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INDIA'S QUEST TO BUILD THE WORLD'S LARGEST SOLAR FARMS

*Pavagada Ultra Mega Solar Park, a clean-power plant the size of Manhattan, could be a model for the world
—or a cautionary tale.*

By Meera Subramanian

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A local farmer grazes his goats along a road overlooking Pavagada Solar Park. Photographs by Supranav Dash for The New Yorker

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Every morning in the Tumakuru District of Karnataka, a state in southern India, the sun tips over the horizon and lights up the green-and-brown hills of the Eastern Ghats. Its rays fall across the grasslands that surround them and the occasional sleepy village; the sky changes color from sherbet-orange to powdery blue. Eventually, the sunlight reaches a sea of glass and silicon known as Pavagada Ultra Mega Solar Park. Here, within millions of photovoltaic panels, lined up in rows and columns like an army at attention, electrons vibrate with energy. The panels cover thirteen thousand acres, or about twenty square miles—only slightly smaller than the area of Manhattan.

As the planet turns and the sun climbs, electricity streams from the panels to eight nearby substations, and, in one of them, a computer monitor decorated with a red hibiscus flower registers their collective power in megawatts. In the predawn hours, the solar park consumes a small amount of electricity for lights and computers, so the monitor may show a negative number. But, within twenty minutes of sunrise on a morning in late February, the park was producing 158.32 megawatts, enough to power, on

average, more than a hundred thousand Indian homes. As the temperature soared into the mid-nineties, the air seemed to shimmer with heat; a single ghostly raptor hovered over the area, looking for prey in whatever patches of grass remained. The wind gusted and overhead power lines hummed. Around 1 P.M., the park's electricity output peaked at more than two thousand megawatts—enough for millions of homes.

Pavagada generates almost four times the power of the largest functioning solar farm in the U.S. The world's biggest solar installation, Bhadla Solar Park, is in the North Indian state of Rajasthan; the second largest is in China. Pavagada, with a capacity exceeding two thousand megawatts, is in the running for third. In a few places, however, its high-tech panels are interrupted by plots of cropland. Some are fenced in with colorful old saris that waft in the wind. And nestled like islands within the silicon sea are five small villages, virtually untouched. They are not powered by Pavagada, at least not directly. "Twenty-two per cent of the electricity in Karnataka is generated here, but for us there is no power," a local school administrator told me. Near the school, I saw a single street light and was told that it was funded not by Pavagada Solar Park but by the *panchayat*, the local village council.

In an office in the metropolis of Bengaluru, four hours south of the solar farm, I met N. Amaranath, the C.E.O. and general manager of Karnataka Solar Power Development Corporation Limited (K.S.P.D.C.L.), which operates Pavagada Solar Park. He had long, dark eyelashes; a salt-and-pepper

beard; and three parallel streaks of white across his forehead, the *tilak* of a practicing Hindu. The Pavagada model is now being replicated around the country, Amaranath told me. “The government of India has a vision,” he said. India has pledged to meet half of its energy needs with renewables by 2030, and to achieve net-zero emissions by 2070. “That is a very ambitious project,” he went on. “Without the parks, that is not possible.”

India is a country of 1.4 billion people that continues to generate most of its electricity from coal, the dirtiest fossil fuel. The success or failure of solar here will go a long way toward determining the speed of the world’s clean-energy transition, and thus the severity of our collective climate emergency. Many of the worst impacts of the crisis will be felt in South Asia, but the subcontinent is sunny enough that, in theory, it could eventually supply clean electricity to a large portion of humanity. Many more ultra-mega solar parks are in the works—and, as photovoltaic panels become even cheaper and more efficient, the primary obstacle to growth may no longer be technological. “Whenever you establish an industry, the main problem is about the land,” Amaranath told me. “The landowners are very attached. . . . They are not ready to spare it.” A fan blew warm air at us as he asked the thirteen-thousand-acre question: “How do you solve that problem?”



Bhargavi Rao and Leo Saldanha are trustees of the social-justice nonprofit Environment Support Group, which advocates in part for rural residents.



A newly constructed electrical pole in Vollur village, near Pavagada Ultra Mega Solar Park.

In 2010, India launched its National Solar Mission, a sun-powered moon shot with a staggering goal: twenty thousand megawatts of installed capacity by 2022. Six months later, in a village several hours southeast of Pavagada, the state of Karnataka opened what was then the nation's largest solar installation. Built with American solar cells on about fifteen acres of land secured by the government,

the panels produced just three megawatts, or a fraction of one per cent of the country's initial goal. News stories at the time touted its benefits for local farmers, who could use the electricity to operate water pumps and irrigate their fields. Today, the facility seems almost quaint.

