Union of Concerned Scientists

EXECUTIVE SUMMARY

Lights Out?

Storm Surge and Blackouts in the Delaware Valley, and How Clean Energy Can Help

HIGHLIGHTS

As sea levels rise, more power plants and substations along the East and Gulf Coasts risk exposure to flooding that can damage equipment and trigger power outages. Our analysis finds that an extensive amount of critical electricity infrastructure in the Delaware Valley and other regions is situated in flood-risk areas today, and that these areas will expand to encompass more infrastructure in the decades ahead. Without sufficient protective measures in place, reliable power supply may be at risk: coastal communities face the potential for widespread, long-lasting power outages and the harm such blackouts can cause.

To ensure a reliable electricity system now and in the future, we need to plan for current and worsening flood exposure over the lifetime of equipment, and deploy resilient clean energy solutions to keep critical facilities powered up even when severe weather strikes.

As global warming pushes sea levels higher, the risk of coastal flooding from storm surge grows, posing a serious and worsening threat to electricity infrastructure along the U.S. East and Gulf Coasts. A large share of the major substations and power plants that provide electricity to more than 70 million coastal residents is already exposed to flooding from hurricanes, nor'easters, or other severe storms. Even more electricity infrastructure stands to be exposed, and to increasing floodwater depths, as seas continue to rise and drive storm surge higher.

Flood mapping of five major metropolitan regions along the East and Gulf Coasts conducted by the Union of Concerned Scientists suggests that if critical components of the electric grid are insufficiently protected, they risk inundation and the flood damage and failure that can ensue. The result can be widespread and long-lasting power outages. According to our analysis of the Delaware Valley, 79 major substations (30 percent of the total) and 35 power plants (representing more than 8,800 MW of generating capacity) in the mapped region could be exposed to flooding from a major storm today; approximately one third of these substations could be exposed to floodwater depths of 10 to 15 feet or more.

To maintain the level of electricity reliability on which our safety, health, and daily lives depend, regulators and utilities evaluating threats to the electric grid must stop relying on historical data that greatly underestimate the risk of current and future flooding. At the same time, our states, towns, and cities should push for widespread deployment of resilient clean energy solutions that not only protect our communities when the centralized grid goes down, but also lower the electricity sector's global warming emissions, which will help limit longer-term sea level rise and other climate impacts.

© Mark Hanrahan

Storm surge and coastal flooding can have devastating consequences. During Hurricane Sandy, NYU Langone Medical Center lost power and its backup generator systems failed, forcing the evacuation and relocation of hundreds of patients.

The Steep Cost of Prolonged Outages

For communities hit by severe coastal storms, the devastation does not end when the skies clear and the floodwaters retreat. Because of outdated flooding assumptions and deteriorating electricity infrastructure, millions of citizens can emerge from being pounded by wind, waves, and water to find that the power is out—and stays out for days or even weeks.

The effects of such outages can be devastating. As arrestingly demonstrated by recent storms like hurricanes Katrina (2005) and Sandy (2012), lack of electricity following severe weather events can be another and separate disaster, triggering urgent patient evacuations from darkened hospitals, millions of gallons of raw sewage flowing into local waterways as treatment plants go dark, and hours-long lines at the few area service stations able to keep pumps running. Widespread post-storm outages can also cause major impacts closer to home, such as the loss of drinking water pumped from wells and throughout high-rise buildings, the inability to use ATMs or credit cards, and the failure of cell phone and Internet communications. Some populations—including the elderly, those with disabilities, and those with low income—are particularly challenged by power outages, and struggle to cope with their impacts.

Faltering Electricity Infrastructure

Power outages can occur because of damage to any part of the electricity system: the thousands of power plants generating electricity, the tens of thousands of substations enabling long-distance power transmission, and the millions of miles of transmission and distribution lines delivering electricity to our homes, businesses, and institutions. But despite our increasing reliance on electricity, our nationwide power grid is increasingly susceptible to failure due to old age and poor condition, and the rate of outages from severe weather has been rising (Figure 1).

With nearly one-quarter of the U.S. population living in counties along the East and Gulf Coasts, there is necessarily a large concentration of energy infrastructure built up in coastal areas. Inundation, or flooding of normally dry land, is the most direct hazard to these electric grid components. This type of flooding is typically associated with storm surge, where seawater presses far inland—sometimes at heights of 10 to 20 feet or more above typical high tide—due to strong winds. Because storm surge severity is determined by local geography, size and path of storm, and other factors, even an otherwise nonmajor storm system can produce severe surge. Submerged equipment can suffer catastrophic failure, and repairs—when possible—can be laborious and lengthy. But the alternative can be far worse: complete replacement of substations can take more than a year and cost millions of dollars.

