International Adventures in Clean Energy

Professor Daniel Kammen combines science with environmental policy in the quest for sustainable power

By Tom Levy

Like the intrepid fictional professor Indiana Jones, **Daniel Kammen** cuts a swashbuckling figure. As a trained pilot, he once flew medical supplies to remote areas of Kenya, ferrying patients back to Nairobi for treatment. Today, the 55-year-old globe-trotting energy and climate scientist and environmental policy wonk straddles two different yet distinguished worlds.

Fresh off a yearlong stint as a U.S. State Department science envoy, Kammen—a professor of energy and director of the Renewable and Appropriate Energy Laboratory (RAEL)—admits he was discouraged by the Trump administration's withdrawal from the Paris climate accord, which he views as the United States ceding its environmental leadership to nations such as China.

Yet he remains optimistic that the momentum for clean energy will continue to swell, especially with leadership from the Golden State. "California is truly ground zero for innovating on science and climate change technology and policies," he says in his Barrows Hall office—tall, trim, and clad in a gray "I ♥ Science" T-shirt.

Astronomers vs. astronauts

At UC Berkeley, Kammen holds appointments in the College of Natural Resources' Energy and Resources Group (ERG), which he now chairs; the Goldman School of Public Policy; and the Department of Nuclear Engineering. In 20 years, the number of students signing up for his Energy and Society class has grown tenfold, from about 35 students for the course's first semester to more than 300.

Beyond academia, Kammen serves as an advocate for worldwide recognition of human-made climate change and wider use of renewable energy to combat it. In 2007, he shared a Nobel Peace Prize as a contributor to a report for the Intergovernmental Panel on Climate Change. (Berkeley Nobelists traditionally win a much-coveted campus parking spot. But in a fitting green twist, Kammen and the other Berkeley contributors requested that their prize be honored with a bike rack near the Free Speech Movement Café.)

International luminaries have sought his battery-technology expertise. And then there's his enduring connection to Africa, where he married his wife, Dele, a pediatric radiologist, in her ancestral Nigerian village. The couple has two teenage daughters, whom he has nudged into attending NASA Space Camp and traveling to Kenya and Borneo.

Insight into his own fascination with both science and policy came to him, he says, after watching *Jurassic Park III*. In that film, another fictional professor, Alan Grant, says that exploring the unknowns of outer space attracts two kinds of people: astronomers, who study the unknown from the comfort and safety of their observatories, and astronauts, who immerse themselves in the unknown, leaving comfort and safety behind.

"What I do now, the science and policy of energy, feels like a mixture of astronomer and astronaut," says Kammen. "There's the basic science story, understanding innovation in renewable energy technology—that's the astronomer. And then there's the rough-and-tumble world of energy policy, and that feels more like astronaut."

Translating science into policy

Born in Cambridge, Massachusetts, and raised in Ithaca, New York, he is the son of Pulitzer Prize–winning historian Michael Kammen. But history was not the younger Kammen's calling. Instead, he studied undergraduate physics at Cornell University, noted for physicist-activists like Hans Bethe, who led the Manhattan Project's theory division. There, Kammen was mentored by other physicist-activists, like David Lee, an expert on how economic development, agriculture, and the environment interact, and Kurt Gottfried, a co-founder of the Union of Concerned Scientists.

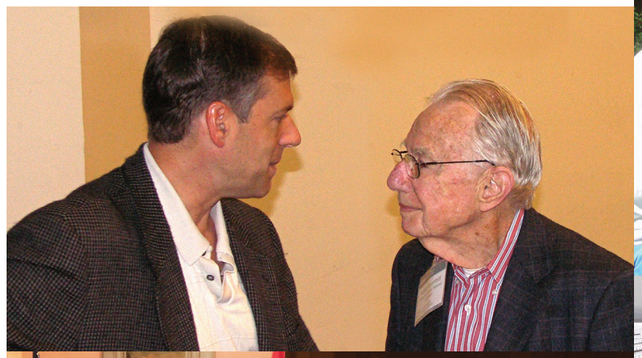
Kammen began channeling his inner astronaut as a Harvard University doctoral candidate in physics, spreading

PHOTO: Elena Zhukova

the word about renewable energy technology in several developing countries and forging lifelong connections with energy scientists and policy makers. “I followed a path I didn’t know was a path at the time,” says Kammen, who earned his PhD in 1988. “And that was the physicist-activist path.”

First as a postdoc at Caltech and then again back at Harvard, he traveled to Nicaragua—with support from Berkeley-based NGO techNICA—to research and publish papers about the Sandinista government’s pioneering solar and wind energy efforts. He also connected with Bill Lankford, who had developed a solar oven design he was sharing with Nicaraguan villagers. But village women, who did most of the family cooking, wanted larger ovens and didn’t want ovens made by men. As the women dissected and improved the designs and then built and shared their own ovens, the two scientists observed “appropriate technology” in action.

