Reflections on the Mojave Sun
By Bruce Barcott

In the cool of the desert night, Jamey Stillings and I roll out of Las Vegas into the dark Mojave Desert. It's a little past four in the morning. With the glitz of the Strip in our rearview, we follow Interstate 15 south across dry desert lakes and wide alluvial fans, through miles of scrub and sand. The road is lonely, just a few long-haul truckers and crapped-out gamblers limping home to Los Angeles. It's a quiet time for humans, but out there beyond the asphalt there's action in the desert. Owls and coyotes are hunting. Bats are darting after moths. Cacti and creosote open their pores to drink in the air's moisture. Now and then a sign marks a lonely outpost: Sloan, Jean, Primm, once-hopeful townsites that never matured into towns. About eight kilometers past Primm, on the California side of the border, we turn onto a road leading into the faint outline of the Clark Mountains. Our headlights catch a sign: Ivanpah Solar Project.

As I write, Ivanpah stands as the largest concentrated solar power installation in the world. It's also one of the most controversial. The $2.2 billion project, commissioned in January 2014, is capable of producing 392 megawatts, enough electricity to power 140,000 homes during peak demand. Like a lot of megaprojects, it took a consortium of major players to make Ivanpah happen. BrightSource Energy designed it. The American people, under the auspices of the US Bureau of Land Management, let out the public land for lease. Ivanpah's owners—NRG (50%), Google (30%), and BrightSource (20%)—financed and own the project with help from a federal government loan guarantee. Bechtel built it. NRG operates it. PG&E and Southern California Edison purchase its power under 25-year contracts. Everything about the project is big.

It's so dark that I can't make out where we are. We're among the heliostats before I realize it. Heliostats are the 173,500 pairs of mirrors that reflect the sun onto Ivanpah's three power towers. Each tower is 140 meters (459 feet) tall, four-fifths the height of the Washington Monument. The mirrors stand upright at night in what their keepers call "sleep position," so when you drive among them in the pre-dawn gloaming it's tough to make them out, what with the hall of mirrors effect and all. Dark reflecting dark reflecting dark...

"It's like an immense art installation," I say to Jamey.

He nods.

Jamey's been documenting the creation of Ivanpah for years, so these mirror-made mirages are nothing new to him. But coming upon them with fresh eyes, my mind can't help but think of the monoliths of Easter Island, and the light-and-sensory artwork of James Turrell. I can't wait to see what happens when the sun comes up.

We pass through security and find our way to NRG's control room, a spacious chamber with computer consoles, dozens of flat screen monitors, and about ten control room engineers. It's 4:46 in the morning. We're here just in time to see the night crew fire up the auxiliary boilers.

The "aux boilers," as the engineers call them, are fueled by natural gas. If the night crew times it right, the aux boilers help the main boilers reach operating pressure just as the sun hits the mirrors. This pre-heating lets the engineers maximize Ivanpah's solar output, sending renewable power to the grid immediately, instead of using the first hour of sunshine to prime the system.

At 5:45 in the morning, the night crew hands over control to the day staff. They exchange notes.

"Unit 1?"

"Blowdowns are all reset. Ready to go."

Ivanpah is one complex made up of three distinct units. Each has one power tower surrounded by 50,000 to 60,000 heliostats.

"Unit 2?"

"Unit 2, we're ready, our boiler's coming up."

Unit 3 is down for maintenance but will come online later in the morning.

Dawn arrives. Out in the desert, nocturnal owls, rats, mice, and bats retreat to their burrows. They want nothing of the day's blasting heat. The heliostats, controlled by computers, slowly rotate into position. The first faint light shines on the dark band of the power towers.

At 8:02, Unit 1 comes online. It starts small, generating six megawatts. Then nine. Then eighteen. At 8:14, an engineer calls from across the room, "We're synched!"

Solar power shoots down the line. In San Francisco, customers of PG&E turn on their radios and heat up their coffee with Ivanpah energy. In Los Angeles, Southern California Edison brightens traffic lights and gives air conditioners their hum with power from the sun.