Many cities and towns along the East and Gulf Coasts have begun to confront the impacts of climate change now that high tides are routinely overtopping seawalls or backing up storm drains and causing nuisance flooding. Flooding precipitated by high tides alone are a harbinger of disruptive change to come; storm surges rolling in atop rising seas present increasingly grave concerns for coastal infrastructure.

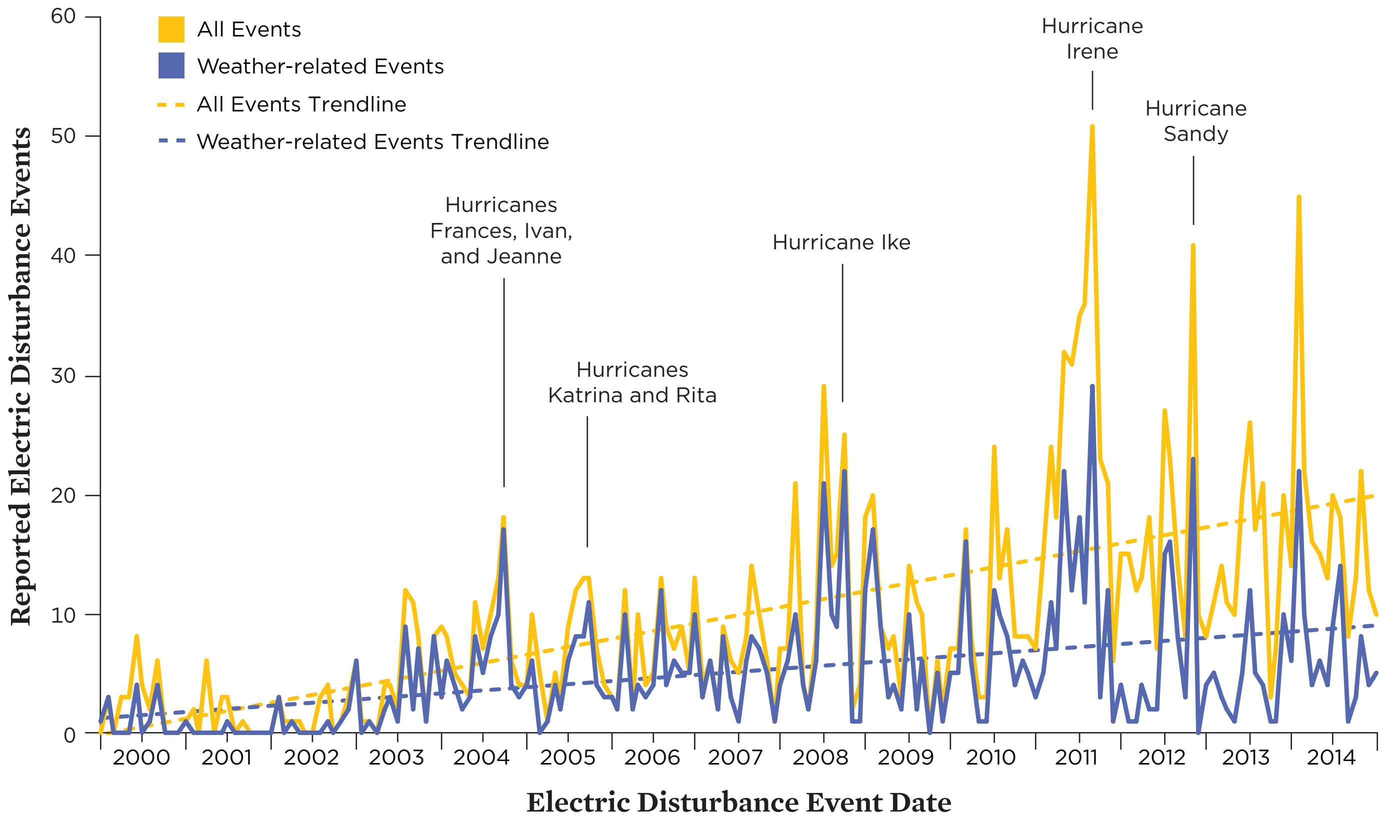
Rising Risks: Present and Future Exposure to Coastal Flooding

To better understand how storm surge threatens East and Gulf Coast electricity infrastructure now and in the future, we modeled the projected inundation of large substations and power plants in five major metropolitan regions: the Delaware Valley, southeastern Virginia, the South Carolina Lowcountry, southeastern Florida, and the central Gulf Coast. Our findings can be considered an indicator of the general magnitude of risk that U.S. East and Gulf Coast cities face today, and can expect to face in the future.

