Power Failure

How Climate Change Puts Our Electricity at Risk—and What We Can Do

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Electricity is vital to our daily lives, but our nation's aging electricity system is vulnerable to extreme weather events, which often cause power outages. Loss of electricity in our homes, businesses, schools, and hospitals is inconvenient at best—and life-threatening at worst.

Today, extreme weather events such as coastal floods, wildfires, intense precipitation (snow and rain), heat waves, and droughts are becoming more frequent and severe in some regions. Sea level rise is already worsening coastal floods, and other extreme weather events are likely to become more severe as the planet continues to warm. Building power plants and electricity infrastructure in areas prone to climate-related threats adds to those growing risks.

To ensure a reliable and affordable power supply for decades to come, the electricity sector needs to become more resilient in the face of the changes we are already experiencing, and also adapt to growing risks. Our energy choices are an important part of the solution: energy efficiency and renewable energy can diversify our electricity system and make it more resilient. But there is more to the picture. By investing in those options, we can also dramatically cut carbon emissions, helping to curb further climate change. That is, smart energy choices will create an electricity system that is more resilient in the face of changes we are confronting today while reducing the long-term damage and costs linked to global warming.

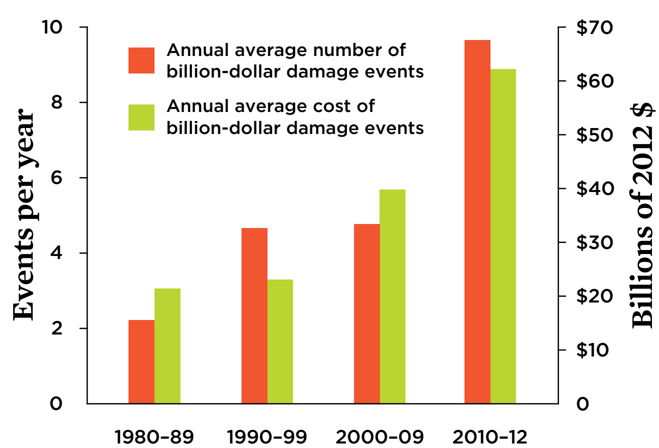
Why Our Electricity System Is Vulnerable to Extreme Weather

Extreme weather events, which often cause electricity outages, have become more common and costly in the United States over the past three decades (Figure 1) (Weiss and Weidman 2013a). For example, temperature and precipitation records suggest that certain types of extreme weather events, such as severe droughts in Texas, are several times more likely to occur now than in the 1960s (Rupp et al. 2012). The average total cost of severe weather events rose from $20 billion per year in the 1980s to $85 billion in the 2010s (Weiss and Weidman 2013a). In 2011 and 2012 alone, 25 extreme weather events nationwide resulted in 1,100 fatalities and costs totaling $188 billion (NOAA 2013a; Weiss and Weidman 2013b).

When customers lose power during extreme weather events, the costs associated with lost output and wages, spoiled inventory, and restarting industrial operations can be significant. For example, weather-related power outages in 2012—when Hurricane Sandy hit the East Coast—cost the nation between $27 billion and $52 billion (EOP 2013).

Our electricity system— including the transportation networks that deliver fuel, the power plants that generate electricity, and the transmission and distribution lines that deliver power to homes and businesses—was not designed to withstand many of the extreme weather events occurring today (GAO 2014; DOE 2013). Many parts of the electricity grid are old, outdated, and in poor condition, making the

FIGURE 1. Number and Cost of Billion-Dollar Weather Events, 1980 to 2012



Extreme weather events have become much more common as well as costly over the past three decades.

SOURCES: NOAA 2013A; WEISS AND WEIDMAN 2013A.

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When Hurricane Sandy hit the East Coast in October 2012, it caused billions of dollars in damage and left more than 8 million residents in 21 states without power.

system even more vulnerable. In fact, the American Society of Civil Engineers (ASCE) gave the overall U.S. energy infrastructure a grade of D+ in its 2013 assessment, reporting that it is "in poor to fair condition and mostly below standard . . . a large portion of the system exhibits significant deterioration" (ASCE 2013, p. 11).