LIFE IN THE DESERT

The Mojave is a deceptive place. The driest and smallest of North America's four deserts—it's a bit smaller than Ireland—the Mojave encompasses an extreme range of topography and temperature. The gentle snow-capped peak of Mount Charleston rises to 3,632 meters (11,916 feet), a mere 46 kilometers (28 miles) west of Las Vegas. It's part of the Mojave just as much as Death Valley, the lowest (86 meters, or 282 feet, below sea level) and hottest place in the United States. In outline, the Mojave is lumpy and misshapen, like a deerskin tossed over the meeting point of California, Nevada, and Arizona.

Its defining quality is the difficulty of sustaining life within it. Anyone who's round-tripped from Los Angeles to Las Vegas knows the Mojave as the journey's major crossing, a sandy sea that requires preparation, supplies, and good luck to reach the other side. "The Mojave is a big desert and a frightening one," John Steinbeck once wrote. "It's as though nature tested a man for endurance and constancy to prove whether he was good enough to get to California."[1]

The animals and plants that survive here are finely adapted to do so. The jackrabbit's paddle ears are lined with shallow blood vessels, which allow the air to cool its blood. Kangaroo rats seal their burrows to capture the precious moisture released when they breathe. Owls and vultures obtain water through the blood of their prey. The desert tortoise, which often digs its burrows under the shade and camouflage of creosote bushes, survives the harshest seasons of the Mojave by estivating: it gorges on cacti, grasses, and wildflowers during spring, then disappears into the cool darkness of its underground home and waits out the heat of summer.

Native Americans have lived in areas of the desert for at least 10,000 years, but humans have traditionally been sparse on the land. Until recently, our need for water limited human habitation to areas where it pooled and ran. The Mojave Indians, congregated mostly along the spine of the Colorado River, a fact reflected in their traditional name, *Pipa Aha Macav*, which means "the people by the river." The nomadic *Chemehuevi* people, whose traditional lands include the Ivanpah Valley, are known as "those that play with fish." Human impacts were minimal until the arrival of miners and ranchers in the mid- to late-1800s. The Clark Mountains attracted swarms of grubstakers seeking silver, borax, copper, lead, tungsten, and fluorite. In the 1880s, the mining town of Ivanpah popped up near where the Ivanpah solar complex stands today. The town did a brisk trade: saloons, a butcher shop, hay yards, hotels, and a weekly newspaper. Around 1900, the minerals ran out and so did the people. The town was abandoned and the desert reclaimed the space.

Just as the seemingly empty and forbidding Mojave actually thrives with life, a desert that can appear bereft of industry in truth supports—and sometimes suffers—quite a lot of it. Though the town of Ivanpah never returned, the mining industry still survives here. Just over the shoulder of Clark Mountain sits the open pit Colosseum Mine, which operated from the early-1980s until 1993. A few kilometers south of Ivanpah is one of America's largest rare earth element mines, which produces the metals used in smartphones, high-efficiency light bulbs, and photovoltaic (PV) cells. Mining is no longer the major industry here, however. Today the area's economic engine is power production.

Look across the landscape. Just over the border in Primm is the Bighorn Generating Station, a 598-megawatt natural gas power plant completed in 2004. Next to it is the Silver State North Project, a 50-megawatt photovoltaic solar farm. When it opened in 2012, Silver State North became the first power-producing solar project on federal land. It's expected to be followed in the next few years by Silver State South, a 250-megawatt sister project, and by the 300-megawatt Stateline Solar Farm Project, a PV farm tucked between I-15 and the Ivanpah heliostats. The Ivanpah Valley is on track to become one of the most concentrated centers of power production in the American West.

RENEWABLE POWER IN THE DESERT

What does this activity mean to the desert landscape itself? It's complicated.

