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KARTIKEYA SINGH

Of Sun Gods and Solar Energy

Come, O Surya, of thousand rays, the store-house of all energies, the Lord of the world, have mercy on me thy devotee, accept this Arghya, O, Mother of the day.

—Invocation of the Spiritual Sun, The Rigveda

Politics, capitalism, and energy poverty are combining in strange ways across India. The result looks like progress —sometimes.

My family's ancestral home in the village of Jakhan in India's western state of Rajasthan exemplifies the challenges and opportunities of facilitating energy access in India. Though Rajasthan is perhaps the most densely populated desert on the planet, near Jakhan the population is spread more thinly, and electrification has been slow in coming. The dreams of people such as my grandparents, who wished to see central electricity access arrive at their doorstep, were unfortunately not met in time. My grandfather filed an application to have a grid connection reach his home in the 1970s. The connection came three decades after his passing. Today, over 300 million people still lack access to reliable centralized electricity in this nation of 1.2 billion people.

To help address the plight of those without energy access, decentralized technologies such as solar photovoltaics are being deployed across the country, thanks especially to innovative entrepreneurs, often working in difficult circumstances. Can decentralized energy sources make a difference to India's people and its future? The question has no simple answer. Since 2007, I have ventured across the nation to try to more fully understand the complexities of solar technology diffusion. India turns out to be an extraordinarily complex solar energy laboratory, a shifting sociopolitical and technological landscape populated by innumerable, distinctive stories of how people are interacting with these innovations. For me, capturing these stories has been nothing short of a personal spiritual awakening. For India, the question is whether they are beginning to add up to a nation genuinely steering the course of development toward a more sustainable path.

Rajasthan: A barefoot revolution

"*Aise, jata hai.*" "*Nahin, yeh dekho.*" "*Yahan par.*" ("It goes like this." "No, see here." "Over here.") Three grannies surrounded me, teeth missing and faces worn, yet wearing their old age with dignity. The sun beat down heavily outside as the warm winds, which locals call the "loo," blew sand against the homes of the villagers. This parched land, blessed with powerful sunshine, was ready for the monsoons to arrive.

I was sitting indoors, surrounded by old, illiterate women, in the most unlikely of places: an assembly plant of sorts. The women, coming from many different states, produced a cacophony of languages, but after four months together they had learned to share a common language through the words that travelled across the room: "capacitor, transformer, jumper wire." I, a literate fool, could hardly imagine being capable of knowing these words, let alone assembling the pieces to which they referred.

The subject of multilingual conversation among the grannies huddled around me was whether I was assembling my very first compact fluorescent lamp circuit correctly or not. The circuit would be part of a solar home lighting system, the likes of which the Indian government hopes to distribute to tens of

millions of homes in an effort to expand electricity access by 2019.

Where was I? Barefoot College, a nonprofit started in 1972 in a remote corner of Rajasthan. This small, self-sustaining initiative has trained hundreds of illiterate women from across rural India and the world as "barefoot solar engineers." These women are able to build absolutely everything—including the tools with which they assemble the entire solar home systems.

Indu Devi, age unknown, was busy building a complex circuit for a solar lantern when I first met her. Her hands moved diligently, soldering wires and connecting small circuits to a board. "Where are you from?" I asked. As she began to share her story, I listened in awe. In her native state of Bihar, only 20% of the population has access to reliable electricity. Monthly rations of kerosene distributed to families living below the poverty line sometimes last only five days. The black market price of kerosene to bridge this gap is astronomically high.

Indu Devi has mothered three children and weathered many of India's harsh rural realities within her lifetime. She aims to go back to her village after the six-month training and help bring light into the lives of the destitute there. Armed with these skills, she wants to set up a rural electronics workshop from which she will fabricate and repair solar systems in her locale.