Using a moderate, localized sea level rise scenario, we modeled the projected depth and extent of coastal flooding under a variety of hurricane strengths today, and factoring in additional sea level rise in 2030, 2050, and 2070. In this analysis, hurricane strength is used as a proxy for severity of storm surge; however, surge levels can vary widely from one storm to the next, including moderate levels from major storms and severe levels from moderate storms. To approximate impacts on the electric grid, in each region we characterized the potential inundation of power plants and higher-voltage substations. We selected those two grid elements because of their potential vulnerability to coastal flooding; their high installation, repair, and replacement costs; and their essential role in the power grid. If sufficiently protected, power plants and substations can be made less vulnerable to floodwaters. Across regions, we found:

- Electricity infrastructure in all five regions already displays significant exposure to storm surge from major storms today. For example, we found the share of exposed substations ranged from 16 percent in southeastern Florida to nearly 70 percent in the central Gulf Coast.
- While the electric grid has built-in redundancies that allow power to be routed around a few damaged generators or major substations, power loss becomes widespread once more than a handful of such key elements are knocked

FIGURE 1. U.S. Electric Grid Disruptions



The Department of Energy tracks major electric disturbance events through Form OE-417. Utilities submit information about qualifying incidents, including when they occurred, where they occurred, what triggered them, and how many customers were affected. Notably, while the reported number of non-weather-related events is high, the vast majority of incidents resulting in customer outages occur because of weather.

SOURCE: UCS ANALYSIS, BASED ON OE N.D.

offline. In all regions examined, we saw evidence of the potential for such widespread losses if electricity infrastructure is unprotected, as floodwater depths often reach 5 to 10 feet, and even 10 to 15 feet, at exposed sites.

- As sea level rise continues to push flood levels higher, the depth of flooding will worsen, and storm surge could extend farther than it does today. For example, in southeastern Florida the number of major substations exposed to flooding from a Category 3 storm could more than double by 2050 and triple by 2070, while in the Delaware Valley, the number of substations facing floodwater depths of 10 to 15 feet or more grows by 15 between now and 2070.

The following assessment of the Delaware Valley illustrates the potential threat that coastal flooding poses to electricity infrastructure in this area today and in the future. Importantly, while our results identify electric grid exposure (i.e., the presence of electricity infrastructure in areas that can expect substantial flooding), this does not mean that every substation or power plant in these areas is vulnerable to flooding, since some utilities may have already invested in reducing the vulnerability of some of this infrastructure (e.g., by elevating equipment). In other words, exposure does not necessarily result in impact. At the same time, our analysis does not capture additional, common storm risks such as wind damage to the grid or flooding associated with extreme precipitation. Finally, our results do not include the many lower-voltage, distribution-level substations that take electricity the last leg of the journey to most end users, and which may face risks similar to their larger counterparts.

The Delaware Valley

© David Newcomber

Even though Philadelphia, PA, and Camden, NJ, are located tens of miles up the Delaware River from the Atlantic Ocean, these cities are still susceptible to flooding from severe coastal storms.

Between its bucolic start in the Catskill Mountains of New York and its triumphant finish at the Atlantic Ocean through the shores of Delaware and New Jersey, the Delaware River serves as a major conduit for industrial activity within the region. Upon passing by Morrisville, PA, and Trenton, NJ, the river becomes a tidal estuary. From there to the sea, it has facilitated the development of concentrated industrialized areas, including Camden, NJ, Philadelphia, PA, and Wilmington, DE. Industries include shipping, chemical manufacturing, and refining. Critically, when hurricanes strike the coast, the Delaware Bay provides an opening for water to push back up the channel toward the cities and industrial sites along its shores.

