12/2/15	OK	Osage Tribe	Tribe	The Osage Tribe has been fighting a wind project pushed by Enel for years. After inaction by the Department of Interior, the tribe is seeking to intervene in a lawsuit that will halt what it calls a "significant invasion" of its property. The project has 84 turbines. Principal Chief Geoffrey StandingBear called the wind project "a harsh form of pollution, and it should go away."	150
11/28/15	PA	Luzerne County	County	Luzerne County Court denied an appeal by EDF Renewables, which wanted to overturn the finding of the Foster Township Zoning Hearing Board, which refused to issue a permit for the company's 15-turbine project.	50
7/21/15	SD	Lincoln County	County	Lincoln County Commissioners denied appeal by a company called Dakota Power Community Wind, which was seeking permission for meteorological towers to study wind energy. The permit for the met towers had previously been denied by the county's zoning board. "The population in south Lincoln County does not support wind energy by a majority of 4 to 1," said Winnie Peterson, chair of We-Care South Dakota.	
3/26/15	VT	Northeastern Vermont Development Association	Essex, Caledonia and Orleans counties, 55 towns	"After discussion, the Board of Directors unanimously approved the Executive Committee's recommendation for no further industrial – scale wind development in the Northeast Kingdom." The development association covers 21% of Vermont's land area and represents 55 communities.	
6/16/15	VT	Rutland Regional Planning Commission	27 towns in Rutland County	Adopted the Rutland Regional Plan, which delineates rules on everything from biomass to wind energy. Wind turbines must have setbacks of 1 mile per megawatt of capacity from any habitable structure.	
11/18/15	VT	Swanton	Town	Town voted 731-160 against the Rocky Ridge wind project, which aims to put seven 499-foot-high turbines in the town.	20
12/15/15	VT	Fairfield	Town	Town selectboard voted to oppose Rocky Ridge Wind Project and sent a letter to VT Governor Peter Shumlin, to let their position be known.	
9/10/15	WI	Forest	Town	Town announced that its legal fight against the Highland Wind Farm will continue, saying that the St. Croix Circuit Court ordered the Public Service Commission of Wisconsin to hold further hearings before approving the construction of the project. The town's press release said "The Town has long fought and will continue to oppose the Highland Wind Farm project, which would place 42 500-foot tall wind turbines close to homes."	102
Total Megawatts					**3118**

Results: 19 of the 21 states are producing wind energy.
Notes: Some 65 governmental entities in 22 states moved to ban or restrict wind projects in 2015. The entities include 30 towns and 27 counties. Some projects were rejected by several towns or countries. Also, planning and development authorities covering 82 additional towns in VT moved to reject wind-energy projects.