Aging electrical equipment has contributed to a growing number of major outages, which rose from 76 in 2007 to 307 in 2011 (ASCE 2013). Even the pipelines that deliver oil and natural gas to power plants are in poor condition: pipeline failures have resulted in deaths, injuries, property damage, and environmental harm, such as land and water pollution (ASCE 2013).

Investments in transmission and distribution infrastructure are not keeping pace with the needs of our nation's aging grid. By 2020, investments in electricity infrastructure will have fallen behind by $37 billion for distribution and $57 billion for transmission, according to the ASCE. And while upgrading the existing infrastructure to current standards is important, the electricity grid will also require new technologies and approaches to withstand even more severe conditions.

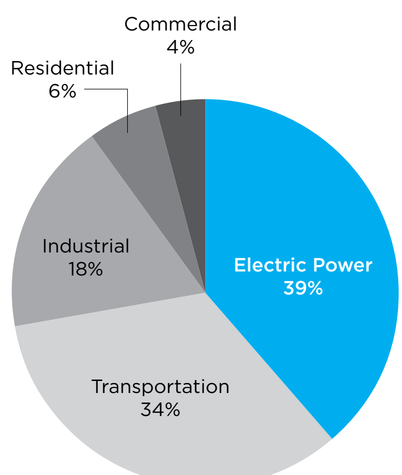
Growing Risks to Our Electricity System

Not only is our electricity system already vulnerable to extreme weather, but those risks will grow in the future. Rising levels of carbon dioxide and other heat-trapping gases in the atmosphere have already caused average global temperatures to increase at least since the 1880s, when scientists began gathering reliable data. Higher temperatures add moisture to the atmosphere, intensify storms, and raise sea levels.

Scientists expect the severity of several types of extreme weather—including coastal flooding, wildfires, drought, the heaviest precipitation events, and heat waves—to increase as a result of continued climate change (IPCC 2012; UCS 2012). Of course, the scale and magnitude of these trends will vary greatly by region. And the link between climate change and other types of extreme weather, including hail and tornadoes, is less clear. However, if global warming emissions continue unabated, coastal flooding, wildfires, droughts, and heat waves are likely to become worse, raising the threat to our already vulnerable power grid.

Our electricity system clearly needs to adapt to these conditions. But it also has a vital role to play in curbing further climate change, as the sector is the leading source of U.S. carbon dioxide emissions. In 2012, nearly 40 percent of energy-related U.S. carbon emissions stemmed from burning coal, natural gas, and oil to produce electricity (Figure 2) (EIA 2013).

FIGURE 2. Energy-Related U.S. Emissions of Carbon Dioxide, by Source, in 2012



Electricity generation accounts for almost 40 percent of energy-related U.S. carbon emissions—more than any other sector.

SOURCE: EIA 2013.

FIGURE 3. U.S. Electricity Facilities Less than Four Feet above Local High Tide

Nearly 100 electricity facilities in the contiguous United States, including power plants and substations, are within four feet of high tide—and are therefore vulnerable to rising sea levels.

SOURCE: ADAPTED FROM CLIMATE CENTRAL 2012.

HOW SEA LEVEL RISE THREATENS OUR ELECTRICITY INFRASTRUCTURE

Sea level rise and storm surge put low-lying power plants and other electricity infrastructure at risk. Today some 100 electric facilities in the contiguous United States, including power plants and substations, are sited within four feet of local high tide (Figure 3). And as sea levels continue to rise, the risks to these facilities from storm surge and floods will also increase.

Climate change is likely to double the risk of coastal flooding by 2030 (Climate Central 2012). Estimates of sea level rise range from eight inches to 6.6 feet above 1992 levels by 2100. However, the lower end of this range is based on historic data on sea level rise. More recent data show that rates of sea level rise have nearly doubled in recent years, suggesting a total rise of 1.6 to 6.6 feet by 2100 (NOAA 2012).

Higher sea levels increase the risk of coastal flooding from storm surges associated with hurricanes and coastal storms. With a warmer atmosphere, hurricane rainfall is

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As sea levels continue to rise because of global warming, storm surge will reach farther inland, threatening our electricity infrastructure. Shown here is the extent of flood damage from storm surge during Hurricane Sandy in 2012.

also projected to increase by the late twenty-first century, which could increase surface runoff and flood risk (Knutson et al. 2013). This puts the electricity infrastructure along our coasts—including power plants, transmission and distribution lines, transformers, substations, and refineries—at greater risk of damage and outages from flooding.

