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High Country News
For people who care about the West

The power grid may determine whether we can kick our carbon habit

by Jonathan Thompson

Minutes before 4 p.m. on a sizzling September day two years ago, right at the time when they were most needed, San Diego's air conditioners suddenly died. Thousands of television and computer screens also flickered into darkness. Stoplights stopped working, gas stations ceased pumping, and traffic slowed to a snarl. Trains ground to a halt and planes idled on the runway. Wastewater treatment pumps shut down, spewing some 4 million gallons of raw sewage into the Pacific. Around 2.7 million "customers" -- amounting to anywhere from 5 to 7 million people -- lost their power, with some remaining in darkness for 12 hours or more.

As commuters extricated themselves from highway gridlock, and batteries faded away on millions of electronic devices, folks flocked to the handful of neighborhood bars that — thanks to generators — were able to keep their lights and refrigeration going. There, they could drink away the darkness and speculate as to what had caused this sudden plague of electrical impotence.

Many assumed it was terrorism -- San Onofre Nuclear Generating Station had been sabotaged, they said, or the North Koreans had set off an electromagnetic pulse that fried the grid, or maybe an Iranian cyberattack had crippled the computers that keep the modern world humming. Others blamed solar flares for disrupting the cosmic electromagnetic field, or suggested that a more earthly storm had caused distant wind farms to go haywire. Then again, perhaps a raven just landed on the wrong piece of equipment out in the desert and got fried, its death rattle reverberating through the transmission lines all the way to San Diego.

Their guesses weren't stupid or outlandish -- they all involved genuine threats to the power grid. But the biggest power outage to hit the Western Grid in a decade actually started hundreds of miles east, at a substation outside Yuma, Ariz. And it began not with a bang, but with a misplaced checkmark that ultimately crashed Southern California's electrical system.

That event was no freak occurrence. It could have happened anywhere, at any time, in the complex machine that generates, transports and delivers power to nearly every corner of the nation. Our proliferating air conditioners and gadgets have put new pressures on the grid, as the demand for electricity has grown twice as fast as the infrastructure needed to carry that power. Now we're straining it even more by trying to get that power from cleaner, more fickle sources. Meanwhile, the electrical grid -- the circulation system of today's modern age -- is still stuck back in the '80s, like one of those guys from high school who clings to a mullet haircut and his Dungeons and Dragons dice. Compared with what's to come, some say, San Diego's blackout might seem in retrospect no more than an excuse for a candlelit block party.

A 6-foot-high, gleaming white cross stands alongside a mostly empty road near Tonapah, Ariz. At its foot is a tiny Nativity scene, and an angel on the end of a stick. The shrine's purpose isn't clear, but its location makes it seem like an altar dedicated to the patron saint of electricity. Behind it, rising from the desert scrub, are the elongated containment domes of Palo Verde Nuclear Generating Station's three reactors. And beyond them lie two huge fields of photovoltaic panels and three natural gas power plants. There is probably no other five-square-mile patch on the planet with more electrical generating capacity.

Yet just as critical is the network of transformers, switches and wires through which all that electricity flows. Congregated just north of Palo Verde, a dozen high voltage transmission lines slice the sky, crackling ominously as they link up in the giant, skeletal "switchyard." The lines, gently curving toward earth between each giant tower, lead inward and outward in every direction, like spokes on a bicycle wheel, making the Palo Verde/Hassayampa switchyard the biggest power-trading hub and crossroads in the region -- the electrical Union Station of the West.

Among these lines is the 500-kilovolt Hassayampa-North Gila, or H-NG, line. On Sept. 8, 2011, about 1,300 megawatts -- almost half of all the electricity imported into Southern California that day, enough to power about 1.5 million homes -- flowed westward through the H-NG line. All that juice was needed because it was so hot; the mercury hit 115 degrees in El Centro, and even sea breeze-cooled Oceanside reached 88. By mid-afternoon, air conditioners cranked across the Southwest, while irrigation pumps pushed water onto the half-wilting lettuce in California's Imperial Valley.

On its way to San Diego, the H-NG line passes through the North Gila substation outside of Yuma. Just before 2:00 that afternoon, Arizona Public Service, the substation's operator, sent a technician out to fix a capacitor bank, used to stabilize voltage in long-distance lines. As he worked -- we'll call him Kilo Watt, since the utility has kept his or her identity secret -- he marked each completed step on a checklist to make sure that he didn't miss anything. But then Watt, distracted, put a mark in the wrong place, causing him to skip one critical step: bypassing all that juice around the capacitor bank so that he could work on it safely.