Government Entities That Moved to Reject or Restrict Wind Projects in 2016

Date	State	Entity	Government	Notes	Capacity (MW)
1/15/16	VT	State Senate		Two Democratic senators file a bill that would prohibit wind projects in the state.	
2/2/16	MA	Bourne	Town	Town of Bourne filed lawsuit against Future Generation Wind, owned by ConEdison, in an effort to stop the project.	8
2/9/16	SD	Davison County	County Commission	Commission voted to deny a permit for a 9-11 turbine project costing $40 million.	20
1/14/16	NY	Yates	Town Board	Board goes on record officially opposing Lighthouse Wind with a unanimous vote, saying the project would be aesthetically negative and that the noise could harm the health of local residents.	
1/27/16	NY	Niagara County Planning Board Somerset	County	The Niagara County Planning Board approved two zoning amendments for the town of Somerset that set strict standards for wind-energy development. The rules are aimed at the Lighthouse Wind project.	
2/24/16	NY	Somerset	Town Board	The Town Board approved a law amending the zoning code that restricts wind turbine development so that no wind turbine can be placed withing 1,500 feet of any residential boundary line. It also restricts noise levels to no more than 35 db-A from 8 p.m. to 7a.m. A wind energy promoter said the new law was effectively a ban on wind projects. The rules are aimed at stopping the Lighthouse Wind project.	200
3/8/16	MD	Allegany County	County	The county filed a petition with the state Public Service Commission to stop a wind project on Dan's Mountain. The move was made after the developer, Dan's Mountain Wind Force LLC, tried to circumvent a December move by the Allegany County Board of Zoning which denied variances for the project.	47
3/9/16	MI	Elmwood Township	Town	The township, located in Tuscola County, enacted a 1-year moratorium on wind turbine construction to "better protect the public health, safety and welfare" of residents."	
3/3/16	MI	Marion Township	Town	The township approved a moratorium that halts any new wind projects for six months. The township is among the sites Exelon is considering for a wind project.	
3/8/16	MI	Argyle Township	Town	Town held a referendum on its wind ordinance, which was voted down 161-139. At issue is a proposed wind project by Invenergy, which wants to build wind turbines on 25,000 acres in Moore, Argyle, Lamotte, and Wheatland townships.	200
3/8/16	MI	Wheatland Township	Town	Town held a referendum on its wind ordinance, which was voted down 105-60. At issue is a proposed wind project by Invenergy, which wants to build wind turbines on 25,000 acres in Moore, Argyle, Lamotte, and Wheatland townships.	
3/8/16	NH	Canaan	Town	Voters approved a warrant article by a margin of 413-225 at a town meeting on March 8. The vote is aimed at stopping the Spruce Wind project being pushed by EDP. All five NH towns that have been targeted for the Spruce Wind project—Alexandria, Canaan, Dorchester, Groton, and Orange, have voted to reject the project.	60
3/8/16	NH	Orange	Town	In January, the Orange Planning Board unaminously appoved a restrictive wind ordinance. It was added to the March warrant for the March 8 meeting. The ordinance restricts noise to not exceed 33 dbA, anywhere, at any time on a non-participating property.	
3/16/16	MI	Lincoln Township	Town	On March 16, the Lincoln Township Board sent a letter to the Huron County Commission saying it was officially opposed to a proposed DTE wind project. The letter, signed by all board members, has two sentences: "We feel that Huron County has done our part as far as Green Energy. We feel that no additional turbines should be allowed in Huron County."	125
3/29/16	NY	Randolph	Town	The Randolph Zoning Board of Appeals unanimously rejected a permit application for a meterological tower that was being sought by Iberdrola Renewables.	
3/30/16	NE	Gage County	County	Gage County Board of Supervisors strengthened commercial wind-energy regulations by lowering noise limits to 45 decibels in the day and 40 db at night. Setbacks were also increased to 3/8 of a mile from non-participating residences.	
4/2/16	MI	Huron County	County Board of Commissioners	The board voted 4-3 in favor of a zoning ordinance that halts all wind-energy development for 90 days or until a new ordinance can be passed.	
4/4/16	MI	Ellington	Township	The Ellington Township Board of Trustees enacted a four-month moratorium on wind turbines at a special meeting. The move puts the Tuscola III wind farm project on hold.	100