Let's start with the big picture: climate change. Prior to the Industrial Revolution, the Earth's atmosphere contained about 275 parts per million (ppm) of carbon dioxide. After centuries of burning coal and other fossil fuels, that figure rose to 316 ppm in 1959, the first year reliable carbon records were kept at the Mauna Loa observatory in Hawaii. We hit 350 ppm around 1990. In 2014, we're at 397 ppm and rising at a rate of two ppm every year. Carbon dioxide, methane, and other greenhouse gases are raising the Earth's global mean temperature, melting the polar ice caps, raising sea levels, acidifying the oceans, and increasing the intensity of droughts, wildfires, and coastal storms.

Humans are already being affected. Storms of greater frequency and violence, such as Katrina and Sandy, pummel coastal cities like New Orleans and New York. In the heartland, killer heat waves strike more often, last longer, and are expected to increase fivefold over the next forty years. Rising temperatures are allowing mosquitoes to expand their range, spreading malaria and dengue fever to previously untouched regions. Rising seas are flooding coastal towns in Alaska, forcing entire villages to relocate kilometers inland. Low-lying island countries like the Maldives have no inland to which they can flee. Maldivian leaders are now looking at buying property in Sri Lanka, India, and Australia, with an eye toward the day when rising seas force them to relocate the entire nation.

Other species are faring far worse. Climate change has been a catastrophe for polar bears who find their hunting grounds literally melting into the sea. The bears are climate change's most famous victims, but they're hardly the only species struggling. According to the World Wildlife Fund, over the past forty years the sizes of 10,000 representative populations of mammals, birds, reptiles, and fish have declined by 50%. Four decades, half the animals gone. Habitat loss, overhunting, and climate change were the causes. Birds are losing critical nesting ground all over the world. Higher temperatures, drier years, and extended drought wither the vegetation in Colorado's Gunnison Basin, which results in more nest failures among the endangered sage grouse. Rising seas and increasing storms threaten to wipe out the piping plover's coastal nesting and foraging habitat. These are but a few examples. Lists of species imperiled by climate change typically run on for dozens of pages.

The problem is so immense. How do we respond? We press for change and we do what we can, today. As Jamey and I were talking over our Mojave itinerary, hundreds of thousands of concerned citizens gathered in New York City for the world's largest demonstration for action on climate change. No one of us alone can reverse the entire planet's warming. But each of us contributes to its cause. NASA climate scientist James Hansen, who has been at the forefront of global warming research for decades, once summarized the challenge. "If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted," he wrote, "paleoclimate evidence and ongoing climate change suggest that CO2 will need to be reduced from its current [level] to at most 350 ppm."[2]

We can get there by cutting back our carbon burn. In the United States, we produce most of our energy—82%—by burning oil, coal, and natural gas. With every megawatt produced from those sources, more CO2 escapes into the atmosphere. Some forms (natural gas) are cleaner than others (coal), but the only sources that move us closer to James Hansen's goal are solar, wind, geothermal, hydroelectric, and nuclear power. Hydro's expansion options are limited, and the methane produced by new reservoirs undercuts their carbon-neutral aspect. Nuclear power has yet to solve its waste and safety issues, which makes it extremely difficult to finance and build new plants. Only solar, wind, and geothermal have the potential to take big chunks out of our carbon budget.

No energy source is perfect, though. Ramping up renewables requires real estate. Wind power only works in places with a consistent blow. Solar power needs acreage; you can't stack mirrors or photovoltaic panels one on top of another. Some of that space exists on rooftops. The expansion of distributed solar has gotten a boost from the plummeting price of solar PV modules, which has fallen by more than 80% since 2008. But rooftop solar has limits. If every house and commercial building in America harvested energy, they'd be able to meet only 60% of the nation's electrical demand. We need more conservation, rooftop solar, better efficiencies, and utility-scale wind and solar.

On the day Ivanpah opened, solar power accounted for only 0.4% of America's electricity budget. "There is an enormous gap between what needs to get done and what is actually happening on the ground," former BrightSource CEO John Woolard said during the plant's construction. "I don't think people really have digested how far behind we are from a policy perspective and how bad the consequences are. On a global basis we have got to put one gigawatt of zero carbon power online every single day between now and 2040 just to stabilize CO2 emissions. Given the size of our carbon footprint relative to that of the rest of the world, the US would have to add one gigawatt of zero carbon power each week."