The deployment of solar technologies in India is not without its challenges. In the village of Dabkan, in the Alwar district of Rajasthan, a community struggled to keep its lights on two years after it received LED-based solar home lighting systems free of charge. Without any replacement parts, supply chains to procure them, or maintenance crews, the community continued to use its systems even as rats chewed through wires, monkeys and peacocks flung solar panels off roofs, and the sticky Thar Desert sand caked itself onto panels when villagers failed to maintain them. Still, lives were transformed: kerosene fuel was saved and the associated costs of having to purchase additional monthly amounts for lighting were avoided; and nighttime productivity of households increased. "There was nothing here 10 years ago except the jungle and we were only connected to the outside world when the road was built," explained Babu Lal, the only shop owner in the village. It was probably thanks to the road that a two-person team from Grameen Surya Bijlee, an early entrant into the market of off-grid solar technology providers, stumbled across the village with a truck full of supplies that they could not install in another village.

The impact of the availability of lighting was so great that even children's test scores were improved. "When I first started teaching here five years ago, most of the children couldn't even write their names properly, and they would fail their tests even with only 50%-60% required for passing," stated the village school teacher. "It took me one and a half years to just get them to memorize the prayer we do in the morning before starting school." According to some accounts, the extended hours of study provided by the lighting systems has led to a 70% improvement in retention of knowledge, and, on average, students in Dabkan are studying one to three hours longer than they did before. The introduction of solar energy into

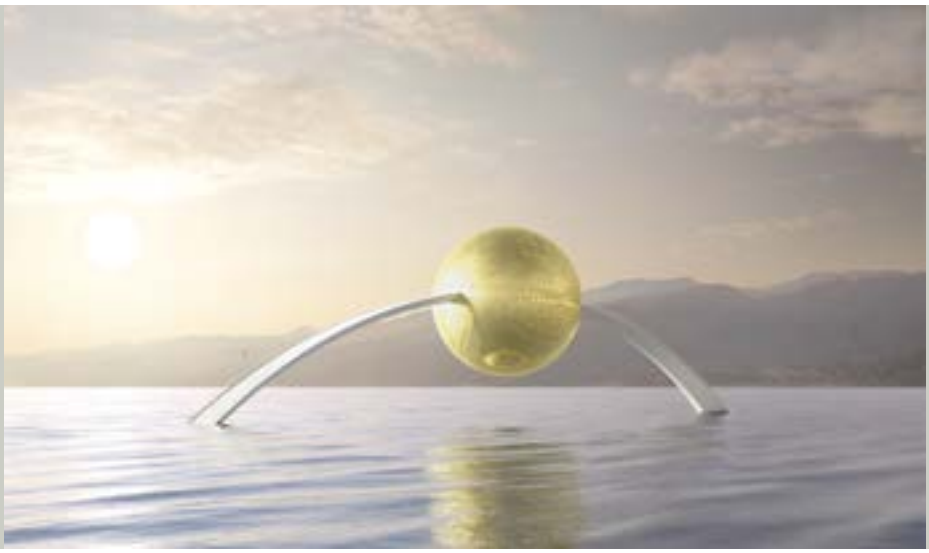
Light Drop

A submission to the 2016 Land Art Generator Initiative design competition for Santa Monica

Antonio Maccá, Flavio Masi

Padova, Italy

Light Drop is a sustainable artwork that expresses its unique profile over the ocean—a new point of reference for the people of Santa Monica. A slender aerial arch raises a mirrored sphere over the line of the horizon. The "drop" houses a desalination plant that converts marine water into drinking water. Tidal-powered pumps convey the water through a pipe system incorporated in the main structure of the arch. The processed drinking water is distributed by gravitational flow from the "drop" to the pier. The design implicitly focuses people's attention on the urgent need to solve California's water crisis.



an energy-starved community is not a mere convenience but can contribute to improved literacy rates and workforce skills for a new economy in geographies otherwise dominated by agriculture.

Karnataka: Two visions of urban India

Energy poverty is not just a rural problem. Over 65 million people reside in India's urban slums and many face a daily struggle to get access to commercial energy.