By 2015, India was planning solar farms that were hundreds of times bigger. The central government formed an alliance with the Karnataka state government to create K.S.P.D.C.L.; the newly minted solar corporation went looking for a site with thousands of sunny acres and found it near the town of Pavagada, where drought had made growing crops difficult. In the light of hundreds of land conflicts that have erupted across India over the years, the government found a way to avoid buying the site or seizing it through eminent domain. In early 2016, K.S.P.D.C.L. approached landowners with an idea that, according to the corporation, had not been tried on a large scale before: it would lease land holdings for a period of twenty-eight years. Locals, of whom thirty per cent are illiterate, would become landlords and the solar company would become their tenant.

K.S.P.D.C.L. would pay landowners a yearly rent of twenty-one thousand rupees—a few hundred U.S. dollars—for each acre leased. (After the first five years, the rent would increase by five per cent every other year.) The corporation drafted a sixteen-page contract and secured nearly thirteen thousand acres from approximately nineteen hundred owners. Within two years, the company had levelled grasslands, dug up mango trees and coconut palms, and planted hundreds of electricity pylons.

According to the solar company's annual report, it built forty-seven miles of road, lined with twenty-seven hundred street lights, along with eight substations to pool the power for India's national grid. Using a strategy known as "plug and play," K.S.P.D.C.L. auctioned off development rights to international corporations such as Adani, Tata, Fortum Solar, and Azure. The developers, which were offered a good rate for each kilowatt of power that they delivered, then installed the panels. By late 2019, Pavagada was lighting up the grid every time the sun shone.

In the race to keep the planet from overheating, this is exactly the scale and speed with which humanity needs to move toward renewable energy. India's solar program met its original twenty-thousand-megawatt goal four years early, and went on to set higher goals; by 2023, the country had more than sixty thousand megawatts of solar capacity installed. But solar farms have footprints of their own. Bhargavi Rao and Leo Saldanha, trustees of the Environment Support Group, a social-justice nonprofit that has advocated for rural residents of Karnataka, told me they were troubled when the government argued that leases would help landowners keep their property and earn a steady income. Rao and Saldanha worried that farmers with withered crops would have a weak negotiating position, and might agree to unfavorable terms. "All the resistance that has happened has come from the point of view of land," Rao told me. "They were caught between a rock and a hard place."



When K.S.P.D.C.L. approached landowners with its offer to lease their land, the Nagalamadike Dam reservoir, situated less than ten miles from Pavagada, was dry. The reservoir is now full of water.

In February, I sat beside Saldanha in his Honda hatchback as he slalomed between cars and trucks on our way to see the solar park. Saldanha wore sunglasses and sandals; Rao, who has a mane of silver hair, sat in the back seat with my interpreter, Elizabeth Mani. Though the area around Pavagada is naturally arid, we saw lakes that looked full from an unusually wet monsoon. After four hours of driving, we arrived at a seven-foot-high chain-link fence, topped with coils of razor wire, that surrounds the expanse of Pavagada Solar Park. A security camera surveilled the area. There, on the edges of the park, the glass shared space with grasslands—habitat for leopards and the critically endangered great Indian bustard—and farms. We met one farmer who pulled up the bright green leaves of a peanut plant to offer us a taste of his crop. Later, on an arrow-straight stretch of road through the northern part of the park, we came upon Ashok Narayanappa, a twenty-eight-year-old man who was steering a bullock cart laden with hay. His two creamy *Hallikar* bulls clip-clopped to a halt.

“All these places were peanut farms,” Narayanappa, who had a closely trimmed beard and a mop of black hair, told us, gesturing at the black glass that surrounded us like a promise or a plague. His family owns four acres nearby, he said, but the land has disappeared under solar panels. Now, to gather fodder for his animals, he has to travel four miles, twice a week, to a plot owned by some relatives. “Before, I could collect right at this place,” he said. Pylons and transmission wires loomed over us. The buzzing made me feel as though I were in the belly of a bee.

Narayanappa had studied business communications nearby and went on to work at a pharmacy in Bengaluru. But he missed the land and his family enough that, when he heard about work as a security guard at the solar farm, he moved home. He said that in his nearby village of Vollur, hundreds of

families used to raise livestock, which serve as living bank accounts, ready to be sold for school tuition or weddings or health emergencies. Only about half a dozen families have been able to hold on to their cattle, and just a few now have sheep and goats. Many move to the city to work as day laborers, he told us.