Given the heavy riverine development in the region—and the electricity demand that such industrial development requires—it is no surprise that so much regional infrastructure is exposed to inundation. A Category 3 hurricane today has the potential to expose 79 substations to flooding (Figure 2a). By 2050, that number climbs to 84, more than a third of which could be exposed at a depth of 10 to 15 feet or more (Figure 2b). Parts of New Jersey west of Camden are projected to be particularly hard hit, with more than 20 major substations exposed, and many at high flood levels.

The Delaware Valley also illustrates the piecemeal approach currently being applied to regional challenges. In the aftermath of Hurricane Sandy, for example, policy makers in the region's three states (Delaware, New Jersey, and Pennsylvania) have reacted in different ways and to different degrees in terms of readjusting flood protection requirements. And as the president and CEO of Public Service Electric and Gas Company (PSE&G) noted in early 2015, his utility builds to the guidelines required of it by policy makers, even when the states around them require more or less, and even if a stronger storm could still knock out their electrical infrastructure.

Summary Facts

Regional Population: 2.8+ million

Projected Sea Level Rise by 2050: 1.3 ft

Main Utilities: PECO, PSE&G, Atlantic City Electric, Delmarva Power

Power Plants: 71 (11,553 MW)

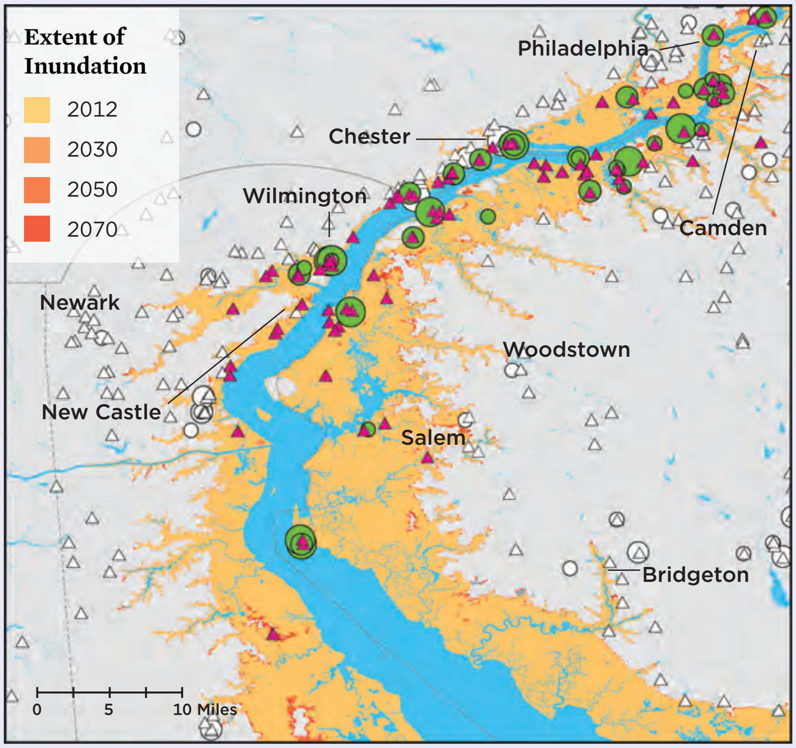
- 2 regulated, 69 merchant
- 2 nuclear, 21 gas, 4 coal, 13 oil, 22 solar, 7 biomass, 2 other

Substations: 263, including 75 x 138 kV, 76 x 230 kV, 13 x 500 kV, and 99 others

Recent Actions: PSE&G has launched a major gas and electricity upgrade in New Jersey following Hurricanes Sandy and Irene, as has Atlantic City Electric. For both, the initiatives involve tree trimming, transmission line hardening, and the elevation or relocation of equipment known to be vulnerable to inundation.

FIGURE 2. The Electric Grid's Growing Exposure to Coastal Flooding in the Delaware Valley

a. Flooding Extent from a Category 3 Hurricane



LEFT: *The potential reach of inundation up the Delaware River from a Category 3 hurricane today could leave 79 major substations and more than 8,800 MW of generating capacity in New Jersey, Delaware, and Pennsylvania exposed. By 2070, sea level rise drives potential storm surge even farther inland, and puts additional electricity infrastructure at risk.*

BELOW: *In the Delaware Valley region, the potential depth of inundation from a Category 3 hurricane in 2050 is significant. Even tens of miles up the river, substations and power plants could face floodwaters of 10 to 15 feet or more. When broken out by flood depth interval over time, an increasingly large number of substations could face floodwater depths of more than 15 to 20 feet.*