On a cool June day in Karnataka state, I found myself in a slum in Bangalore, the city known as home to India's high-tech companies. Within the shadow of fancy apartment buildings on an empty plot of land lay a community of 60 families in an informal settlement typical of those referred to as "blue sheet communities." The blue sheet represents the color of the tarps residents use to cover their informal tenements and shield themselves from the elements. Trailing a young man named Sanjay as we went door to door, I learned about the plight of India's urban poor, many of whom face the same energy poverty as their rural brethren. Families typically spend approximately $1.20 a week on 1.3 liters of kerosene to meet their lighting needs alone. This represents 10% of an average family's weekly income.

In India's solar energy innovation ecosystem, Sunjay is a "pollinator," an energy entrepreneur from one of Bangalore's low-income communities who is working for Pollinate Energy, a social enterprise that seeks to provide low-cost solar lighting solutions to slum dwellers throughout India. The model is simple: pollinators are trained in sales and management of solar lanterns and assigned a region to work in by Pollinate. Working under a system of monthly sales targets and corresponding financial incentives, pollinators go out in the evenings (when slum dwellers are at home) selling the devices and handling any maintenance or repairs that need to be made to products already sold. Pollinators may choose to hire a local "worker bee" who is paid a commission to provide leads to the pollinator and facilitate sales of solar lanterns. The approach is helping make lives a little easier for those living under the blue sheets. "The black market price of kerosene is too high," explains a Neelam, a young girl from the community. "Ever since we've purchased these lights, we no longer need to pay high prices or go without light in our home."

Sixty kilometers southwest of Bangalore in the city of Channapatna, I was offered a different vision of solar technology diffusion for a wealthier urban Karnataka. Twenty-six-year-old Srikant sat in his gleaming shop, its glass-paneled storefront resembling that of a fancy boutique. A web designer by training, Srikant has seen his monthly income rise from the equivalent of roughly $83 to $1,000 a month since he started selling solar products. He is one of Orb Energy's roughly 170 franchisees who are licensed to sell Orb's solar hot water heaters, street lights, and grid-connected as well as off-grid solar home lighting systems. "I got into this business for the name, fame, and money," he says with a grin.

Srikant took a $12,000 loan to set up and stock his shop. To stay afloat, he must make a minimum of $3,300 a month. Entrepreneurs like Srikant leverage the brand of Orb Energy's products as well as the software and training provided by the company to set up and run their businesses. The parent corporation guides franchisees to meet sales targets and they are rewarded for achieving or exceeding them. According to Orb, within two or three years of working as a franchisee, some of these entrepreneurs go on to start their own businesses. Though not its intention, Orb is essentially unleashing a trained workforce of solar sales agents and technicians into the solar energy ecosystem. These individuals will be critical for helping to ensure that this technology is well managed from factory to rooftops.

Karnataka offers a window into the future of solar technology diffusion in a country under various stages of economic development. New models are evolving to capture different segments of the market: not only urban versus rural but also the poor and the wealthy.

West Bengal: Islands in the solar stream

Kolkata, the capital city of the eastern state of West Bengal, looks like a yellowing old photograph. Yet not everything seems trapped in time. I am here to witness the diffusion of newer technologies. Thanks to progressive state policies, this city is home to many solar energy companies, including Onergy, started in 2009. As I depart Onergy's office on a cloudy July day, I hear the rumblings of thunder, and soon find myself caught in a deluge, feeling the full force of a monsoon storm. Streets become choked with murky water and my rickshaw puller wades knee-deep past rats swimming for their lives. If the city infrastructure holds up a bit longer, I will soon begin the lengthy journey to the world's largest mangrove forest, the Sundarbans.

The journey starts from Kolkata's Howrah station on a local commuter train that takes me to a small town at the end of the line in West Bengal's 24 South Parganas District. From there, I take a cycle rickshaw to one of Onergy's regional energy centers (RECs), where I am greeted by Sandeep, an Onergy technician. I do not speak Bengali, so Sandeep explains in broken Hindi that although the electricity grid has reached this town, not everyone is connected, and even those who are on the grid experience planned brownouts for four-to-five hours each day. REC employees thus provide and service the solar technologies for an evolving energy ecology that mixes distributed solar with centralized electricity.