At approximately 3:27 p.m., he cranked open the disconnect switch, an event that should have been uneventful. Instead, the 500 kilovolts still running through the line began to arc -- the current leaping through the air, much the way the evil Emperor zapped Luke Skywalker in *Return of the Jedi*. Watt continued cranking the switch, hoping to manually break the arc. Instead, the writhing electrical serpent grew larger, and some 43 milliseconds later, the entire H-NG line "tripped," like a home circuit breaker, and shut down.

The chain reaction, which would climax just 11 minutes later, had begun.

But the roots of the San Diego blackout are deeper than that Yuma substation. In order to really understand what happened, we need to travel back in time to the grid's primordial days among the hardrock mines of the Rocky Mountains.

During the spring of 1891, in a canyon in the mountains southwest of Telluride, Colo., icy water from the South Fork of the San Miguel River rushed through a funnel-like tube, crashing into and turning a Pelton waterwheel attached to a nearby 100-horsepower generator in the Ames hydropower plant. As the turbine spun, it generated 3,000 volts of alternating electrical current, which was then shipped by copper wire three miles to a huge motor in the Gold King Mill, perched on the side of a treeless slope far above.

Even as the motor roared to life, a battle raged over the future of what would become the electrical grid. On one side was direct current, or DC -- the kind generated by batteries, lightning and static electricity -- which Thomas Edison had used to light up a Manhattan neighborhood in 1882. On the other side of this so-called War of the Currents was AC, alternating current, embodied by Nikola Tesla, the eccentric Croat genius who had worked for and later been spurned by Edison.

Edison, in a morbid fit of desperation, played the danger card. He used alternating current to publicly electrocute house pets, sheep, horses and, finally, a retired circus elephant named Topsy, that, to be fair, had already been sentenced to death for killing three of its trainers. Topsy's demise was immortalized on film, and today you can find a YouTube video of the smoking elephant in all its grainy, demented glory. Yet even fear didn't help Edison's cause. After traveling at useful voltages for about a mile, DC petered out. AC, meanwhile, could be "stepped up" to high voltages in order to push it across long distances, then "stepped down" with transformers for use in home or industry. The Ames power plant, one of the first commercial industrial applications of AC, dealt a severe blow to DC, and was a seed of what today is a mostly AC grid.

The owners of the Ames plant strung new lines from the plant to more mines, then to town and beyond, becoming the Telluride Power Co., which would own and operate several generating stations and hundreds of miles of transmission lines. Similar systems, built by similar utility monopolies, grew up around the nation.

Until World War II, each utility's grid was fairly self-contained, with fossil-fueled or hydroelectric power plants located close to the residents and industries that used their power. But in the middle of the 20th century, as long-distance transmission technology improved, the utilities oozed outward, building huge coal power plants in the Interior West near the mines, which sent power hundreds of miles across mesa and canyon to Los Angeles, San Diego, Phoenix. Meanwhile, each of the three distinct grids -- the Western, Eastern and ERCOT, or Texas -- became more internally interconnected to increase reliability.

The Western Grid's 240,000 megawatts of generating capacity come from sources as varied as dams in British Columbia to coal-fired plants in northern Mexico, traveling on 120,000 miles of high voltage transmission lines, plus countless miles of distribution lines, the smaller wires that deliver power to your home. As it expanded from one-town micro-grids to today's weblike Leviathan, the grid grew in an organic fashion, with new components welded on to the old ones, like additions slapped on to trailers in the rural West. Hydropower from that same Ames plant now travels alongside coal- and solar-generated electrons in transmission lines built in the 1980s.

Operation and regulation of the grid is a similar mishmash. In the late 1970s and early 1980s, as the Bell telecommunications monopoly was dismantled, a similar effort was made to transform electricity from a service provided by monopoly utilities into a commodity traded on an open market. For the first time, non-utilities were able to build power plants, mostly natural gas-fired, and sell power to the utilities. In 1998, California dove into the open-market concept by opening the California Power Exchange. But unscrupulous operators gamed the system, with some producers creating false power shortages in order to up prices, and the infamous Enron engaging in its own crazy scheme of shipping power out of state, then back in, to dodge state price caps. That drove the utilities to the verge of collapse, caused "brownouts," led to the recall of

California Gov. Gray Davis and, in 2001, ended the power-exchange experiment.