Consider, for example, the havoc wreaked on the electricity sector in October 2012 by Hurricane Sandy. The storm surge that rode in on higher sea levels caused record flooding along the coasts of New York, New Jersey, and Connecticut (Blake et al. 2013). More than 8 million customers across 21 states lost power, and utilities reported damage to some 7,000 transformers and 15,200 poles (DOE 2013). In the aftermath of the storm, New York City found that 37 percent of the capacity of its transmission substations, and 12 percent of the capacity of its large distribution substations, are at risk of flooding during extreme weather events (PlaNYC 2013).

THE THREAT FROM WILDFIRES IN THE WEST

Higher air temperatures have led to drier forests and earlier snowmelts, both of which contribute to wildfire risk (Tebaldi, Adams-Smith, and Heller 2012; Stewart, Cayan, and Dettinger 2005). The average number of large wildfires per year in the western United States rose from 140 in the 1980s to 250 between 2000 and 2012 (USGS 2013). Droughts and higher air temperatures also help make wildfires more intense and longer-lasting.

Wildfires have important consequences for the power sector. They can damage the poles carrying transmission lines, for example. However, the greatest risks come from smoke and particulate matter. Smoke and ash from fires can ionize the air, creating an electrical path away from transmission lines. This can shut down the lines and produce power outages (Ward 2013; Sathaye et al. 2012).

For example, in summer 2011, the Las Conchas wildfire in New Mexico put two high-voltage transmission lines that deliver electricity to about 400,000 customers at risk. The

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Wildfires are becoming more frequent and severe in the western United States because of droughts and higher temperatures. Smoke and ash from wildfires can raise the risk of power outages even more than fire damage to the poles that support power lines.

fire also forced Los Alamos National Laboratory—one of the nation's three nuclear weapons labs—to close (DOE 2013; Samenow 2011).

In California, more frequent and intense wildfires linked to climate change are projected to put a large share of transmission equipment at risk. Some major transmission lines in the state face a 40 percent higher probability of wildfire exposure by the end of the century (Sathaye et al. 2012).

THE VULNERABILITY OF WATER-DEPENDENT POWER PLANTS IN A WARMING WORLD

The U.S. electricity sector is highly dependent on water for cooling. Nearly all thermal power plants—coal, natural gas, nuclear, biomass, geothermal, and solar thermal plants—require water for condensing the steam that drives the turbines. In fact, power production accounts for the single largest share—two-fifths—of all freshwater withdrawals in the United States.

As average global temperatures continue to rise, droughts and reduced water supplies are likely to become the norm in some regions. Hydrologic patterns are changing seasonally as well. In the Northern Hemisphere, for example, snow is melting earlier in spring, and soil is becoming drier earlier in summer, when users need water the most (Root et al. 2005). Greater variability in water quantity and quality—particularly its temperature—because of climate change puts the power sector at greater risk (Rogers et al. 2013).

Power plants can run into several types of water-related problems. If the temperature of the incoming water at a power plant is too hot, it can reduce the plant's efficiency or cause unsafe conditions. If the temperature of the discharge water is too high, a power plant can be out of compliance with federal and state temperature regulations set to protect local ecosystems. When either of these conditions occurs, power plants must dial back production or shut down temporarily, often forcing utilities to purchase more expensive replacement power. For example, in the summer of 2007, triple-digit heat in North Carolina meant that water used for cooling Duke Energy's Riverbend and G.G. Allen coal plants on the Catawba River was too hot to discharge

(Figure 4). As the utility scaled back production at those two plants, blackouts rippled through the area.