But the REC also distributes products to the Sundarbans, where there is no grid, and for the penultimate leg of my trip there, Sandeep and I board a bus that is bursting with people. For the next two hours it's standing room only as we pass through a landscape dominated by palm trees, rice paddies, and the occasional water buffalo. The bus dumps us unceremoniously at the last stop in mainland India. After a brief lunch stop of fish curry and rice, we board a large wooden ferry which takes us on a 20-minute ride across the estuary and, finally, into the Sundarbans.

Straddling India and Bangladesh, the Sundarbans provide a critical habitat to endangered tigers and dolphins in addition to their large human population. Extending power infrastructure to a region where people live in pockets strewn over thousands of islands is obviously difficult. Over the past decade, the government has prioritized the distribution of off-grid solar technologies to meet peoples' needs for lighting and small-scale industrial activity. Responding to government incentives, solar energy companies in the state compete aggressively for market share. This competition makes the Sundarbans a laboratory for studying how people interact with solar technologies and how the technologies fare in this harsh ecosystem.

On the islands, perfectly laid brick roads guide our motorcycle driver through a winding pathway past homes built of everything from concrete and brick to stones and mud. Solar panels dot the thatched roofs of many. My pulse rises with excitement and I start counting them, but I soon realize that they cap nearly every home. I have finally arrived in a place where rooftop solar panels are a common part of the landscape. We make our way to a market area where a solar powered micro-grid was supposed to provide local shops with cooling and lighting. Instead, as the local technician explains, the area's diesel mafia felt undercut by the technology and forced shop owners to switch back to using diesel. Alas, now this 10 kilowatt (kW) system is used to charge peoples' cell phones instead of providing power for refrigeration, lighting, and other small-scale commercial activity.

The Sundarbans are a laboratory for studying how people interact with solar technologies and how the technologies fare in this harsh ecosystem.

I begin to realize that micro-grids, heralded as the future of genuine energy access in many parts of the developing world, can come with surprising political and economic consequences. At a village down the road, an entrepreneur, Krishna, has taken on a bank loan to set up a 30 kW solar micro-grid in his village. With no competition, he has essentially become the local utility company. Although this is a welcome way to speed the diffusion of solar energy technologies, entrepreneur-based micro-grid deployment also has the potential to create power monopolies. In a country with caste and religious tensions, such monopolies could be used to create further economic disparities (by charging wildly different rates for the same level of service, for example) in communities that are already too far-flung to police. As I conduct interviews with local customers of Krishna's micro-grid, I wonder if this is something that philanthropies and development aid agencies are thinking of when they support solar energy diffusion.

The solar entrepreneur is thriving here in the Sundarbans. One afternoon I walk the streets of a small town to interview one of the many shop owners who are assembling and selling solar home lighting components. I interrupt Sidmol, a young man in his early 20s, who is busy assembling a small fan that would be sold as part of his solar home lighting kit. He has been operating his shop for the past two years. "Business is good," he states. "During the monsoons, I can sell up to 1,200 solar lanterns a month." He also sells 150 to 200 bigger solar home systems per month. What surprised me the most was that informal sales agents such as Sidmol (who may number in the thousands across the country) often get paid in cash.

This seems strange. After all, the government provides end-user subsidies for these technologies, so why use one's own cash? But one must have a bank account to access the subsidies, and most people do not have accounts. Banks would have to hand-hold potential buyers of solar products to get them to open accounts—even assuming that bank managers knew that the subsidy existed. Coupled with the amount of paperwork required to facilitate the transaction, it is no surprise that most solar sales for rural Indians happen outside the subsidy regime. Yet