Today, about 80 percent of California's grid is run by the California Independent System Operator, a nonprofit entity that allows wholesale power producers access to the grid. It's essentially still the open market, though purportedly less prone to gaming than the earlier exchange, and follows the same model as in most of the Eastern and Texas grids. The rest of the West, though, is stuck somewhere in between the old model and the new, with monopolized utilities -- a mixture of investor-owned, municipal and co-ops, each of which is regulated differently -- still running the show.

Federal policy -- or the lack thereof -- hasn't helped. The authors of the 2011 MIT report, *The Future of the Electric Grid*, bemoan the fact that in other industries such as natural gas, telecommunications and airlines, federal policy was reformed after the 1970s to reflect market realities. "In contrast," they write, "despite dramatic changes in the electric power sector, federal policies established in the 1930s ... still play a central role in that sector." In other words, just as new pieces have been added onto the old grid, new policies have been piled on top of antiquated ones.

It sounds chaotic, and as the San Diego outage and others reveal, it often is. When the H-NG power line shut down back at Palo Verde, the electricity sought out the path of least resistance towards its destination, which in this case was a tangle of lines in the inland desert that weren't equipped to handle such high voltages. Seconds after that arc had crackled over the Yuma substation, lines, transformers and other equipment from Mexico up into the Imperial Valley were pushed to their limits, and began to fail. Some physicists will tell you that this phenomenon is an inevitable consequence of a grid that has evolved to operate under principles of self-organized criticality, prone to the same sort of non-linear, cascading cataclysm as wildfires, avalanches or earthquakes.

But for the most part, this gargantuan contraption is so seamlessly reliable that most of the millions of people who use it forget it exists. A small army of technicians is dedicated to keeping it that way, perching in front of monitors in rarely seen control rooms around the country.

On the south end of Scottsdale, Ariz., a low-slung, mostly windowless brick building sits back from the street between a Spanish colonial apartment complex and an upscale mobile home park. No sign tells the curious passerby what might lie within, yet the gleaming razor wire atop the surrounding wall raises unsavory possibilities. A guard is there to stop the curious, and if she fails, the device that pops out of the pavement and rips your tires to shreds will definitely succeed.

This is the operations center for the Salt River Project, one of the nation's largest municipal utilities. The executives and the clerks hang out at another building a couple miles away in Tempe, but this is where the real grid action goes down. When potential crises strike, operators here do their best to keep them from spreading. (SRP wasn't hit by the San Diego blackout, but since it operates the Palo Verde switchyard, it was peripherally involved.) Most of the time, though, technicians spend their time keeping power flowing to some 1 million customers in the Phoenix metro area from the utility's power generators, which range from shares in coal plants as far away as northern Colorado to small hydroelectric facilities on Scottsdale's canals.

You'd think the stress of keeping all those air conditioners running would wear on Mark Avery, SRP's grid manager. But he's fit, trim and looks no older than 50, with a full head of salt-and-pepper hair. When he tells me that he started his career as an operator trainee in 1974 at Navajo Generating Station in northern Arizona, I have to ask him to repeat himself.

Of all the baffling facts about the grid, perhaps the most mind-boggling, Avery tells me, is its constant need to be kept in balance. "The Western Grid is like a giant bucket," he says, "with a bunch of spouts running in and out, and you have to keep the water level constant." That is, the amount of electricity being fed into the Western grid by thousands of generators must always be equal to the load — meaning the amount being used by its millions of customers. Lose the balance, and the frequency of the alternating current will drift away from the optimum 60 cycles per second, which could cause equipment to fail and result in outages. In the Western Grid, that balancing act is performed simultaneously by 38 different authorities; Avery and his colleagues oversee one of them.