“We need more employment,” Narayanappa said. The sun glinted off a silver hoop that adorned his left ear. He is one of the lucky ones who found a job here, but even his living must be cobbled together from his security-guard paycheck, lease income, and sustenance from the cattle. Nine months ago, his first daughter was born. Narayanappa seemed skeptical that his community had benefitted from solar. “In my opinion,” he said, “farming land should be kept for farming.” His bulls seemed restless; he climbed back onto his cart and resumed his journey through the solar sea.



Ashok Narayanappa drives a bullock cart carrying hay, along a stretch of road lined with pylons, in Pavagada Solar Park.

Sunlight is the most abundant source of energy on the planet. At any given moment, billions of megawatts of solar power are hitting the Earth's surface; humans could meet all of their energy needs by harnessing just 0.01 per cent of it. According to the Carbon Tracker Initiative, such an undertaking would require an area slightly larger than the size of California—a whole lot of land, but less, it turns out, than the current footprint of fossil-fuel infrastructure. And, with help from other energy sources, such as wind and water, this area shrinks. In the U.S., 2050 clean-energy targets could be met with solar and wind by transforming an area of land roughly the size of West Virginia, according to researchers at Princeton University.

The climate crisis may make parts of the planet uninhabitable for humans: seas are rising, heat waves are spreading, fires and floods and storms are escalating. But the fight *against* climate change can pose a risk to the land, too. What becomes of a place that has been punctured by concrete pilings and canopied by metal and glass? After a twenty-eight-year lease, farmers might not even recognize their land, let alone know how to grow a lush green field of peanuts there.

To transform the planet and its energy systems on the scale needed, countries and corporations—many of which stood in the way of climate action until very recently—will have to win over the keepers of the land. “If social justice considerations are ignored, we will end up exacerbating social

tensions, increasing inequality, and as a result slowing down the transition,” Deepak Krishnan, the associate director of the energy program at World Resources Institute India, told me in an e-mail. Already, activists like Greta Thunberg are protesting wind farms sited on traditional Sámi territory, in Norway. In Indiana, locals have filed lawsuits to resist a Pavagada-sized solar park on valuable farmland. In Colombia, advocates of the Indigenous Wayúu people, whose ancestral lands are ideal for wind farms, argue that the government and multinational corporations have failed to uplift the community, and have sparked local conflicts that could escalate into “wind wars.” Clean-energy projects risk gaining a reputation for being extractive, in the same way that many fossil-fuel projects are. “Transformations are happening at this scale without any democratic process,” Saldanha said.

When developers set out to build Pavagada Solar Park, Indian law did not require them to study the social or environmental impact of their work, because solar projects are considered clean energy and the government was not purchasing the land. However, the World Bank, which invested a hundred million dollars in India’s solar infrastructure, commissioned two reports on Pavagada that predicted profound changes to the region and its people. Solar leases “would act as a source of assured income for the land owners,” one of the reports said. But, those who didn’t own land, including many working women, would lose jobs as day laborers on local farms. The report also noted that Dalits and Adivasis, the most marginalized groups, constituted a disproportionately larger share of landless residents.

The solar company had the resources to support local villages, the authors of the report said. They estimated that five million dollars would be enough to build community toilets, equip households with small-scale solar panels, and guarantee income for out-of-work farmers as they trained for new jobs, among other things. K.S.P.D.C.L. has set aside more than that for local development. Still, villagers told me that little has been spent on these types of improvements, and, in some places, it has been slow to arrive. Several people complained that development funds were being spent outside the community; in an annual report, K.S.P.D.C.L. said that it had funded the construction of stone benches at a community hall five hours away.

In the village of Thirumani, I saw solar-funded community investments at work. A new road was under construction and a heap of gravel blocked the way. As I stood there, an auto rickshaw approached the pile and attempted to drive over it. For a minute and a half, the determined driver revved the engine without success. Then he gave up and turned around. Four years had passed since Pavagada started producing power. If only village roads could be built as speedily as substations, I thought.

At the primary school in Thirumani, I met Baby Shyamala Chandrashekara, a young teacher whose position was partly funded by Fortum Solar. We spoke in the headmaster's office while more than a hundred students sat in the schoolyard, in circles of ten, eating from stainless-steel plates.

Chandrashekara had studied computer science at the local women's college, and had learned about the teaching job when she went to collect her certificate.