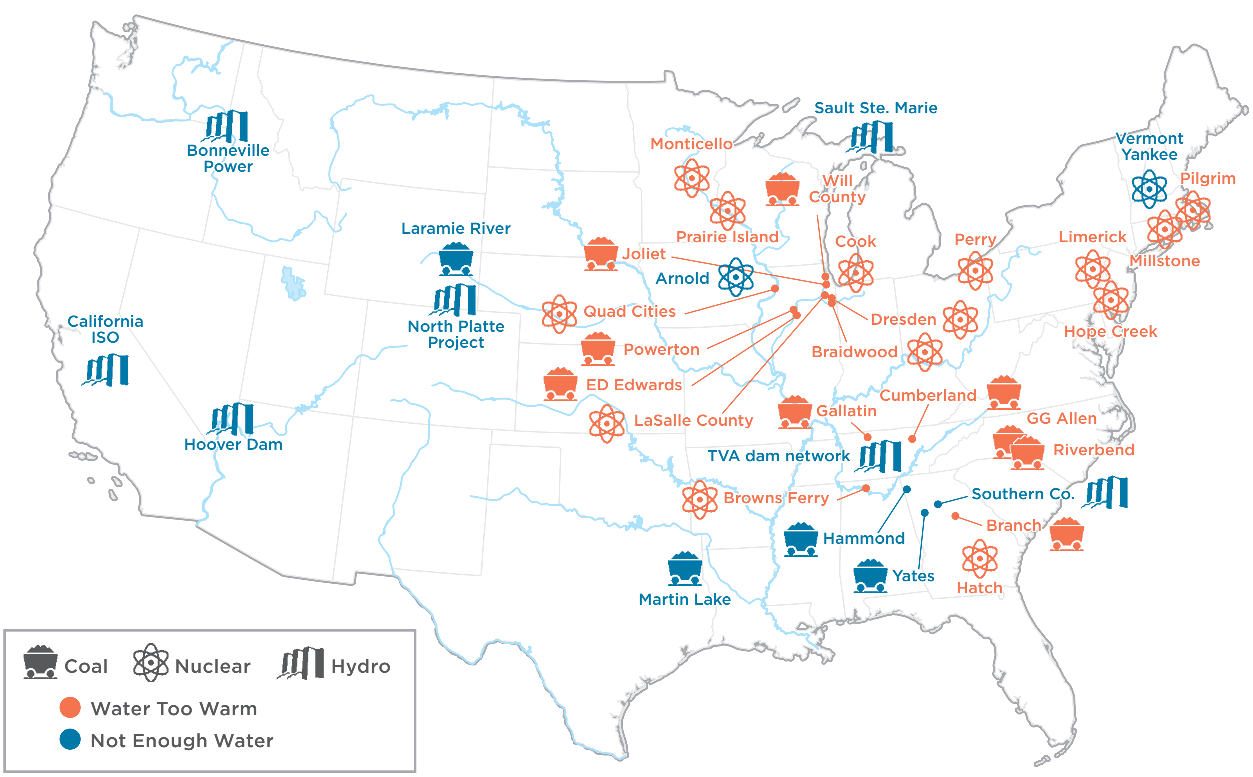
Droughts can be just as troublesome as high water temperatures for power plants. In summer 2012, water levels in Iowa's Cedar River were so low that operators of the Duane Arnold Energy Center, a nuclear power plant, had to dredge the river to ensure access to enough water (*Telegraph Herald* 2012).

These situations occur most often in summer, when customers need electricity the most (Rogers et al. 2013). During the summers of 2007 and 2008, the Laramie River Station, a coal-fired power plant in Wheatland, WY, risked running out of cooling water because of drought. To avert a production cutback or shutdown, operators drew on water sources typically used for irrigation (Rogers et al. 2013; NETL 2009).

Because thermal power plants rely heavily on water for cooling, a changing climate is likely to put them at higher risk from drought. Inland flooding from extreme precipitation events also poses a major risk to electricity infrastructure, because power plants are sited near rivers and lakes (EPA 2013). Fort Calhoun, a nuclear plant near Omaha, NE, had to close from April 2011 to December 2013 because of damage caused by record flooding along the Missouri River and concerns about plant safety (NRC 2013).

> ***Because thermal power plants rely heavily on water for cooling, a changing climate is likely to put them at higher risk from drought.***

FIGURE 4. Power Plants That Have Shut Down or Reduced Output Because of Water Problems, 2006–2013



When water used to condense steam at power plants is too hot or supplies shrink, the plants run into trouble. Operators have had to shut down or curtail production at numerous power plants because of water-related risks in recent years.