Each day, using models based on weather forecasts and historical patterns, SRP's marketing team draws up a demand forecast for the following day, and schedules generation from SRP's own array of generators, (or from neighboring utilities if it's cheaper) to "follow" the demand curve. They also schedule plenty of extra backup power -- usually from fast-firing natural gas or oil "peaking" turbines -- to make up for forecast errors or to compensate for a downed power line or plant. The grid operators are then responsible for implementing the daily plan, and for tweaking it as it unfolds with hourly forecasts and scheduling. Over the course of the hour, they make up for energy imbalances -- or deviations from the plan -- by turning generation up or down. Minor, second-to-second bobbles are "regulated" automatically by software, typically by adjusting Hoover Dam's hydroelectric turbines.

Over time, this balancing act has become more and more challenging. Four decades ago, the greatest demand came from big industrial facilities like factories or mines that ran round-the-clock or on a set schedule. The generation sources were also steady and predictable, coming mostly from "baseload power" — meaning coal or nuclear.

In the 1980s, the demand side of the equation began to change radically. As manufacturing moved overseas and people poured into the region, residential and commercial customers -- whose electricity demand curve has bigger daily ups and downs -- took up a larger share of overall demand. The air-conditioning revolution arrived at the same time: Between 1980 and 2009, the percentage of Western homes with air conditioning shot up dramatically, so that now there are more than 18 million homes with power-gulping cooling systems on the Western grid. On a summer's day in the desert Southwest, the overall electrical load at 5 p.m. can be twice what it was at 5 that morning, mostly due to the energy it takes to cool us all down; it can account for about 30 percent of total peak electricity demand in California or Arizona.

The new sources of power feeding into the grid are even less predictable. Solar and wind energy can swing up and down dramatically during a single hour. A massive dust storm or thunderheads moving in on a summer afternoon can cut production from a photovoltaic array by 80 or 90 percent in a matter of seconds. Wind-power swings are less violent, but can be huge: California's collective turbine output can vary by 3,000 megawatts or more over the course of a day, and by 100 megawatts in an hour. The greater the percentage of solar and wind in the mix, then, the greater the potential for errors in the day- and hour-ahead scheduling, and the more potential for imbalances, instability and outages.

"It's not the same kind of dispatchable, turn a lever, decide a day ahead what you're going to run the next day with any kind of certainty system that we're used to," says Brian Parsons, transmission and wind integration group manager at the National Renewable Energy Laboratories in Golden, Colo. Utilities typically respond to that uncertainty by adding two megawatts of natural gas backup capacity for every three megawatts of added wind power, chalking up the expense of building and operating the reserve to wind's "ancillary costs."

For Mark Avery, the variability is virtually a non-issue, because only about 3 percent of SRP's energy mix comes from solar and wind. But in California, where the state has required utilities to get 33 percent of their power from renewables by 2020, it's been a significant source of hand-wringing, as officials scramble to make sure they have enough reserves to cover wind and solar's variability. Fossil-fuel pushers regularly warn that replacing their steady plants with fickle solar and wind will plummet us all into darkness. They point to Germany, which now gets more than 20 percent of its power from non-hydroelectric renewables, primarily solar and wind. That has pushed the transmission system to "the brink of capacity," according to that grid's federal overseer, and renewables-caused voltage swings have resulted in machine malfunctions at Hamburg factories.

But is the problem really with renewables, or with the grid and the way it's run?

In the spring of 2011, rivers in the Pacific Northwest swelled when an unusually ample snowpack melted, and the water backed up behind the big electricity-generating dams of the Columbia River and its tributaries.

The Bonneville Power Administration, which manages the dams and its own grid-balancing area, either had to run that extra water through the turbines, and put thousands of megawatts of additional power into the grid, or spill it over the dams without generating electricity. The decision seemed simple -- produce the power and sell it for a bundle, right? But it wasn't, because of the limitations of the grid and the presence of native fish.

Even during normal water levels, the collective power plants and dams in BPA's balancing area generate far more power than its customers can use. In late April of this year, for example, the dams and a growing number of wind farms together cranked out as much as 6,000 megawatts -- enough for some 6 million homes -- more than BPA's customers could use. So both BPA and many of the wind farms have contracts to sell that power elsewhere, much of it going directly to California by way of the Pacific Intertie, an 850-mile-long, high-voltage DC "electricity superhighway" from near the Columbia River's Dalles Dam down to Los Angeles.