Solar development supported free training for many young women, for example in tailoring and

weaving, but Chandrashekara said that none of those she knew had jobs at the solar farm itself. She wished that she could work as a data operator, to put her skills to use. “Whatever work is available I would like to take,” Chandrashekara told me. She was excited that the clean-energy transition had come to her community, and she wanted to be part of it—just as some of the men in her village were. “We have requested many companies, and also the government office, to give us employment, but nothing has happened so far,” she told me. I thought of something that Rao once wrote: “The energy sector overall is designed by men for men.” But it doesn’t have to be.

Across the schoolyard, I saw mounds of rock and brick near a sputtering diesel cement mixer. Money from the solar project, I learned, was paying for the construction of a new two-story schoolhouse. But near the entrance to the school loitered the landless: an old woman with her hand out, begging, perhaps for school-lunch leftovers; a taxi driver who told me that his life was unchanged by the arrival of solar.

“Solar people are building schools in all the villages, building roads,” Varshitha Gopala, an eighteen-year-old who lives in Vollur, told me. “For people, they haven’t done anything.” Gopala’s family lives in a Dalit-majority area, and her mother, Alvelamma, told me that Dalits were given farmland to work generations back. Before solar came, all women who could work did work, she said, whether on their own lands or as laborers for their landowning neighbors. But this arrangement had never come with a deed, which meant that Dalits were ineligible for a lease agreement and lost access to the land. Their landed neighbors now earn lease income, but the jobs are gone. Instead, Alvelamma picks up agricultural work in far-off villages, and the family relies on income from its small shop, a tiny shipping container coated with peeling blue paint.

During a drive through the solar park, near a hut with a sign that said “Caution: Snakes,” I met a forty-five-year-old security guard named Lakshminarayana, who invited me to visit his home in Thirumani. In one room of his concrete house, sacks of rice were stacked across from a small television. Lakshminarayana joked that he was getting fat and lazy since he had stopped farming. His wife, daughters, and mother were there, along with a rotating cast of neighbors: Shridhar, another guard; Chandra Prathap, a junior engineer at the solar park; Harish, a software developer who was visiting home from Bengaluru.

“They promised a lot but only gave very little,” one man said.

“Only the lease amount is coming,” another complained.

“Employment is the biggest problem,” someone pointed out. “They promised employment to every household.”

Shridhar observed that the solar companies hired workers from neighboring states, such as Andhra Pradesh. “They’ll work for less,” he said. “We have well-educated engineers in the village, but the solar companies do not employ us.”

I thought of Amaranath, the solar C.E.O. When we met, he had acknowledged that of the thousands

of construction jobs at Pavagada, many had been given to men from other states, such as Bihar in the north. But Mongabay, an environmental-news service, reported that around eighty per cent of the roughly sixteen hundred permanent jobs at the solar farm—engineers, technicians, security guards, grass cutters—have gone to locals. “You can’t satisfy every soul,” Amaranath told me. “It is natural that expectations are very high.”

In Lakshminarayana’s house, Chandra Prathap, the junior engineer, said that the solar company hadn’t promised to give electricity to locals, but many villagers had assumed that it would. Most people have access to electricity, but some struggle to afford it. Chandra Prathap, with both his paycheck and the income from ten acres of land he had leased where his family used to grow peanuts, said he was managing.



Lakshminarayana (right), a security guard at the solar farm, with his wife, Parimala (left), and his mother, Venkatalakshamma (seated).



Chandra Prathap is a junior engineer with K.S.P.D.C.L.

“Whoever owns a lot of land gets that much richer,” Lakshminarayana said. But, he went on,

“compared with life before, it’s better. We are surviving.”

The women in the room had been listening carefully, and I turned to them. “I wish we women had got some jobs at the solar farm,” Parimala, Lakshminarayana’s wife, said. The men were still talking; I moved my audio recorder so that it was right in front of her, and the men quieted down.

Parimala said that representatives for the solar company had spoken of a garment factory that would employ women, but it had not materialized. (The solar company said that it had never made such a commitment.) Still, the lease income had allowed some people to stay in their villages. “Before the solar, a lot of people migrated to big cities,” she told me.

“Solar is good because there were a lot of crop failures before,” Parimala’s mother-in-law, Venkatalakshamma, said. She was sitting on the edge of the circle in a light-pink sari. Lease money was more reliable, she went on, though she wasn’t a fan of the store-bought food that had replaced the produce from their farm, like the bag of rice that her son was using as a cushion. Her main complaint was that the solar company hadn’t compensated them enough. The lease rate rises at only half the recent rate of inflation in India, according to an Australian research team that studied the solar farm.

She shot a look at the men in the room. “They should have demanded more,” she said. Women hadn’t been included in negotiations. “If they had, I would have gone!”