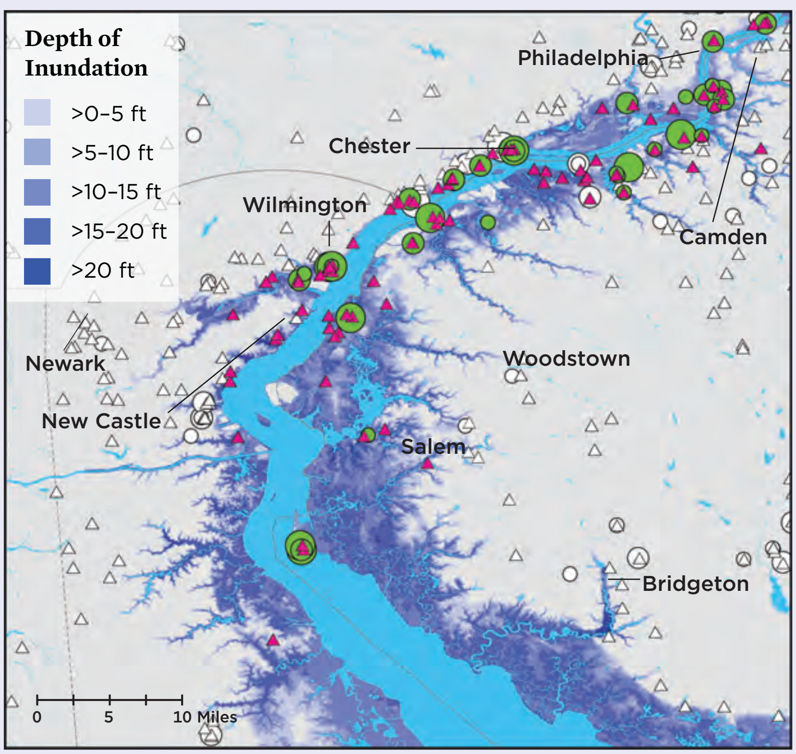
Power Plants

Exposed	Unexposed
>0–20 MW	>0–20 MW
>20–200 MW	>20–200 MW
>200 MW	>200 MW

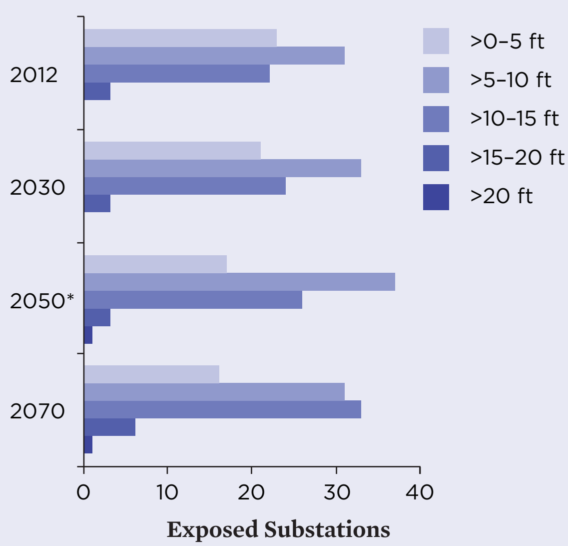
Substations

Exposed	Unexposed

b. Flooding Depth from a Category 3 Hurricane, 2050



c. Potential Depth of Inundation of Regional Substations from a Category 3 Hurricane



* Scenario mapped at left

Note: These maps are for discussion and research purposes only. They are not appropriate for detailed analysis.

Protecting Our Electric Grid Requires Foresight

In a warming world, building for today's conditions leaves one unprepared for tomorrow. At present, it is common for a piece of infrastructure's current floodplain location to dictate the scale and scope of flood protection applied to it. But with rising seas, that point of reference can shift over time. Using such a system as a basis for locating and designing long-lived infrastructure leaves major investments increasingly vulnerable to shifting realities. State or local governing boards can increase the stringency of flood protection requirements beyond those commonly informed by the Federal Emergency Management Agency's (FEMA's) static assessment, but few have taken the first step of conducting their own future risk analysis and vulnerability assessment to spark that change.