Kammen’s first teaching job was at the Woodrow Wilson School of Public and International Affairs at Princeton University, where he also collaborated with the physicist-led Center for Energy and Environmental Studies (CEES). He continued his research—on biomass as an energy source,



GLOBAL ENERGY CONNECTIONS

Daniel Kammen is pictured (clockwise from upper left) with Berkeley professor of physics and former California energy commissioner Art Rosenfeld in 2013; with Virgin Group founder Sir Richard Branson in 2006; with former California governor Arnold Schwarzenegger at the Paris COP21 summit; in South Sudan with a soldier/guide at a mini-grid project site near the Ugandan border; with then–secretary of state John Kerry in 2016; at a solar installation in Ouarzazate, Morocco; with Representative Jackie Speier at a 2017 town hall meeting in San Francisco; with then–U.S. ambassador to Morocco Dwight Bush in 2016.

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cookstoves suitable for use in East Africa, and what could be learned about technology innovation by tracking patents. Gradually he developed a vision for building a research community around appropriate and alternative energy.

“All those types of projects—not only on the science of clean energy, but on translating science into policy—led me to Berkeley,” says Kammen. “Back then, the CEES group at Princeton and the Energy and Resources Group at Berkeley were two of the very few places doing interdisciplinary science.”

From Silicon Valley to the Silicon Desert

When famed physicist-activist John Holdren left Berkeley’s ERG faculty for Harvard in 1998, Kammen was hired as an associate professor. “Holdren was one of the physicists in the same tradition I was in,” says Kammen. “In fact, he was one of the people who inspired me to do this kind of thing.” During Barack Obama’s presidency, Holdren became the longest-serving science envoy ever.

Kammen, too, took a turn in Washington, in 2010, as the first chief technical specialist for renewable energy and energy efficiency at the World Bank.

In the last year of Obama’s term, Secretary of State John Kerry named Kammen a science envoy, one of several asked to leverage their knowledge and networks toward sustained collaborative international science efforts. Kammen was assigned to increase renewable energy capacity in Africa and the Middle East.

In the Middle East, Kammen focused his science envoy work on Jordan; in Africa, on Kenya and Morocco, which he calls “the Californias of Africa.” “Kenya and Morocco are quite different but, like California, they’re very much on the leading edge of the clean-energy transition on their continent,” says Kammen. “What made Morocco and Kenya leaders was choosing early on to emphasize diversity in their energy mix, just as California has done.”

Morocco and California are of similar size, population, climate, and geography, and each possesses coastal areas as well as sizable mountain and desert regions. Each has one of the planet’s largest solar power facilities—Morocco’s at Ouarzazate and California’s at Ivanpah. And each has set aggressive 2030 climate targets, says Kammen: Morocco to reach 52 percent renewable energy, intentionally topping California’s 50 percent goal.

Kammen has been assisting Morocco’s efforts to emulate California’s example of encouraging powerfully productive academic-tech partnerships. Morocco’s goal: a “Silicon Desert” connecting young science researchers with budding local tech companies helping to build out the country’s renewable energy grid.

Influenced by the rising use of big data in the United States, and Berkeley’s own data sciences initiative, Kammen partnered with Morocco’s premier science institution. The School of Data Science at École Nationale Supérieure d’Informatique et d’Analyse des Systèmes parallels Berkeley courses and workshops on using big data, smartphones, apps, and connecting telecoms to efficiently nurture clean-energy growth and the smart management of water resources. “We’re working on a proposal right now to train young entrepreneurs in Morocco, largely by having them interact with Silicon Valley companies and universities,” says Kammen.

Nation-sized solutions

In Kenya, Kammen’s deep network of friends and contacts helped him to dive into furthering the nation’s goal of growing its renewable energy grid. “Kenya is the China of Africa,” Kammen says, with economic

Kammen meets with the dean and students in the School of Data Science at École Nationale Supérieure d'Informatique et d'Analyse des Systèmes in Rabat, Morocco.

PHOTO: Courtesy of U.S. embassy, Rabat

and infrastructure growth but also a lingering issue of off-grid energy-access challenges. So Kammen's RAEL team cranked up research and collaborations with an open-source energy-modeling package called SWITCH (solar and wind integrated with transmission and conventional power), a big-data tool for looking at largescale—nation-sized—climate change solutions.

Using SWITCH as the simulation platform, the lab's team members marry systems modeling with detailed explorations of new theories to understand the speed of energy innovation and adoption. For example, they look at patent-application activity and gauge the effects of changing economic and financial activity. Other measurable factors fed into SWITCH include the rapidly decreasing price of solar panels; accelerating efforts to replace heavy, rigid solar panels by bringing lightweight, flexible panels to market; and massive new investment in battery research.