SOURCE: ADAPTED AND UPDATED FROM ROGERS ET AL. 2013.

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The Fort Calhoun nuclear power plant closed from April 2011 to December 2013 because of record flooding on the Missouri River. Because they are sited near rivers and lakes, many power plants are vulnerable to inland flooding caused by extreme precipitation events.

THE IMPACT OF HEAT WAVES ON POWER PLANT OPERATIONS AND ELECTRICITY DEMAND

Climate change will bring more intense, more frequent, and longer-lasting heat waves in North America (IPCC 2012). Record high air temperatures now occur twice as often as record low temperatures (Meehl et al. 2009). The past 37 years (through December 2013) have been hotter than the twentieth-century average, and nine of the 10 warmest years on record have all occurred in the twenty-first century, according to the National Oceanic and Atmospheric Administration (NOAA 2013b).

Factors such as limits on water discharge temperatures could cause power plants in the central and eastern United States to lose 12 percent to 16 percent of their capacity, on average, by mid-century (van Vliet et al. 2012). But higher air temperatures can also directly reduce power plant capacity. A study for the California Energy Commission found that under a scenario of high global warming emissions, climate change could reduce the capacity of existing natural gas–fired power plants by 23 percent on the hottest August days by the end of the century, compared with 17 percent today (Sathaye et al. 2012).

Higher air and water temperatures can also lead to reduced efficiency at thermal power plants, which require a strong temperature difference between the steam in the turbines and the water used to condense it to function optimally. When it is hot outside, water temperatures are higher, so the power plants produce less electricity per unit of fuel. A similar loss of efficiency occurs for transmission and distribution equipment, which does not operate as efficiently or carry as much current at higher temperatures (Ward 2013).

As people turn on their air conditioners on hot days, demand for electricity rises, further taxing the system. For example, electricity demand in California could increase by as much as 21 percent on especially hot days (those in the ninetieth percentile) by the end of the century. Higher average temperatures are projected to raise the need for transmission capacity by 31 percent in that state in coming decades (Sathaye et al. 2012). Cities and states around the country are likely to face similar challenges as temperatures rise.

Options for Making Our Electricity System More Resilient and Reliable

To reduce the vulnerabilities of our electricity system today and ensure reliable electricity in the future, the power sector will need to both adapt to and mitigate climate-related risks. Our energy choices will play a vital role in both improving the resilience of the electricity system and reducing global warming emissions.

ADAPTING TO CLIMATE CHANGE TO HELP KEEP THE LIGHTS ON

Because some of the effects of climate change are unavoidable and already occurring, the electricity sector clearly needs to better prepare to withstand and recover from those effects. Some of the most common adaptation measures are known as "hardening" measures, as they can protect equipment from weather-related damage. Examples of hardening measures that utilities have proposed in response to extreme weather events include:

- Building protective sea walls
- Restoring naturally occurring protections, such as sand dunes, beaches, and wetlands
- Elevating or relocating important electrical equipment along the coasts, to protect it from flooding
- Burying transmission and distribution lines underground where feasible
- Reinforcing aboveground poles with sturdier materials, to reduce damage during storms and wildfires

Other common adaptation measures include trimming trees near transmission and distribution lines, to prevent damage from high winds and icing, and installing backup diesel generators for homes and buildings. However, diesel generators also produce carbon and other harmful emissions, making them a less attractive option.

While some level of hardening the electricity system is necessary, these measures are often expensive and may not be the most cost-effective long-term solution. PSE&G—a New Jersey utility hit hard by hurricanes Sandy and Irene—is proposing to spend $3.9 billion over 10 years on hardening measures such as relocating equipment in vulnerable locations, trimming trees, and burying power lines (PSE&G 2013). A 2011 study by Entergy Corp. found that hardening electric utility systems along the Gulf Coast would cost $15 billion from 2010 to 2030 (Entergy 2011). All potentially attractive measures to protect the company's energy infrastructure would cost $120 billion over 20 years, although they could avert $200 billion in losses (Entergy 2011).

