This grid moves energy, but not always reliably

More than three million people in Puerto Rico lost electricity in September 2017. Back-to-back hurricanes had just slammed into the island. Floods from Maria, the more powerful of them, knocked out many power plants. Winds and mudslides toppled towers and the power lines they carried. Explains climate scientist Juan Declet-Barreto: “Losing power is not merely inconvenient. In a climate-ravaged, tropical area like Puerto Rico, it’s life-threatening.”

With no electricity, hospitals had to delay surgeries. They couldn’t run many scans or tests, either. Without timely care, some patients died. Puerto Rico’s water-treatment plants lost power during Maria. As a result, people across the island lost access to clean water. And few people could cook or refrigerate food. Anyone lucky to have a portable stove or generator had to stand in long lines for fuel. Meanwhile, schools and businesses closed or cut their hours.

The *electric grid* is a term for the system that brings electricity from where it’s made to homes and businesses. Nearly everyone depends on that system. Yet as important as it is, this grid faces a host of threats. Some are simple and old. Others are complex and very new. Fortunately, engineers are working on them. Their research aims to keep the grid going, despite natural — and some decidedly unnatural — disasters. Other projects are looking at how to get the lights back on more quickly after power outages. Still more work looks for ways to rely less on fossil fuels (mainly coal, oil and natural gas) and instead generate more electricity using cleaner wind and solar energy. The cleaner sources might not only help slow global warming, but also make the grid more resilient to shutdowns.

Bad weather and more

The grid has many thousands of pieces and parts. Power lines can stretch across continents. The grid's electricity flows along many paths. Both its supply of energy and the public’s need for it can vary with the weather, time of day or day of the week.

Power engineers find it a challenge to keep such a complex system running smoothly. “We need to keep things perfectly balanced” says electrical engineer Chris Pilong. In other words, the electricity coming onto the grid at any time must match the amount being used. Pilong works at PJM Interconnection in Audubon, Penn. That company runs the grid for all or parts of 13 states plus Washington, D.C.

It doesn’t take much to throw the system out of whack. Too many people using too many air conditioners, computers, ovens and other appliances at the same time can disrupt the grid. Winds, falling trees and a build-up of ice can all bring down power lines. In fact, bad weather and other routine problems cause most U.S. power outages, a May 2018 report finds. It was authored by Grid Strategies. That’s an energy-analysis group based in Washington, D.C

PJM and other grid operators know problems can and will arise. That’s why they often have power plants on standby. Those plants can power up if another plant goes down. However, catastrophic storms can overwhelm most backup plans, says Declet-Barreto. And climate change could worsen such events and make them more frequent.

The sun can set off a different type of "weather" problem. Though rare, it can be severe. One 1989 power *blackout* in Quebec and the northeastern United States, for instance, was triggered by a *coronal mass ejection.* That's a powerful burst of gas and magnetic energy from the sun. This stellar storm hurled electrically charged matter into space that messed with Earth's magnetic field. This sent rogue electrical currents through parts of the grid.

Andrew Phillips is an electrical engineer. He works for the Electric Power Research Institute, or EPRI, in Charlotte, N.C. His group's mission: Toughen the electric grid "to put up with events that come and hit us."

For one project, Phillips' team is developing a special *porcelain* coating for electric wires. Teeny structures in the ceramic material won't let moisture stick. Water or ice "rolls off in a ball," Phillips notes. In freezing weather, this should prevent an ice build-up that could bring power lines down.

EPRI also is working on coatings to keep salt and other chemicals from harming *insulators*. These are materials that jacket power lines or equipment. They prevent a range of problems. (These include *short circuits* — accidental diversions of an electric current). If field tests go well, electric companies could start using some of these new coatings within a year or two.

Phillips and his team also work on robots, advanced sensors and remote-controlled drones. Such tools can pinpoint problems such as downed wires or too much heat along wires and in other grid equipment. Teams might then rush in for repairs before a fire breaks out, equipment shuts down or other problems take place.

Looking at the big picture

Protecting elements of the grid is good. But sometimes that may not be good enough. The grid contains thousands of parts. So a piecemeal fix for failing parts may not always be the best way to go, says Karagiannis at the European Commission's Joint Research Centre.