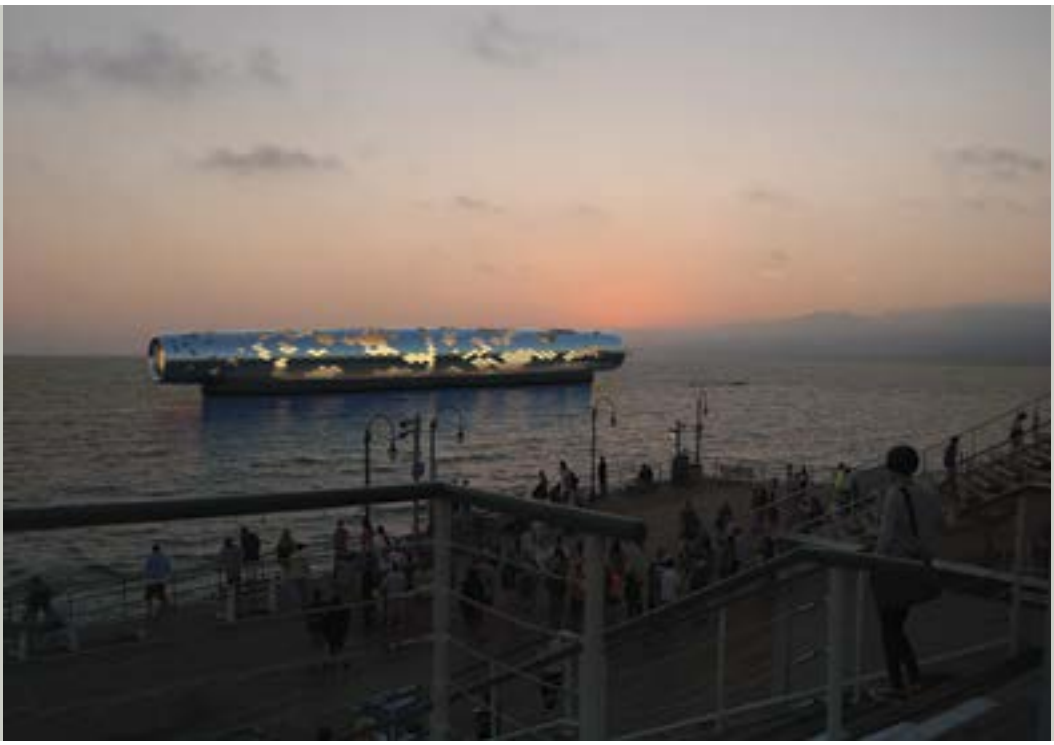
with solar systems costing as much as $500, it seems that development practitioners and academics may have underestimated people's ability to pay for these technologies.

Back in Kolkata, I learn about solar entrepreneurs recalibrating their livelihoods in peri-urban areas such as Hingolganj, where the technological landscape straddles both the off-grid and an advancing central grid. Joy Chakravorty, divisional engineer at the West Bengal Renewable Energy Development Agency (WBREDA), explains the complex regulatory challenge of energy access risk stranding assets and miss the opportunity to arm a workforce capable of managing a dynamic energy ecosystem that will power the future of a nation.

Bihar: Everyone's a sales agent

Leaving West Bengal behind, I make my way to Bihar, one of the most impoverished states in the country. Here, the energy poor are taking matters into their own hands to light up their communities. My hotel in the capital city of Patna is near the famous solar bazaar on Exhibition Road. Shop after shop of sales agents hawk their photovoltaic panels and batteries. Posters of Indian cricket star Sachin Tendulkar smiling over a solar home lighting system—no doubt a good cut-and-paste job—adorn some of the shops. They are targeting those living in urban areas as well as passersby from the rural hinterlands who, unlike city dwellers, don't even have access to the erratic electricity supply from the grid.

As I head toward Vaishali District just outside of Patna, I pass a defunct cooling tower from a local power station—signs of the state's complicated history with power generation and distribution. Bihar used to be one of the most industrialized states in the country. A history of power politics and underinvestment in power infrastructure has crippled the energy generation and distribution



The Pipe

A submission to the 2016 Land Art Generator Initiative design competition for Santa Monica

Abdolaziz Khalili, Puya Kalili, Laleh Javaheri, Iman Khalili, Kathy Kiany (Khalili Engineers)

Vancouver, Canada

From the beach, a gleaming pipe floats on the horizon. Multiple pools of hot and cold crystal-clear saltwater invite visitors to experience a ritual that takes them away from the stress of daily life. Relaxing on the pool deck, listening to the sound of the waves, and looking out to the ocean, visitors can be blissfully unaware of the seamless technology at work all around them.