Other utilities and state and local governments are already making smart adaptations to climate change. EPB, the local utility in Chattanooga, TN, has made several investments in "smart grid" technologies. These include smart switches, which adjust the flow of electricity during outages to isolate problem areas, minimize the effects, and ensure that emergency services such as hospitals have access to power. Those investments have already reduced the number of power outages and provided significant savings to customers (Hand 2013). Massachusetts plans to invest $40 million to make the electricity grid more resilient, including in technologies such as solar panels that will also reduce emissions (Governor Deval Patrick 2014).

Adapting to the effects of climate change is important, but it's not the whole story. Unless we reduce global warming emissions and mitigate the worst effects of climate change, the need for costly adaptation measures will only grow.

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Burying power lines makes them less vulnerable to extreme weather and can help prevent outages, but that step is also expensive. PSE&G—a New Jersey utility hit hard by hurricanes Sandy and Irene—is proposing to spend almost $4 billion over the next 10 years on these types of hardening measures.

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The Grand Rapids Art Museum in Michigan meets the gold standard for sustainability established by the U.S. Green Building Council. Energy efficiency measures and passive solar technologies, like those employed in this building, significantly lower energy use.

[Energy efficiency measures can be a win-win solution for both adapting to and mitigating climate change.]

Beyond adapting to changing conditions, the electricity sector also needs to cut its carbon emissions dramatically. The next sections outline solutions that can fulfill both goals.

REDUCING THE PROBLEM BY REDUCING DEMAND

Energy efficiency measures can be a win-win solution for both adapting to and mitigating climate change. Energy-efficient homes and businesses require less electricity, deferring or eliminating the need to build new power plants and power lines. Less energy infrastructure means less equipment is vulnerable to damage from extreme weather events. Increasing energy efficiency is also one of the fastest and cheapest ways to meet electricity needs while saving consumers money on their energy bills and reducing carbon emissions from coal and natural gas plants (ACEEE 2013).

Energy-efficient buildings and appliances reduce electricity demand, save money, and ease the need for cooling during hot summer months. Boston's Renew Program has produced $2 million in annual savings by making homes more energy-efficient (Boston 2013). Spurred by the U.S. Environmental Protection Agency's Energy Star program to buy more efficient appliances and other products, Americans saved $26 billion on their electricity bills—and electricity equivalent to that used by 35 million average homes—in 2012 (EPA 2014). And because incorporating energy efficiency measures into new buildings is much more cost-effective than adding them retroactively, rebuilding after major storms provides an important opportunity to reap the benefits of energy efficiency and increase a community's resilience (ACEEE 2013).

Many cities are also implementing green and cool roof programs, in which rooftop gardens cool the building through evaporative cooling, or reflective materials on roofs deflect heat from the sun. Green and cool roofs reduce the urban heat-island effect while reducing the need for air conditioning, making buildings more comfortable and

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Green roofs—such as this one in New York City—help keep buildings cool and reduce the urban heat-island effect, cutting the amount of electricity used for cooling.

improving urban air quality (Gaffin et al. 2012). Installing green or cool roofs on 50 percent of residential, commercial, government, and public-use buildings in Southern California could save enough energy to power more than 127,000 homes, reduce energy bills by $211 million per year, and cut carbon emissions by 465,000 metric tons annually (NRDC 2012).

Many utilities and grid operators are also implementing "demand-response" programs, which pay large consumers to cut electricity use during periods of high demand, or charge higher prices to encourage them to do so. Those programs make the grid more flexible and resilient. For example, during a September 2013 heat wave that set a record for electricity use in Pennsylvania, PJM, the regional grid operator, used demand response to curb demand by six gigawatts—equivalent to the output of 10 coal-fired power plants. That program kept the grid stable and air conditioners running when customers needed them the most (*Sacramento Bee* 2013).

© Make It Right Foundation–Concordia

After Hurricane Katrina hit New Orleans in 2005, the Make It Right project helped rebuild the city's homes with solar panels and energy efficiency measures. In addition to lowering residents' electricity bills, these homes will keep residents more comfortable during future power outages.