That means land use. Ivanpah's heliostats range over fourteen square kilometers (3,500 acres) of publicly owned, federally managed desert landscape. That's four times the size of New York City's Central Park. The Silver State North PV farm covers two-and-a-half square kilometers. Stateline will shade another seven square kilometers.

There's no way of getting around it. Those are significant chunks of prime Mojave habitat. And therein lies the dilemma for environmentalists.

MICROS, MACROS, AND THE BATTLE JOINED

Over the past five years, increasing concern over climate change has given rise to a conservation schism between micro-enviros and macro-enviros. It's playing out in places like the Ivanpah Valley.
The micros know their own backyard on a species-by-species level. They are the riverkeepers and watershed watchers. For generations, these champions of the natural world pushed back against industrial pollution, unnecessary development, and roughshod trammeling. They saved countless species from extinction. They created national parks and our national wilderness system. They kept dams out of the Grand Canyon.

The macros sympathize with the micros, but they see a planet on fire. In their view, dousing the flame—i.e., cutting the carbon emissions that cause global warming—must be the first order of business. If you can't contain climate change, all those tens of thousands of micro conservation projects will be undone. Ultimately, micros and macros are on the same side. They just believe those on the other side are undermining the cause they're fighting for.

Ivanpah has been their field of battle. Local environmental groups raised the alarm about losing fourteen square kilometers of high-quality tortoise habitat to Ivanpah's footprint. The desert tortoise, *Gopherus agassizii*, is a long-lived and emblematic Mojave Desert species. It's been listed as "threatened" under the federal Endangered Species Act since 1980. In some areas, the desert tortoise population has decreased by as much as 90% in the past thirty years.[3] And the Ivanpah Valley, by all accounts, is excellent desert tortoise habitat.

That forced a number of environmental advocates, who usually champion solar power, to take a hard look at the Ivanpah project. Solar power "should go on rooftops or in appropriate places, not the pristine desert," said April Sall, director of the Wildlands Conservancy. "We need to tackle warming, but not forget there are other things at stake."[4] Local chapters of the Sierra Club found themselves divided on the issue. Some favored Ivanpah for its carbon-free energy; others thought the wildlife costs were too high. After BrightSource, Bechtel, and NRG agreed to a number of tortoise-mitigation measures, the national Sierra Club gave the project its blessing. "We need to jump-start renewables to combat climate change," said Sierra Club energy specialist Barbara Boyle, "and large-scale solar has to play a big role in that."[5]

Ultimately, though, it shouldn't be an either/or issue. As Ivanpah has proceeded, the project has become a critical test case for the proposition that large-scale renewable power plants can adapt to their surroundings and push back against global warming without trampling the local biota underfoot.

SOLAR FLUX AND RELATIVE RISK

At midday, Jamey and I drive into the heliostat field with NRG Operations Manager Len Cigainero. We stop at the boundary between the inner and outer ring of mirrors that bounce sunlight onto the boiler of Tower 2. "The inner ring is cleared and graded," Cigainero explains. "Beyond that it's left in as natural a state as possible." Jamey and I wander amid the concentric circles. Each heliostat contains two garage-door-size mirrors. "There's nothing that special about them," Cigainero tells me. "They're mirrors just like you'd have in your bathroom." Except much, much bigger.

As the day's heat reaches its peak, Len Cigainero leads Jamey and me 115 meters (376 feet) up Tower 2. Above us, the 570°C (1050°F) heat generated by the focused solar energy of 60,000 heliostats is creating superheated steam that cranks a power-producing turbine.