Above, solar panels provide power to pump seawater through an electromagnetic filtration process below the pool deck. What results are two products: pure drinkable water that is directed into the city's primary water grid, and clear water with 12% salinity. The drinking water is piped to shore, while the salt water supplies the thermal baths before it is redirected back to the ocean through a smart release system, mitigating most of the usual problems associated with returning brine water to the sea.

system. No wonder solutions such as solar have taken root here.

Green Light Planet (GLP), a Mumbai-based company, sold 2.5 million solar lanterns in 2014, more solar energy products than any other company in India. Regional Sales Manager Vijay Tiwari accompanies me out toward their rural distribution area and explains their dual business model. GLP sells their Sun King-branded products through partners such as microfinance institutions and nonprofits, but they also have a direct marketing arm, with locally embedded sales agents who sell and service products directly to customers in their communities. In the same manner as Pollinate Energy's pollinators, GLP's sales business associates (SBAs) are part-time employees who operate under a system of sales targets and financial incentives to sell vast quantities of solar technologies.

Walking door to door with Rajeev Ranjan Kumar, who has been an SBA for GLP for approximately two years, I learn more about the business of solar in the area. "I have a target of selling 40 solar products a month," he states. Part of his sales strategy is to go to a local shop owner and leave a solar lantern that the owner can turn on at night. Visitors, drawn to the light in the evening, inquire about the product and get Rajeev's contact details from the shop owner. Targeting early adopters and community leaders is a great strategy for new innovations in such environments. "One of the first things we did was take a solar lantern to the head of the village," explains Vijay Tiwari. The village chief, who I met later, explains that he managed to convince approximately 80 other people to purchase lanterns. Nearly everyone I talked to there explained that they managed to convince others to buy lanterns. "Everyone is essentially a sales agent here," states Tiwari. Now, nearly everyone is saving money by not burning kerosene for lighting, and many families are selling surplus kerosene into the black market to earn extra cash. A local poultry farmer explains how switching out 20 kerosene-burning lamps in his poultry sheds for 20 of GLP's lanterns has boosted his profit margin.

But this model of selling solar can have its downsides. Dinesh Rai, another SBA who has sold the most monthly products in the region, explains that "this is the business of tying the noose of debt around others." His frustration stems, in part, from the fact that he is leveraging his social capital to make sales, but allowing people to pay for the products in small monthly installments instead of full upfront payments. The company does not encourage such practices but leaves it up to the SBAs since they take on the financial risk of the products once they purchase them from the parent corporation. Looking through his debt book he laments that he is owed nearly $500 from community members.

Local embedded SBAs have an advantage in making sales. Not only are customers more comfortable purchasing new technologies from a person they know, but they can also report maintenance and servicing needs to someone who will be more responsive than a service rep from a company's nearby district headquarters. Indeed, maintenance is almost as important for building out the solar innovation ecosystem as sales support. Bloomberg Energy reports that globally, the market for unbranded solar products may be as large as the formal market. If these products are of poor quality or lack after-sales support from parent companies, consumer confidence may suffer, and along with it the market for quality solar products.

Bihar provides other cautionary tales of development in India and the fate of good ideas caught in the crosshairs of politics. On another day, I head to Dharnai, a village two hours south of Patna. I am supposed to be attending the inauguration of a grid-ready 100 kW solar micro-grid. The state's chief minister, Nitish Kumar, was supposed to come to Dharnai for the inauguration. Under his watch, Greenpeace had allied itself with other organizations to help assist in the chief minister's vision of developing Bihar and providing universal electricity access using solar energy.

For reasons unknown, the inauguration, I learn, has been pushed back. The change in plans reflected the changing political calculations of the Kumar-led Janata Dal Party (JDP), which feared losing to the central government-led Bharatiya Janata Party (BJP) in the upcoming state elections. The JDP sought to distance itself from Greenpeace, which was labeled "antinational" by the central government for protesting coal and nuclear energy projects. The JDP was also unnerved by protests that emerged overnight, pressing for "real electricity" from the grid and not solar for Dharnai—all a surprise given the amount of stakeholder consultation with locals that went into the design of the solar project.