A variety of options are technically feasible for preparing new and existing electricity infrastructure for coastal flooding. These options can be grouped into three adaptation strategies:

- **Protection.** Continue to use vulnerable, unmodified equipment by building defenses, such as seawalls, bulkheads, or berms, around it.
- **Accommodation.** Modify new or existing infrastructure to enable it to operate normally in the presence of water. This can include elevating substations, using submersible equipment, and installing flood monitoring equipment to know when electricity loads should be redirected.
- **Retreat.** Retire or relocate at-risk infrastructure in situations where protection or accommodation may be technically, socially, or financially impractical.

© Garrett Nantz / Shutterstock.com

Hurricane Irene struck the northeastern U.S. in August 2011 and caused significant and damaging flooding. In Hoboken, NJ, rising floodwaters forced PSE&G to take the Marshall Street substation offline, affecting approximately 8,800 customers. After flooding again inundated the substation following Hurricane Sandy in 2012, the utility decided to retire the site and add the load to a different raised and rebuilt area substation, at an estimated cost of $26 million.

Even with the availability of these solutions, many adaptation initiatives in the electricity sector have lagged due to an absence of best practices for determining when, and to what degree, such solutions should be deployed. Promisingly, some forward-looking policies and tools are beginning to emerge at the federal, state, and local levels to help address these gaps. They include broader cost-benefit analyses for adaptation measures, updated design standards to ensure "hardened" (flood-protected) infrastructure remains functional in the face of climate impacts, and providing local decision makers with the data they need to make informed adaptation plans.

Clean Energy: A Pathway to Resilient Power and Reduced Emissions

To maintain our present and future access to reliable electricity—and all the health, safety, and economic benefits such access allows—we must prepare our electric grid for increased coastal flooding. One necessary approach is adapting electricity infrastructure. However, it is also critical to simultaneously pursue solutions that go beyond intervening with specific pieces of equipment. For that, we can look to bolstering the overall electricity resilience of critical facilities and vulnerable populations.

Resilient power offers a system that is flexible, can respond to challenges, can quickly recover, and remains available when we need it most. Developing resilient power means shifting away from a centralized electricity system to a more decentralized one designed to meet critical needs even during extreme weather. When the power goes out, hospitals, water and wastewater treatment plants, community shelters, fire and police departments, and other critical facilities typically rely on backup diesel generators until the main electric grid can be restored. Backup diesel generators themselves, however, present a host of reliability and implementation challenges, including being prone to failure due to infrequent use.

Given the vital nature of the services provided by our critical facilities, the intrinsic flaws of the backup systems on which they rely, and the continued likelihood of power outages due to rising seas, it is essential for policy makers and utilities to look beyond current practices to create a more resilient power system. Clean energy technologies have the potential to be an important part of the solution, exceling

> ***Resilient power offers a system that is flexible, can respond to challenges, can quickly recover, and remains available when we need it most.***

© Mike Steinhoff/Creative Commons (Flickr)

When renewable resources such as solar are coupled with batteries or other energy storage devices, critical facilities like wastewater treatment plants are able to maintain power even if the centralized grid goes down, without needing to depend on unreliable and expensive diesel generators.

where diesel generators and the centralized grid have struggled. Foremost among such solutions are:

- **Renewable energy with energy storage.** When coupled with storage systems such as batteries, renewable resources with variable output like solar and wind power are able to provide energy to users even when the sun sets, the wind stops blowing, or the centralized grid goes dark. In New Jersey, a multimillion-dollar initiative is under way to fund energy storage projects that support renewable energy systems at critical facilities.
- **Combined heat and power (CHP) plants.** CHP, also called cogeneration, produces electricity and captures thermal energy from a single fuel source; this dual-use approach can greatly increase fuel efficiency while independently supplying heat as well as power to critical facilities. During Hurricane Sandy in 2012, the CHP system at the Water Pollution Control Facility in Little Ferry, NJ, kept running, so the treatment facility—unlike many of its counterparts—did not need to dump raw or partially treated sewage into area waterways.
- **Microgrids.** These can be self-contained, self-sustaining systems that generate and consume all the energy within a compact geographical "island;" alternatively, they can be interconnected with the broader electric grid and choose when to shift into island mode. During major outages, microgrids can turn into bright beacons of electricity amid widespread darkness. The Massachusetts Department of Energy Resources is currently hosting a $40 million, multi-year initiative to support municipal resilience with measures including microgrids.