Pavagada Ultra Mega Solar Park goes by another name: Shakti Sthal, literally “power place.” In Hinduism, Shakti is the goddess responsible for creation. Without her, the world stops.



Residents stand outside a temple in a Dalit-majority section of Thirumani village. “Solar people are building schools in all the villages, building roads,” a teen-ager told me. “For people, they haven’t done anything.”

On my last day at Pavagada, I finally found a woman who works at the solar farm. I didn’t get her name, but she brought my interpreter and me coffee as soon as we stepped into Substation 5. As I sipped it, I thought of the villagers’ struggles; at the same time, looking around, I marvelled at how clean this form of energy production is. For too long, our energy sources have left a legacy of ills: epidemics of black lung, oil spills, radioactive waste. Solar has the potential to change that for billions of people; with modest investments in local communities, its benefits would ripple outward. In much of South Asia, the sky is heavy with a layer of pollution nearly two miles thick—an amalgam of emissions from wood-burning stoves, smoldering crop stubble, and hundreds of coal-fired power plants. Could all of India have blue skies again?



Baby Shyamala Chandrashekara teaches at the primary school in Thirumani. Her position was partly funded by a company that operates some of the solar blocks.

“Electrify everything” is a mantra of the global transition away from fossil fuels. When I wrote a book about solutions to India’s environmental problems, almost a decade ago, I repeated the refrain myself. But Pavagada shows that clean energy is only part of the solution. Some scholars have warned that a relentless focus on cutting emissions, by scaling up renewables at any cost, could create a “carbon autocracy.” Green technologies will need to share space with humans and ecosystems; when climate activists talk about a just transition, they are imagining people, power, and nature working in harmony. I saw half a dozen men in Substation 5 that day, including Chandra Prathap, the junior engineer; he

was wearing faded jeans and a plaid shirt, working at a computer adorned with a flower. I thought of their families and neighbors, and wondered how much they would share in the fruits of a cleaner economy. Is it possible for climate change to be not only a threat multiplier, as the U.S. Department of Defense has called it, but also an opportunity multiplier?

Other futures are possible. Large renewable-energy projects could take root in former mines or fossil-fuel installations, where the land is already too degraded for agriculture or human settlement. India could reinvigorate efforts to install rooftop solar panels, which do not interfere with agriculture. And it is possible to build literal solar farms, where the sun's rays energize crops and photovoltaic panels at the same time. A recent study found that some crops grown under solar panels, in so-called agrivoltaic systems, help to keep the units cooler, extending their lifespans and improving efficiency. Certain plants grow better in the shade, especially as temperatures rise. If less than one per cent of cropland around the world was shared with solar panels, global energy needs would be met, according to one estimate. In the U.S., the National Renewable Energy Laboratory is leading research into agrivoltaics, including the use of sheep—not as walking bank accounts but as lawn mowers, to reduce fire hazards. When I asked Amaranath and the farmers about agrivoltaics, they were hesitant, but others in India are trying it and finding success.

A more radical shift could redefine ownership. Beginning in the nineteen-thirties, a government

program financed farmer-owned coöperatives that helped to electrify rural America. Nathan Schneider, a journalist and media-studies professor who writes about coöperatives in “Everything for Everyone,” argues that we should all be asking, “Who owns the engines of the economy, and how are they governed?” Solar companies could share a percentage of their revenue with communities—or communities could own solar parks. Either model could turn locals into shareholders, invested in the success of the clean-energy transition. Surely, solar parks could power cities and countries while allowing a grandmother to enjoy homegrown food, enabling a young woman to find a high-tech job, and helping a family earn a good living that keeps up with inflation.

When we first set out for Pavagada, Saldanha spoke from the driver’s seat about solar parks that he has studied with Rao, not only in India but also in Europe and Africa. These projects had prioritized carbon over communities, he argued. “You cannot project the future of society merely from a technocratic perspective,” he said. Still, full-throttle solar development could win full-throated support, he suggested, if new models can overcome the mistakes of the past.

Through the car window, we saw a temple perched on an ancient granite monolith. We drove through a town where hundreds of elderly men were buying and selling cattle. At one point, we passed a truck that was weighed down with a massive orange-and-white wind-turbine blade. The present, I thought to myself, is where the past and the future intersect. It’s also the only place we can ever act. Midway through our journey, Saldanha pulled over so that he and Rao could consult a map. The car’s turn signal ticked like a clock. There were several ways to get where we wanted to go, he explained. Which one should we choose? ♦

Elizabeth Mani contributed reporting.