It's an awesome sight, standing at the rail, looking out at the mirror field—120,000 brilliant white cards, all pointed in our direction. I imagine it's something like Jimi Hendrix saw at Woodstock. It's an interesting vantage point to consider one of Ivanpah's environmental flashpoints: avian mortality. Wildlife advocates raised early concerns about the effect of Ivanpah's solar flux field on passing birds. Solar flux is a measure of the light energy in a given area. Ivanpah's solar flux field encompasses the airspace between the mirrors and the tower boilers. Ivanpah's heliostats don't create super-heated air. Air absorbs very little light energy. Any object placed in the solar flux field, though, will absorb light energy and convert it to thermal energy. Therein lies the risk to birds. If they fly through the flux field, close to the towers, they can singe their feathers and even catch fire.

Through the first six months of Ivanpah's operation, on-site biologists recorded 321 bird deaths. Of those, 133 were related to solar flux. That extrapolates to roughly 640 birds per year. That number is higher than anybody wants, and the companies operating Ivanpah are working to lower it. Biologists, using bird dogs, currently search the tower and heliostat areas daily to find and record avian carcasses, in order to get a better understanding of the problem. Engineers like Len Cigainero are trying new solutions like switching to LED bulbs on the towers at night, which might attract fewer insects—and fewer birds who feed on those bugs.

Ultimately, Ivanpah's bird issue comes down to a question of relative harm. The number of birds lost to solar flux pales in comparison to those killed in the United States by other anthropogenic causes. Each year, hundreds of millions die from building window collisions, power lines, automobiles and trucks, communication towers, pesticides, oil and chemical spills, not to mention the significant impact of domestic and feral cats. But that comparison only gets us so far. It's more useful to measure concentrated solar plants like Ivanpah against other forms of power generation in a watt-by-watt comparison. Benjamin Sovacool, a Vermont Law School professor and energy policy analyst, has done just that. By looking at a wide range of data—from bird collisions with nuclear cooling towers, to wind turbine mortality, to the effects of mercury poisoning and acid rain—Sovacool came up with a set of figures that compares fossil fuel generation beside nuclear and wind power. The estimates were astonishing. Fossil fuel power plants (coal, oil, natural gas) were responsible for 9.4 bird deaths per gigawatt hour (GWh) of power produced. Nuclear facilities were responsible for 0.6 avian fatalities per

GWh. Wind turbines, which have a reputation for causing bird mortality, turned out to be significantly safer than fossil fuel power generation. Sovacool estimated that the turbine blades and towers were responsible for 0.3 avian mortalities per GWh.[6]

Sovacool didn't include concentrated solar power in his calculations. The technology was too new and the data simply didn't exist. But if we do some preliminary calculations based on an early, small sample size, Ivanpah's avian mortality lands somewhere in the wind turbine and nuclear power range. Ivanpah is expected to produce somewhere in the neighborhood of 1,000 gigawatt hours of power in a year. If all bird deaths are counted, that means the plant would be responsible for 0.6 avian fatalities per GWh; if only solar flux losses are counted, the figure comes down to 0.2.

This is a classic example of what I call the fallacy of visible harm. We see a bird with singed wings and are moved, rightly, to call for more protection for these imperiled creatures. But what we don't see are the millions of birds killed by the indirect forces—habitat loss, acid rain, mercury poisoning, and climate change—perpetuated by our continued addiction to fossil fuels. The comparison isn't even close; it's a full order of magnitude. Coal-fired and gas-fired power plants kill more than fifteen times as many birds per GWh as wind and solar facilities combined. The difference is, they're dying hundreds of kilometers from the source of their death. Birds can't make that connection. They don't possess the cognitive power. But we do. And so we take a hard look at the tradeoffs involved in the act of power generation, weigh the benefits and losses, and move ahead with the technology that promises the best outcome for ourselves and the environment around us.

HEAD START FOR THE DESERT TORTOISE

As the sun makes its first move toward the western horizon, Jamey and I drive over to Ivanpah's biological center, a modest collection of shipping-container offices and fenced tortoise habitats. This is Ivanpah's desert tortoise biological center, a place that's become known as the Desert Tortoise Head Start.