The resilience-building attributes of these technologies include their location at or near where power is used (which eliminates reliance on long transmission lines or fuel supply chains), and their ability to start without a major outside electricity source (unlike most large generators). They can also provide power year-round, so absent an outage, consumers can either use that electricity directly to reduce their electric bills or, in some cases, sell it back to the grid or generate revenue through other grid support markets.

One of the best enablers of recent resilient power projects has been the decline in the cost of renewable energy and energy storage technologies. The 60 to 70 percent drop in the cost of wind and solar power over the past five years, combined with innovative financing methods emerging for funding such projects, has made these systems cost-effective for communities across the income spectrum, and vulnerable populations in particular can now be affordably buffered from the worst outage impacts.

Vitally, all these interventions must take place within a broader framework of purposeful reductions of the carbon emissions that drive climate impacts, including rising seas. Absent such a commitment, we face the prospect of increasingly severe future climate impacts. The strategic deployment of clean energy solutions enables us to reduce our fossil fuel use and support our communities with resilient power resources. And as the largest single contributor to U.S. global warming emissions—representing nearly one-third of total emissions in 2013—the power sector has a critical role to play in ensuring that we avoid the worst of future climate consequences.

Recommendations and Conclusions

The increasing threat of climate-related sea level rise and storm surge to our coastal electricity infrastructure is cause for serious concern. Ensuring reliable access to electricity now and into the future requires us to take thoughtful steps to consider the challenges not just of today, but also tomorrow. These include:

- **Protecting the grid from current and future impacts.** Utilities and regulators must take immediate action to protect electricity infrastructure from coastal flooding today, and ensure that interventions undertaken now incorporate the evolving context of climate impacts over the lifetime of investment decisions. Necessary immediate actions include consideration of the best available science by local decision makers, initiation of long-term adaptation plans by utilities, FEMA flood hazard maps that take climate impacts into account, and proactive use of federal disaster recovery funds.
- **Increasing the electricity resilience of communities.** We must move beyond the current focus on protecting the centralized grid and support our communities through the strategic deployment of distributed, resilient power resources. Regulators must enable cost recovery for utilities' prudent investments in resilience, federal and state agencies must fund resilient power projects, and federal and state agencies must provide dedicated support to vulnerable populations.
- **Adopting strong policies to reduce carbon emissions.** We must place all actions within the broader framework of de-carbonizing the electricity sector in order to limit the severity of long-term climate impacts. Without such a plan in place, our adaptation approaches could eventually prove inadequate. Necessary steps include supporting strong state and federal carbon standards, adopting or strengthening renewable energy and energy efficiency standards, and increasing clean energy research, development, and deployment.

[With our safety, health, and daily lives tightly intertwined with electricity, it has become increasingly critical that we limit the risk of power outages from coastal flooding.]

Our grid is already susceptible to coastal flooding. Rising seas and increasingly severe storms mean that unless we take purposeful action to adapt to worsening conditions, the electric power sector could become even more vulnerable to crippling outages over time. With our safety, health, and daily lives tightly intertwined with electricity, it has become increasingly critical that we limit the risk of such impacts. We must, therefore, apply foresight to long-term grid planning and encourage the purposeful adoption of clean energy solutions that bolster the electricity resilience of our communities, while limiting the scale and scope of future climate impacts.

Union of Concerned Scientists

FIND THE FULL REPORT AND TECHNICAL APPENDIX ONLINE: www.ucsusa.org/lightsout

The Union of Concerned Scientists puts rigorous, independent science to work to solve our planet's most pressing problems. Joining with citizens across the country, we combine technical analysis and effective advocacy to create innovative, practical solutions for a healthy, safe, and sustainable future.

NATIONAL HEADQUARTERS
Two Brattle Square
Cambridge, MA 02138-3780
Phone: (617) 547-5552
Fax: (617) 864-9405

WASHINGTON, DC, OFFICE
1825 K St. NW, Suite 800
Washington, DC 20006-1232
Phone: (202) 223-6133
Fax: (202) 223-6162

WEST COAST OFFICE
500 12th St., Suite 340
Oakland, CA 94607-4087
Phone: (510) 843-1872
Fax: (510) 843-3785

MIDWEST OFFICE
One N. LaSalle St., Suite 1904
Chicago, IL 60602-4064
Phone: (312) 578-1750
Fax: (312) 578-1751

WEB: www.ucsusa.org

PRINTED ON RECYCLED PAPER USING VEGETABLE-BASED INKS