4/14/16	NY	Newfield	Town	Town Board approved a 90-day moratorium on new wind projects.	16
4/14/16	MA	Falmouth	Zoning Board of Appeals	The town's Zoning Board of Appeals rejected a special permit for one of two municipally owned wind turbines. "The majority of its members found fault with the town's application on more than one point, including a zoning requirement that the turbine known as Wind 1 not have "adverse effects" on either the neighborhood or the town." Noise from the turbines has been a source of controversy in the town for years and neighbors of the turbines have repeatedly complained about the noise. In May, the town announced it was filing a lawsuit against its own zoning board over the decision.	
4/15/16	NY	Orleans	Town	Town board voted to approve a six-month moratorium on wind projects after Iberdrola proposed a wind project in the town.	200
4/26/16	NY	Jefferson County	Planning Board	The Planning Board voted to recommend that Clayton Town Board extend its proposed moratorium on wind projects from six months to one year.	
4/27/16	NY	Clayton	Town Council	Council adopted a six-month moratorium, called Local Law No. 2, on meterological towers as well as applications for wind-energy facilities.	96
5/2/16	NY	Orleans County	Planning Board	The Orleans County Planning Board expressed official support for the six-month moratorium on wind-energy projects requested by the Town of Yates.	
5/9/16	ME	Maine	Land Use Planning Commission	The commission voted to remove 13 townships and plantations from the expedited permit area.	
5/11/16	NY	Hartsville	Town Board	The Town Board denied variances to its wind law that had been requested by NextEra Energy. It also unanimously approved a resolution declaring it was "not a willing host" for the Eight Point Wind Project "or any other wind energy facility" that doesn't comply with the town's rules.	103
5/12/16	NY	Yates	Town Board	The Town Board unanimously approved a six-month moratorium on wind-energy projects. The move is the latest effort by the town in its fight against Apex Clean Energy and the Lighthouse wind project.	
5/16/18	RI	North Smithfield	Town Council	The Town Council passed an ordinance that places a moratorium on the creation of turbines.	1.5
5/24/16	MI	Sanilac County	County Judge	A county judge sided with the Bridgehampton Township Planning Commission which tabled a public hearing on Exelon's application for a special land use permit for its planned Michigan Wind 3 project.	153
5/27/16	IN	Rush County	County Superior Court	Special Rush Superior Court Judge Matthew D. Bailey ruled May 27 to let the July 2015 decision, by the Rush County Board of Zoning Appeals, to approve special exception permits for the construction of wind turbines for the proposed Flat Rock Wind project stand, despite claims from APEX Clean Energy—the company behind the project—that the BZA overstepped its authority in stipulating that the setback distance for those turbines would have to be 2,300 feet from non-participating property lines, instead of 1,000 feet.	180
5/31/16	MD	Allegany County	County Commission	The commissioners filed a motion with the Maryland Public Service Commission to dismiss a Dan's Mountain Wind Force request for a required certificate for a 17-turbine wind farm project on Dan's Mountain.	47
6/1/16	OR	Federal Judiciary	Ninth Circuit Court of Appeals	The court ruled that the Bureau of Land Management did not adequately address the threats to the sage grouse from a proposed wind project.	104
6/5/16	VA	Rockbridge County	Board of Supervisors	The board, in a letter sent to state regulators, raised concerns about an industry that it says would sit just beyond its control while affecting its residents, environment and economy.	75
6/8/16	ME	Maine	Land Use Planning Commission	The commission voted to remove 14 townships and plantations from the area, where environmental reviews of wind projects are fast-tracked to encourage development: Cathance, Concord, Edmunds, Long Pond, Mason, Misery Gore, Molunkus, Salem, Sapling and Sapling Administrative Area 1 townships; Denniston, Pleasant Ridge and Rangely plantations; and Taunton & Raynham Academy Grant. "Committee members say wind development in those areas would detract from land value, spoil viewsheds and disrupt the tourism industry around the lake."	
6/9/16	TN	The City of Crossville	City Council	The City Council voiced opposition to a wind farm on Millstone Mountain in Cumberland County near Crab Orchard being proposed by Apex Renewable Energy.	71

6/9/16	SD	Letcher Township	Board of Supervisors	The township adopted an ordinance to establish a 1-mile setback for any turbine larger than 75 feet tall. Under the approved ordinance, no large wind energy system could be built within 5,280 feet of the nearest residence of a non-participating homeowner, or within 1,500 feet of the nearest neighbor's property line. Of the 77 registered voters living within township limits, 50 signed a petition stating their opposition to the Juhl Energy project, which was to have nine to 11 turbines.	
6/13/16	VT	Windham	Selectboard	The board sent a letter asking wind developer Iberdrola to stop a 96-megawatt wind project.	96
6/14/16	OH	Rushcreek Township	Township Trustees	Township trustees adopted a resolution in opposition to the EverPower plan to build wind project in Logan County.	225
6/15/16	OH	Logan County	County Commission	County commissioners voted unanimously to reject EverPower's request for a payment in lieu of taxes to build 18 wind turbines in northern Logan County. The project is called Scioto Farm. After the county's move, EverPower said they will not locate any turbines in Logan County.	
6/16/16	PA	Lehighton	Water Authority	The Lehighton Water Authority rejected Iberdrola's proposal to build three wind turbines, a small piece of a larger 100-megawatt wind energy project proposed to be built on nearby land surrounding Bethlehem's drinking water in Penn Forest Township.	100
6/19/16	IN	Henry County	Planning Commission	The commission denied two requests from Apex Clean Energy to build towers in the southern part of the county to gather wind data.	180
6/21/16	NC	State	Senate	Lawmakers passed a bill that would prohibit wind farms from being built in most of central and eastern North Carolina.	
6/23/16	ME	Woodstock	Board of Selectmen	The board voted to sign a letter of support asking the Maine Land Use Planning Commission in Bangor to remove Milton Township from the state's expedited permitting area for wind energy development.	
7/20/16	NE	Cherry County	Planning Commission	The commission recommended against approving a conditional use permit for a potential wind farm in the county.	
8/2/16	MI	Marion Township	Referendum	Residents vote to stop the development of a 24-turbine project called Michigan Wind 3 owned by Exelon.	153
8/22/16	NH	Stoddard	Board of Selectmen	The board voted to oppose a proposed 9-turbine wind project in nearby Antrim.	28.8
Total megawatts					**2,589.3**