As the massive 2011 snowmelt began, power consumption everywhere was down, due to a combination of the recession and mild temperatures in the Northwest and California. The grid operators had to figure out how to curtail power production in order to maintain balance. Spilling the water over the dams, though, would raise the percentage of dissolved gases, such as nitrogen and oxygen, in the river downstream, which, in turn, could kill migrating endangered salmon with something called gas bubble trauma. So the power behemoth forced the wind farms, which rely on BPA's transmission to get their product to market, to shut down so that it could keep its hydropower operation going full-tilt.

For nearly two months, 2,000 wind turbines sat idle, causing their owners to lose between $2 million and $5 million in potential revenue, even as the dams -- not to mention coal plants in other parts of the West -- continued to generate juice. The wind companies, claiming discrimination, sued BPA and filed a formal complaint with the Federal Energy Regulatory Commission, or FERC. Save our Wild Salmon intervened on wind's side, arguing that BPA was using the salmon-saving argument without basis -- the group believes that the benefits to fish from spilling water offset the harm from gases -- to keep from having to unload its hydropower at "negative prices" (paying others to take the electricity, a not uncommon practice in electricity markets). FERC ruled in favor of wind and sent BPA back to the drawing board. Last year, BPA curtailed far less wind power and compensated wind companies for resulting losses to the tune of some $3 million (mere chump change for BPA, whose total budget is around $4.4 billion).

Most observers agree that's not a sustainable solution; the FERC commissioners noted in their ruling that an expansion and improvement of the grid, i.e., more transmission, could alleviate the pain of all the parties involved by opening up more pathways to market that surplus power. In so doing, the commissioners allied themselves with a growing group of environmentalists who want to change the grid by integrating massive amounts of renewable energy to help combat climate change. Enter the grid-oriented greens.

Amanda Ormond has been involved in energy issues for over two decades, including a seven-year stint as director of the Arizona State Energy Office, and a subsequent career as a consultant, working mostly with renewable energy companies. Today, she is considered one of the region's foremost experts on solar power and is a member of the Western Grid Group, an independent organization made up largely of former utility regulators and state officials, who are devoted to transforming the grid to increase the amount of renewables in our energy mix. Ormond has a wholesome look -- long brown hair cut straight at the bangs, freckles on her nose -- that belies the intensity with which she thinks and talks about these issues.

To those who fret about the destabilizing effects of adding too much solar and wind to the grid, Ormond has a quick response: Cooperate, share and take advantage of the West's geographical diversity to iron out those variable output curves. The concept is called geographical smoothing, and it's been embraced by everyone from grid-oriented greens to scientists and engineers. "The West is very diverse, and that's a good thing," says Ormond. "You want plants all over the place, because the wind's always blowing somewhere."

"The more geographically diverse your (wind and solar) systems are, the less variability," says David Mooney, center director at the National Renewable Energy Laboratory. In other words, a dip in output by a wind farm in Tehachapi, Calif., can be offset by turbines in Wyoming; ditto for a solar farm in New Mexico, which might reach peak output two hours before a facility near San Diego. It's also easier to predict fluctuations over a broader area: An MIT study found that when a geographic region's diameter is increased, forecast errors are reduced by as much as half.

To help accomplish this smoothing, grid-oriented greens would like to see the West's 38 balancing areas join together into an "energy imbalance market," or EIM, that would allow them to share both renewables and the natural gas-fired plants that back them up. Electricity sales would take place on a five-minute schedule, rather than an hourly one, because that's more in rhythm with the ups and downs of solar and wind. That would alleviate the need for each utility to build its own backup plants, and would therefore lower the cost of integrating renewables into the grid. "Say a utility has 50 generators," says Ormond, "but there are 4,000 in the West. If you had access to all 4,000, it would be more efficient."

"For renewable energy, it makes zero sense to stay in your small area," says Tom Acker, a professor of mechanical engineering at Northern Arizona University. He compares the utilities' current approach — building up all their own natural gas reserve plants — to buying a big SUV for everyday use, even though you really need it only a few days out of the year. Under an EIM, a bunch of balancing utilities would be able to share their renewables and that SUV, not to mention the transmission lines. "The progressive way of thinking is to share ... that is absolutely crucial or we'll never get renewable energy into the system."

Indeed, an energy imbalance market, says Cameron Yourkowski, policy analyst at Renewable Northwest Project, a Portland-based advocacy group, would have allowed wind operators or BPA to put all that surplus power up for bid during the spring of 2011.