RENEWABLE ENERGY: KEY TO A RESILIENT, RELIABLE ELECTRICITY SUPPLY

Replacing power from conventional plants with renewable energy can make the electricity system more resilient while also helping to curb further climate change by reducing heat-trapping emissions. Renewables provide these benefits because:

- **Renewable energy is often smaller-scale and more distributed.** Large coal and nuclear plants make the grid less flexible and more vulnerable to blackouts when they go off-line. The potential for a sudden outage also means that grid operators must have enough generation and transmission reserves on hand to immediately replace output from the plants. And when they do shut down, coal and nuclear plants often require repairs that take several days or weeks before they can resume operation.

  Renewable energy technologies such as rooftop solar panels and wind turbines tend to rely on smaller, more distributed units, greatly reducing the impact on the grid when weather damages them. And many renewable energy facilities have weathered storms and heat waves better than conventional power plants (see the box on p. 12).
- **Renewable energy lowers water risks.** Wind turbines and solar panels are more resilient to drought and heat because they do not require water to produce electricity. These technologies offer an important solution for regions of the country with limited freshwater supplies, or with high concentrations of thermal plants that have run into problems related to high water temperatures. Dry-cooling systems, which use air instead of water, can dramatically

How Renewables Are Already Making Our Electricity Supply More Resilient

Several climate-related extreme weather events have revealed that renewable energy is already contributing to a more resilient electricity sector.

In summer 2011, Texas suffered from a record-breaking heat wave, forcing many coal and natural gas power plants to shut down. Wind power made a significant contribution to the electricity system for several days, helping to keep the lights on and prevent rolling blackouts (Bode 2011; ERCOT 2011). Wind power also eased pressure on water supplies during one of the worst droughts in the state's history.

Texas has made significant investments in wind power, and now has more than twice as much wind capacity as any other state. Wind turbines produced more than 8 percent of the electricity used in Texas in 2013, making the state's power sector more resilient in the face of climate change while reducing carbon emissions.

In October 2012, as noted, Hurricane Sandy exerted major stress on the Northeast's electricity grid, damaging power plants, transmission lines, and pipelines or forcing them to shut down. Some 8 million customers in 21 states lost power (DOE 2013). Yet no wind turbines or solar facilities suffered any damage from the hurricane, according to ISO New England, one of the regional grid operators (Wood 2012). The five-turbine Jersey Atlantic Wind Project, off the coast of Atlantic City, survived the storm and quickly began producing power after it had passed (Jervey 2012).

New Jersey is a leader in solar energy, ranking fifth in the nation in capacity for solar electricity installed in 2013 (SEIA 2013). Solar energy has thrived in the state thanks to: New Jersey's renewable energy standard, which requires utilities to obtain a growing share of their power from renewables; net metering policies, which allow customers with solar to feed excess electricity into the grid; and rebate programs, which lower the up-front cost of installing solar equipment.

reduce water use at thermal power plants. Coupling these systems with renewable technologies such as concentrating solar and biomass can cut both carbon emissions and water use dramatically.

- **Renewable energy reduces fuel supply risks.** Renewable resources are far less vulnerable to interruptions in fuel supplies stemming from extreme weather, because most renewables do not use fuels that must be extracted, processed, and transported. The fossil fuel supply chain, in contrast, entails many steps that are vulnerable to the effects of climate change.

  Drilling for fossil fuels and producing them often require freshwater resources, for example, which are expected to decline with climate change in many regions and some seasons (DOE 2013). And the delivery of oil, natural gas, and coal requires transportation networks such as pipelines, railroads, and waterway barges—all vulnerable to the effects of climate change (Epps 2014; Cruz and Krausmann 2013). Because most renewables do not rely on fuels that are subject to price spikes, they also add price stability for consumers.

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Renewable energy technologies, such as rooftop solar panels, can make the electricity system more resilient in several ways. These approaches are smaller and more distributed. They do not use water to produce electricity, and they do not rely on fuel supplies that are vulnerable to disruption from extreme weather. And by reducing carbon emissions, they help curb the impact of future climate change.

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Wind power does not depend on water to produce low-carbon electricity, one of the many advantages of renewable technologies that can lead to a more resilient electricity sector.