At Ivanpah, the desert tortoise acts as an umbrella species. The protocols taken to safeguard the reptiles and their habitat benefit a multitude of other species in the ecological web. NRG's permit from the US Bureau of Land Management allows them just nine desert tortoise "takings" (deaths) over Ivanpah's planned 30-year lifespan. They've already had one. "A biologist ran over a tortoise when doing a tortoise check," Cigainero told me earlier that morning. "The tortoises look for shade, and this one found it under the wheel of his parked truck." Ever since then, everybody on-site does a vehicle perimeter check before starting up.

It's not just direct hazards that Ivanpah workers have to watch out for. There are indirect dangers, too. "We're very careful about trash," Cigainero told me. "We work hard at making employees understand the importance of keeping the area trash-free in order to not attract ravens." Desert tortoises have a coterie of predators: ravens, kit foxes, coyotes, red-tailed hawks, golden eagles, badgers, and burrowing owls. A spilled Coke or a misplaced Carl's Jr. bag might be enough to draw these predators—especially ravens—to the site. And then their sharp eyes might spot a tasty tortoise.

At the biological station, Jamey and I meet up with Max Havelka, a biologist who oversees the juvenile tortoise pens. The heat of the day has come up, and Havelka's decked in full desert workwear: a widebrimmed straw hat, extra-dark sunglasses, and a slathering of sunscreen. He tells me about the tortoise relocation operation that's been going on for four years now.

"This turned out to be better tortoise habitat than anyone imagined," he says. In the fall of 2010, before Bechtel broke ground on construction, a team of biologists scoured the Ivanpah site. Fall is typically an active time for tortoises who emerge from their long summer burrow to graze in the cooler autumn temperatures. The biologists gathered 173 adult and juvenile tortoises and relocated them to temporary holding pens in a one-and-three-quarters square kilometer (433 acre) preserve set aside for rare plants and wildlife. "We started with sixteen tortoise pens, and ended up with more than 100," Havelka tells me.

Tortoises have a slow and precarious reproductive cycle. They can take up to twenty years to reach sexual maturity, and females lay eggs only when environmental conditions are optimal. Most hatchlings don't survive. Researchers estimate that up to 98% of juvenile tortoises are killed by predators in their first years of life. That makes what happened after the tortoise-gather all the more curious and remarkable. Female tortoises in Ivanpah's temporary holding pens began laying eggs left and right. Maybe it was coincidental. Maybe it was a response to stress. Maybe the females looked around at the plentiful forage, water, and predator protection and thought...conditions optimal! Havelka and other biologists don't know for sure. What they do know is that by the spring of 2011 they had 53 new juveniles on their hands.

After fitting the adult tortoises with tiny transponders, Havelka and his colleagues released them back into the Ivanpah Valley, outside the heliostat fields. The transponders allow NRG's staff biologists to locate the reptiles and check on their health twice a year. To release the juveniles, though, would be to lose 98% of the next generation of a federally threatened species. So biologists like Havelka continue to nurture them behind protective fencing in what became known as the Head Start area, named after the US government program that provides early childhood education and healthcare to children in low-income families.

"We'll keep them here until their carapace reaches twelve centimeters in length," Havelka explains. That's about as long as a Pepsi can is tall. "At that point they're able to fend for themselves."
As we stroll through the Head Start area, it's tough to spot any tortoises. And yet we're surrounded by dozens of them. "There's one," Havelka says. A four-inch juvenile crawls glacially under the shade of a creosote bush. Desert tortoises live up to 95% of their lives underground, and when they do emerge, they exhibit none of the darting movements that alert predators to their presence. Rule of survival: you can't eat what you can't see.