For example, floods can trigger explosions at electrical *substations*. (These centers control the voltage of the electric current. They make it possible for cities and neighborhoods to use the electricity that power plants generate.) One way to prevent flood damage is to build substations on higher ground. Another is to put walls around them to keep flood waters at bay.

But those actions deal with just one bit of the grid and only one threat, Karagiannis notes. His preference: Make sure each local area in the grid can get power from at least two sources. Then if a flood hits one substation, some other source could still supply power. So-called "smart grid" technologies could use sensors and computers to do the re-routing. He and his colleagues described this in a December 2017 report from the Joint Research Centre. Electric companies still would need to deal with flooding or other disasters, but many fewer people might lose electricity.

Using more clean-energy sources, such as wind and solar power, also should help strengthen the grid, Karagiannis and Declet-Barreto argue. Those and other renewable resources generated almost one-sixth of U.S. electricity in 2017, notes the Energy Information Administration in Washington, D.C.

Most electricity is generated by burning fossil fuels. That burning has been polluting the air and contributing to global warming. Cleaner forms of energy could curb those emissions. And here's another potential payback from such a change: Slowing global warming should cut the growing number of extreme storms and heat waves that themselves stress the grid.

Wind turbines and solar power also can be spread throughout a region. This is known as *distributed generation*. If a large power plant goes down or a storm crops up at one spot, unaffected generators could still provide power.

Puerto Rico's grid relies heavily on a few large power plants. A problem at any one of these — or at some link between them — could cause a widespread power outage. And that's what happened when hurricane Maria struck. A similar problem happened early in 2018. That's when a bulldozer brought down a line between two power plants on Puerto Rico's south coast. An island-wide power blackout followed.

In a June 2018 report on Puerto Rico's electric grid, the U.S. Department of Energy advised the island to produce more of its electricity from renewable sources and distributed generation.

Microgrids and batteries

As strange as it might sound, one way to make the electric grid stronger is to break it up into tiny pieces. But not all the time — just when there's a problem. A *microgrid* can add protection. These are systems that can make and distribute electricity to a small area. It's a type of distributed power generation.

Under normal conditions, a microgrid connects to the full grid. But in an emergency, it can break that link and power some small region on its own. New York University became one such microgrid when Hurricane Sandy hit New York City in 2012. While most of the borough of Manhattan lost power, the school's lights stayed on.

NYU could do this because it burns natural gas to heat water and its buildings. Some of the heat produced normally ends up as waste. The university uses that excess heat to run a *turbine*. It powers a generator that makes electricity. This bonus power even runs air conditioners for cooling.

Based on sunlight, weather and the time of day, solar energy and wind power produce varying amounts of electricity. People also tend to use more electricity at certain times most days, such as middle- to late afternoons.

Power companies pay more (and may charge more) for energy at times of greatest need — those periods of peak use. Homeowners or companies that own solar panels or a wind turbine would rather feed their energy into the grid during these peak times to earn more money. But much of their power may have been generated at non-peak times. Storing that power for sale later at peak periods takes good batteries.

"Batteries are really where we're going to see the future evolve," says Abramson. More battery power would let renewable energy replace more fossil-fuel power plants. Batteries can make renewable energy work like "always-on" power. Batteries also can become a back-up if the larger grid goes down. They can allow customers to temporarily break away from the grid and use the energy they've stored.

Toward that end, several projects at Case Western Reserve focus on what are known as flow batteries. Instead of a fixed-size battery, they store different liquids in separate tanks. When these liquid chemicals are allowed to mix, they react to produce electricity. In theory, the chemical tanks could be any size. And they should last longer than normal batteries. So flow batteries could supply a big building, a microgrid — or perhaps even a larger part of the grid.

Electric cars will be part of the grid's future too, notes Laura Cozzi. She's an economist and environmental engineer in Paris, France. There, she works for the International Energy Agency. Batteries power these vehicles. People often charge them up at off-peak times, when the electricity costs less. If enough people get electric vehicles, many of those batteries could work together with the grid.