Like many fossil fuel and nuclear power plants, renewable energy technologies such as wind power and large-scale solar projects are often sited far from large cities, and require transmission lines to deliver power to consumers. If the grid goes down because of extreme weather, delivering power from *any* facility is challenging. However, as noted, our nation's electricity infrastructure is in need of repairs and upgrades. Advances in grid technology and new transmission lines will make the grid more flexible and resilient while allowing it to integrate more renewable energy.

Recent studies have shown that installing solar panels with battery storage on homes and businesses could be economically viable in many states within 15 years (CEG 2014; RMI 2014). That approach would provide an attractive alternative to backup diesel generators, which emit carbon and other pollutants and pose public health and safety risks. Incorporating solar heating, daylighting, and other energy-saving approaches into building designs—and investing in efficient bioenergy heating and geothermal heating and cooling systems—can also greatly reduce energy bills and emissions, while making buildings more comfortable during power outages.

Recommendations for a More Climate-Resilient Electricity Sector

Although vital to daily life and our economy, our nation's electricity infrastructure is not prepared for a future with rising sea levels and more drought, extreme heat, wildfires, and flooding owing to climate change. Fortunately, many solutions are available now to help us better respond to extreme weather and climate change, while also reducing harmful emissions to curb the severity and costs of further warming.

- **Conduct vulnerability assessments.** Understanding risks and vulnerabilities is a critical first step for communities in determining which steps to take to protect themselves from the effects of climate change. Cities, counties, and states should conduct thorough assessments that include the risks of climate change to the electricity sector.
- **Create public-private partnerships to invest in climate resilience.** Federal and state governments and private institutions should work together to identify resources and invest in technologies and other measures that make the electricity sector more resilient while helping to curb further climate change.
- **Incorporate climate adaptation and mitigation measures into utility resource planning.** State and local governments should require utilities to consider the costs

of adapting to climate change in their long-term resource planning. Utilities should also consider the costs and benefits of investing in technologies that significantly reduce emissions and future climate effects.

- **Upgrade the electricity infrastructure in ways that strengthen its resilience and reduce outages.** Power plant owners should install technologies that use less water—such as dry and wet-dry hybrid cooling systems or new wind and solar photovoltaic (PV) projects—to ensure that our electricity system is more resilient in the face of heat and drought. Utilities and grid operators should also pursue approaches that make the grid more flexible and allow it to integrate renewable and distributed energy resources. These include expanding transmission capacity and energy storage, adopting demand-response programs, developing microgrids (which can better isolate outages), and improving forecasting and scheduling.
- **Adopt strong state and federal clean energy policies.** Policy makers should adopt proven policies and programs to ensure the timely expansion of renewables and energy efficiency, such as renewable electricity standards, energy efficiency standards, tax incentives, financing mechanisms, and funding for research and development. By encouraging innovation and reducing costs, these approaches will help overcome market barriers that are inhibiting the development of clean energy technologies.
- **Enact strong federal carbon standards.** The U.S. Environmental Protection Agency (EPA) should finalize and implement strong standards to reduce heat-trapping emissions from new and existing power plants, to help mitigate further climate change and its costs. The EPA should allow states to use renewables and efficiency investments to comply with these standards. The federal government should also set limits that will reduce the nation's carbon emissions at least 80 percent by 2050.
- **Encourage home owners and businesses to do their part by investing in energy efficiency and renewables.** Investing in more efficient buildings and appliances—as well as clean technologies such as rooftop solar PV panels, solar heating and daylighting, and efficient bioenergy heating and geothermal heating and cooling systems—can greatly reduce electricity bills and global warming emissions. Those investments will also keep buildings more comfortable during extreme weather events and power outages.

The resilience of our electricity sector will determine the extent of power outages and damages from the next major drought, coastal flood, storm, and heat wave. Making smart choices to improve the resilience of our electricity grid and produce clean power will minimize the impact of these events while strengthening our energy security and helping to curb further climate change.

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Investing in wind power and other renewable energy resources will dramatically reduce carbon emissions from the power sector, helping to curb future costs and risks from climate change. Updating our old and outdated transmission and distribution infrastructure can also allow it to integrate more renewable energy and help prevent future outages.

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