EIMs are slowly taking hold in the West. Xcel Energy, which serves most of Colorado's heavily populated Front Range, is pushing for an energy imbalance market to expand the pool of reserves -- both fossil fuel and renewable -- from which it can draw to back up its burgeoning quiver of wind power. And in February, the California Independent System Operator and PacifiCorp announced that they would create a real-time energy imbalance market by autumn of 2014.

But a well-connected market requires a well-connected grid, and that's the catch: The current fossil-fuel-centric grid has left many of the windiest, sunniest places marooned, without a way to get solar and wind power to population centers. How much new transmission is actually needed remains uncertain. "Local groups will say we can do this with rooftop solar," and therefore minimal additional transmission, says Gary Graham, of the Boulder-based Western Resource Advocates. "It's just not the case. You can't get that many solar panels on roofs that fast in the West" to reach his group's goal of 50 to 80 percent renewables by 2050. "You need utility scale." And that, says Graham, could require up to 25,000 miles of new transmission in the West alone.

In today's climate, that would be a herculean feat. Try stringing 600 miles of cable, held up by hundreds of 200-foot towers, and someone will try to stop you, guaranteed. Transmission is notoriously difficult to build because a single line can cross so many jurisdictions, from private land, where landowners only get a one-time payment for an easement that will last forever, to federal, tribal and state lands. While the feds can push a natural gas pipeline across multiple states using condemnation powers, they can't do the same with transmission lines, thanks to a 1935 law. A provision in the 2005 Energy Policy Act established "national interest" transmission corridors -- including one leading from southern Arizona into the San Diego area to alleviate congestion there -- through which the feds could, theoretically, have backstop condemnation authority if the states dawdled. However, courts sympathetic to environmental concerns have mostly hamstrung the law.

About two dozen major interstate transmission lines to enable renewables are in various stages of permitting in the West, but none are proceeding very quickly.

Colorado billionaire Phil Anschutz wants to build a huge wind farm near Rawlins, Wyo., and ship the power to California via Las Vegas via a 600 kilovolt, $3 billion direct current line, the TransWest Express. Environmentalists aren't thrilled about 1,000 turbines in sage grouse habitat. And at a recent pro-transmission conference in Denver, Bill Metcalf, of the Rocky Mountain Farmers Union, balked at the TransWest line because it is direct current -- meaning few or no on- and off-ramps en route -- so other wind farms along the way won't be able to connect to it, making it exclusively Anschutz's electricity highway. The proposed Sun Zia line from wind-rich central New Mexico to the Tucson area has hit opposition because it could cross through environmentally sensitive areas such as southern Arizona's San Pedro River Valley. In California, a relatively short line, from the wind farms of Tehachapi to the Los Angeles grid, is on hold thanks to resistance from a well-to-do community in its path.

In 2010, FERC tried to push grid expansion by encouraging stronger regional planning efforts, and bringing in stakeholders at an earlier stage. Ormond is somewhat optimistic about how that's working in the West. "Instead of looking just at voltage flows and contingency plans," she says, "they've been looking at: What do we need, holistically, going forward? Let's look at all these possible futures and concentrate on building the paths that are most necessary."

Stringing wire all over the landscape is not the answer, says Ormond, though some wire must be strung. Even more important is putting the tangle of wires we've already got to better use. "If we do a combination of using the stuff we have better, doing some better sharing, adding new technology products like EIM ... then we're not going to need tons and tons of transmission," says Ormond. Operators have to make the grid "smarter" by outfitting it with better monitoring equipment and automating more of its operations: During the San Diego outage, controllers in each of the five affected balancing areas had to call each other on the phone to figure out what was going on. Transmission lines that are filled to capacity only during a few hot days in the summer should be opened to wind and solar for the rest of the year. Rooftop solar and other distributed generation sources should be beefed up with strong incentive programs. Viable energy storage would solve nearly all of the problems posed by intermittent renewables. But technology on a large-enough scale is still years, maybe decades, away.

If the green gridders are a faction of the environmental movement, they are not fire-in-the-eyes activists; they're more like technocratic problem solvers, working behind the scenes with environmental groups, utilities and state and federal regulators to make the grid less carbon-intensive. They're making progress, though it's slow. Rather than opposing new transmission projects outright, as they might have once done, environmental groups such as The Wilderness Society and the Natural Resources Defense Council have taken a role in the FERC-pushed, stimulus-funded transmission planning process and actively push projects that will bring more renewables to the grid so long as their aesthetic and environmental impacts are deemed acceptable.