Like a lot of conservationists, Havelka is aware of the tough tradeoffs involved in an industrial-scale renewable project like Ivanpah. He sees the gains and losses every day. The Mojave, he says, "...is amazing. It's like a desert version of an old-growth forest." It's an apt description. The Mojave's creosote bushes can thrive for centuries. They're drought-hardy and so oily that herbivores don't touch them. "King Clone," a Mojave Desert creosote bush ring, is believed to be one of the oldest living organisms on Earth. University of California, Riverside, botanist Frank Vasek, who discovered the bush in the late 1970s, has estimated the plant's age at around 11,700 years.[7]

Desert tortoises don't live quite that long, although in the wild they can survive for fifty years or more. Their survival into the next century, however, may depend on whether we can ramp up our renewable energy output—because they, too, are imperiled by climate change. Female tortoises lay fewer eggs during drought years, and soil temperatures affect the sex of embryos. Temperatures above 31.5°C (88.7°F) favor the development of females, so an increasing number of heat waves could leave the population here with a reproductive ratio problem. In other words, doing nothing about climate change is as risky to the long-term health of the desert tortoise as are the disturbances imposed by projects like Ivanpah Solar.

FADE TO BLACK

Late in the afternoon, Jamey and I climb into a Robinson R-44 and rise thousands of feet above the desert floor. As the horizon pulls the sun closer, the helicopter offers us yet another perspective on the Mojave. From 2,000 meters high we can see over and beyond Clark Mountain and the Castle Range, the two mountain bands that define and drain into the Ivanpah Valley. The light's low angle raises the contrast on the land. A multitude of dry creeks, washes, deer paths, Jeep trails, rail lines, and dirt roads crosshatch and serpentine over the terrain.

At 5:11, all three Ivanpah power blocks glow an eerie white. They're lit up like tall candles on a dining room table. Tiny movements ripple through the mirrors as the computer controlling the heliostats milks every last watt from the sinking sun.

Twenty minutes later the shadow of Clark Mountain reaches out across the valley floor, nearly touching the outer ring of Unit 3's heliostats. The darkness moves at a hiker's pace, slow but steady. All three power blocks blaze until finally, at 5:56, Unit 1 and Unit 3 begin to fade.

The end of the solar day arrives quickly. Within two minutes, the power block on Unit 3 is dark. Unit 2 still shines, but Unit 1 is fading fast. One minute later, Unit 1 is dark. By 6:03, all three tower boilers are black. Ivanpah is off the grid.

Back in the control room, NRG's engineering team closes out the day. One-by-one the heliostats move into sleep mode, standing vertically, reflecting darkness.

Meanwhile, in the desert, the nocturnal creatures start to emerge. As the intense heat of the day dissipates, they peek out of burrows, foxholes, and caves. Bats flutter into the evening sky. Tortoises crawl out of their holes to forage. The Mojave Desert stirs back to life.

As we take one last swoop over the darkening valley, it strikes me that the Mojave has found, in the desert tortoise, its perfectly emblematic species: one that captures all the slow vigor, fragility, reticence, deception, indomitability, and strange beauty of the desert. Like the desert itself, its wonders and charms aren't apparent upon first glance. It takes some time to learn, to understand, and to appreciate. The same might be said of the Ivanpah project. It's compelling, strange, and not easily comprehended. But it represents one of our best shots at getting right with the tortoise, the Mojave, and the planet. It's a step in the right direction.

NOTES
1. John Steinbeck, *Travels with Charley*. (New York: Bantam Books, 1963), 209. First published 1962 by Viking Press.
2. James Hansen, et al, "Target Atmospheric CO2: Where should humanity aim?" *Open Atmospheric Science Journal* 2 (2008): 217-31.
3. "Fact Sheet: Desert Tortoise," Defenders of Wildlife website, 2015.
4. Ken Wells, "Where Tortoises and Solar Power Don't Mix," *Bloomberg Businessweek*, October 10, 2012.
5. Ibid.
6. Benjamin K. Sovacool, "The Avian and Wildlife Costs of Fossil Fuels and Nuclear Power," *Journal of Environmental Sciences* 9, no. 4 (December 2012): 255-78.
7. Frank C. Vasek, "Creosote Bush: Long-Lived Clones in the Mojave Desert," *American Journal of Botany* 67, no. 2 (February 1980): 246-55.