Though I witnessed a village that was about to become self-sufficient in energy thanks to its 100 kW solar micro-grid and had the capacity to add more power through solar should the villagers need it, the political support for the project evaporated. To further improve his election chances, Nitish

Kumar managed to get the central grid once again connected to Dharnai, and he has asked the state utility to give free electricity (paid for by the state) even to customers living above the poverty line. Not only is this approach to electrification economically and politically unsustainable, it is not even new: Dharnai had been down the path of electrification decades before, and through power politics and lack of investment, lost its connection. It seems hard to believe that just two hours south of Dharnai, in the town of present-day Bodh Gaya, the Buddha found enlightenment. Politicians in Bihar need to find a way to harness a bit more of that kind of power.

Governments, entrepreneurs, and gods

After a year of exploring India's solar energy ecosystem, it seems fitting that my journey ends at Delhi's international airport in front of a large statue of Lord Surya, the Hindu god of the sun. In its presence, I think back on the many stories I have heard, stories that even today convey a faith in the sun and its power, through solar technologies, to deliver India's people from darkness. Although the aspirations of these people cannot be met through off-grid solutions alone, in a country with only 240 gigawatts of total power installed currently, the Indian government says it will add 100 gigawatts of solar energy capacity by 2022. But to realize this vision, India must find a way to streamline conflicting policies, clarify others to give better direction to investors and entrepreneurs, and above all, invest in the ecosystem of support structures that can manage and maintain the technologies once they are in use.

My exploration has revealed that firms in the business of deploying off-grid solar technologies in India are finding ways to work in or around a flawed regulatory regime. Most of the firms selling off-grid solar products are doing so in urban and peri-urban areas with grid access. In some ways, then, the market for such technologies may depend on the continued unreliability of the grid. Rural areas face more fundamental challenges that seem inadequately addressed by government policies and development assistance. I've learned that getting more locally embedded entrepreneurs into the game of deploying solar micro-grids is an important element of success stories. But many micro-grid companies are reluctant to invest in rural areas without having a clear sense of potentially competing national policies for building out the central electricity grid. To address this uncertainty, some states, such as Rajasthan and Uttar Pradesh, are starting to experiment with policies that clarify how micro-grids may work in tandem with the central grid system.

On financing, if the government continues to provide end-user subsidies for consumers to purchase solar technologies, then it must also accelerate financial inclusion programs that help the rural poor to open bank accounts. But another option may be to provide financing for those businesses that find innovative ways to make access to solar energy easy and reliable without subsidies. Examples include pay-as-you-go solar energy services or the ability to make mobile phone payments for however much local, micro-grid electricity consumers want to consume. Regulations could also encourage crowdfunding to support the solar entrepreneurs who are deploying the best technologies with the best financial models. At a time when incomes are rising and the cost of technology is falling, financial innovation in the deployment of solar technologies remains important because it is still unclear how poor people are making purchasing decisions.

India is angling to be a world leader in solar energy. It has indicated its commitment not only through domestic political targets, but also by introducing and leading the International Solar Alliance, launched at the November 2015 Paris climate conference. But, as the stories I heard make clear, solar technologies are being deployed across India thanks to innovative entrepreneurs who can manage working in difficult and often uncertain regulatory regimes. What these entrepreneurs need from India is not hyped political targets, but policy coherence, quality standards, better training, better access to testing facilities, access to more finance, and better support for incubation or acceleration of their ideas.

Solar energy in India is not a story of a battle between decentralized, renewable energy technologies and centralized grid distribution. Both approaches to providing energy in a nation as diverse and complex as India offer valuable lessons and opportunities. More important is India's need to get its people access to energy to maximize their ability to thrive in the changing climate of the future. How this energy is delivered will take many forms and, perhaps, require the assistance of many gods.

Kartikeya Singh is an IDRC Fellow at the Center for Global Development and Deputy Director and Fellow of the India States initiative at the Center for Strategic & International Studies. *His doctoral research was supported by the Center for International Environment & Resource Policy at the Fletcher School of Law & Diplomacy.*