"I think we are moving in the right direction ... toward a more regionally integrated system," says Ormond. But she worries that progress might be impeded by deepening political partisanship; Ormond worked under two Republican governors, and Arizona's current solar incentives were put in place by a GOP Arizona Corporation Commission. Today, however, Republicans routinely use renewables -- especially news-making failures, such as Solyndra -- as a whipping boy. "Clean energy does not need to be a partisan issue. In fact, it's really bad if it is," she says. "Bottom line is, it's not good for the country."

As the spark that lit the San Diego Blackout hurtled full-throttle across the electrical landscape, various lines, substations and generators tripped off-line, throwing the system out of balance. Grid operators tried to extinguish the flare-ups by cranking up peak generators, but they weren't quick enough. Meanwhile, the various collapses in the system forced virtually all of San Diego's electricity onto one set of power lines, running from San Onofre Nuclear Generating Station southward into the city. At 3:38:21 p.m., the lines tripped, and San Onofre's reactors shut down. Milliseconds later, all of Southern California was without power.

The ensuing 12 hours of darkness cost the city and its businesses an estimated $100 million for everything from spoiled food to lost productivity to government overtime. Officials at San Diego Gas & Electric quickly used the failure to their political advantage, speculating that if the Sunrise Powerlink -- a controversial power line bringing solar and wind power 120 miles from the Imperial Valley west to San Diego -- had been in operation, it might have prevented the outage or helped facilitate a quicker recovery. (The Powerlink started carrying wind power from the also-controversial Ocotillo wind farm this January.)

It took regulators six months to sort through what had happened, and in spring 2012, they released a report detailing the to-the-millisecond timeline, and assigning blame for the outage on poor communication, bad procedures and sloppy planning. Grid-oriented greens were at least somewhat validated: Had better "real-time situational awareness," or a smarter grid, been in place, the whole thing might have been avoided, according to the report. A good energy imbalance market might have given grid operators quicker access to backup, alleviating some of the pain.

One thing is certain: More blackouts will occur. California grid operators worry they could come this summer: San Onofre has been offline for repairs (unrelated to the 2011 outage) since January 2012, and no one can be certain when it will be back in service.

But perhaps the biggest, most insidious threat is our warming climate, which is already attacking the grid on many a front, according to the report, *Global Climate Change Impacts in the United States*. Weather-related outages have increased tenfold in the last two decades, and it's only bound to get worse. Hotter days mean bigger peak loads; higher loads and higher temperatures strain power lines, causing them to lose more of the electricity flowing through them and to sag into vegetation: The West's biggest outage thus far put some 7.5 million people across seven states into the dark when, during a triple-digit heat wave, a line near Portland sagged into a filbert tree, sparking a cascading outage. And of course, heat and drought exacerbate wildfires, which can take out major power lines as happened in 2007 in San Diego, as well as diminish hydroelectric capacity from reservoirs. Meanwhile, it's our fossil-fueled electricity system that emits the largest share -- some 40 percent -- of greenhouse gases.

We may have reached the point at which adaptation is the best approach. While shopping malls across San Diego shut down entirely, and Hooters turned away customers, some bars fired up generators to keep the lights on, and the customers poured in. An Albertson's grocery store kept the coolers humming with a natural gas-powered fuel cell and had a banner day. They had all effectively thumbed their noses at the 20th century's finest engineering achievement and instead gone back in time to the days of the ultra-local Ames micro-grid. By doing so, they breezed right through what so many others experienced as a catastrophe.

On Sept. 8, 2011, Sasha Seyb, a freelance decorative artisan in her late 30s, who has lived in downtown San Diego for several years, was driving from work on the coast to her home when the outage hit. She first noticed that streetlights were blinking, and then realized that neither her radio nor her cellphone worked. Her first reaction was to panic, thinking some sort of major catastrophe had hit. But after she got home, and the news circulated that it was merely a technical glitch way over in Arizona, she and her whole neighborhood simply breathed a sigh of relief.

"Everybody was outside, the kids were all eating ice cream, adults were drinking their beer and grilling steaks," she says. "It was a giant block-party barbecue. It was a really neat vibe, a nice feeling. And that night, you could actually see the stars for once."

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