Results: 47 Entities in 18 states. (This tally doesn't include the 45 entities in Maine that have requested to be excluded from the state's expedited siting program.) Total wind capacity at issue: 2.5 gigawatts.
*Excel file with links to sources at robertbryce.com

Endnotes

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3 Bill McKibben, "A World at War," *The New Republic*, Aug. 15, 2016.

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5 James H. Williams et al., "Pathways to Deep Decarbonization in the United States," Energy and Environmental Economics, Inc., Revision with technical supplement, Nov. 16, 2015. In the Pathways report, for vehicular data, see p. xiv and fig. 17. For projected 2050 energy demand, see p. 19 and fig. 8. In 2014, U.S. energy consumption totaled about 98 quads, or 103 exajoules. The DDPP projects that by 2050, U.S. energy needs will total 55 exajoules.

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13 "Letter to Governor Cuomo from 112 Groups Opposing Nuclear Subsidies in NY," Alliance for a Green Economy, June 30, 2016.

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24 Williams et al., "Pathways to Deep Decarbonization in the United States." The DDPP report assumes a 2015 baseline for decarbonization. At that time, U.S. emissions totaled 5.5 billion tons. In 1990, those emissions totaled 5.1 billion tons.

25 Mark Z. Jacobson, et al., "100% clean and renewable wind, water and sunlight (WWS) all sector energy roadmaps for the 50 United States," *Energy and Environmental Science* . . . http://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf

26 "Energy Plan," Bernie Sanders Presidential Campaign.

27 See Stanford Group Postings Blog for a list of Jacobson's publications on WWS. The spreadsheet discussed in the 2015 report with details by state is also posted online by Stanford. On the spreadsheet, look for the tab labeled "Intermediate details by state."

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32 For an EPA discussion of greenhouse gas emissions, see "Sources of Greenhouse Gas Emissions."

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[35] The U.S. gigawatt solar capacity figure in this analysis can be confirmed by looking again at the WWS scenario, which requires a total of 3.2 terawatts of solar capacity.

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In September 2016, the DOE reduced its capacity density for offshore wind projects from 5 W/m^2 to 3 W/m^2; see "National Offshore Wind Strategy: Facilitating the Development of the Offshore Wind Industry in the United States." On p. 9, the report states that it is lowering the capacity density estimate for offshore wind projects "from 5 MW/square kilometer (km^2) to 3 MW/km^2 to adjust for greater array spacing."

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REPORT 21

Abstract

Politicians from federal to local levels have joined in a pledge known as 80 by 50, an effort to cut carbon-dioxide emissions 80% by 2050. The pledges are long on fanfare but short on details. There is, however, a published literature that determines how to achieve so-called deep carbonization, and it involves a massive increase of renewable-energy sources, primarily wind and solar.

This report analyzes the extraordinary amount of land that would be needed to achieve 80 by 50 through wind and solar, the amount of additional high-voltage transmission capacity, and the growing resistance to local wind-energy projects. It also looks at what all this means for the populations of birds and bats, including endangered species.

Key Findings

1. Relying on wind and solar energy to achieve an 80% reduction in carbon-dioxide emissions will require installing energy infrastructure over 287,700 square miles, a surface nearly as large as Texas and West Virginia combined. It also will require adding at least 200,000 miles of new high-voltage transmission lines, roughly double the existing capacity.

2. The U.S. would have to install about 1,900 gigawatts (1 gigawatt is equal to 1 billion watts) of wind capacity—26 times the existing U.S. amount and four times the global wind capacity—if it plans to rely primarily on wind energy to cut greenhouse gas emissions by 80%.

3. Rural communities, acting through more than 100 government entities, have resisted expansion of renewable-energy capacity by moving to reject or restrict wind projects in about two dozen states since January 2015. Solar projects have also faced opposition.

4. Wind turbines kill birds and raptors, including bald and golden eagles. The turbines also are the largest cause of bat mortality, including several bats that are categorized as endangered. Attempting a 26-fold increase in wind-energy capacity may have devastating impacts on bird and bat populations.

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