Kammen's team has also built SWITCH models for other African nations, South American countries, western U.S. states, and elsewhere. Its largest effort to date, a model for China, ties in with that nation's aim to peak its carbon emissions in 2030, with steady reductions thereafter. Kammen plans to visit China three times in the next five months to work on U.S. partnerships with its research community and to see how to get ideas suggested by SWITCH modeling put into practice.

The economic juggernaut has a tradition, like California, of learning from small-scale pilot programs. China just finished a five-province carbon-pricing test. And because its powerful central government, unlike the U.S. government, can avoid years-long policy-change debates, Kammen says, the country plans to go national with carbon pricing this year.

In August, Kammen regretfully resigned from his science envoy position in a letter responding to President Donald Trump's "attacks on core values of the United States." The letter went viral on Twitter, with more than 100,000 likes and 40,000 retweets in 24 hours. But Kammen's global collaborations will continue. On the horizon for him, in November, are the United Nations Climate Change Conference in Bonn, Germany, and a meeting at the Vatican possibly including a face-to-face with Pope Francis.

Solar-powered batteries for the stars

Perhaps one of the most tantalizing new dishes on Kammen's upcoming research menu is his lab's work on battery technology. Cheap storage of sun-generated energy could give the world access to reliable baseload solar power, even when the sun isn't shining. It's today's energy-rainbow pot of gold.

But the physics of battery-efficiency limitation are ugly. Lithium-ions may be the battery du jour, found in mobile phones, laptop computers, and soon perhaps huge arrays like Tesla Powerwalls. But like other commonly used rechargeables, such as lead-acid batteries in cars, they eventually lose their ability to hold a charge.

In 2004, a phone call from Virgin Group magnate Richard Branson led Kammen to pursue an alternative. Branson wanted a renewable energy system with a supersized battery able to run his entire private Caribbean island. Price was no object. Kammen's lab began looking at "flow" battery technology: two tanks of diffuse sulfuric acid separated by a membrane. In this battery, which behaves more like a fuel cell, physics minimizes the charge-holding problem.

Kammen's team did some preliminary work, but didn't build Branson's entire project. Shortly afterward, a representative of the Marlon Brando estate called. He also wanted a renewable energy system with a backup battery, to power the late actor's private South Pacific island. Now a Kammen lab–built flow battery, possibly the world's second largest, powers the island of Tetiaroa in French Polynesia.

"Flow batteries started out as a luxury good," says Kammen, who flew to Tetiaroa in August to evaluate the power system's performance and to work with the UC Berkeley–run Richard B. Gump South Pacific Research Station on neighboring Moorea. "But now research labs are looking at ways to miniaturize them, to build everything from a flow battery for your home or business to a tiny battery that could run your phone or laptop for several weeks."

These days Kammen spends more time building relationships, managing, and conducting diplomacy than doing physics. So the scientist in him gets a big charge watching the battery world show as much interest in chemistry and physics as the solar world once did.

"This is feeling increasingly far from my physics roots, but this is where the clean-energy world takes you," says Kammen. Even without Indiana Jones's renowned sable fedora, he gives off an air of confidence that more adventures and discoveries are yet to come.

AN ENVIRONMENTAL WIN IN BORNEO

China and Southeast Asia, now among the world's hottest economic regions, have drawn **Daniel Kammen**'s attention for some time. The latter region is also where his collaboration with indigenous environmental activists, in Malaysian Borneo, scored a major victory in 2016.

"I caught the Borneo bug early, and it has held tight to me ever since," says Kammen, describing a 1985 trek he and his brother took across the poorly mapped Indonesian portion of the densely forested island.

Three decades on, deforestation has made much of Borneo unrecognizable. Vast swaths of native forest have been clear-cut for palm plantations, displacing whole communities of indigenous people.

Kammen returned to Malaysian Borneo in 2007 to research fossil-fuel alternatives for a group of NGOs battling a 300-megawatt coal-fired power plant in Sabah State. Four years later, their win stopped the coal plant in favor of electricity from natural gas and renewables.

That victory led to a request for assistance from activists in Sarawak, Malaysia's poorest and most rural state. Officials had proposed building 12 massive hydropower dams and two coal-fired generating plants—with a combined capacity of 9,380 megawatts—to attract factory investment and fuel manufacturing.

The first of the 12 hydropower projects—the 2,400-megawatt Bakun dam, Asia's largest outside China—was completed in 2012. It flooded thousands of acres, displacing about 10,000 people in Sarawak. In 2013, the 944-megawatt Murum dam went online, and plans for the 1,200-megawatt Baram dam were waiting in the wings.

The research Kammen co-led showed that it was unlikely that Malaysia would ever need this much electricity. It also identified appropriately sized, ecologically friendly power alternatives. Local indigenous people and other environmental activists had fought the dams and coal plants for years. Together they stopped the Baram dam, and native land-ownership rights were reinstated. There is no funding for the other proposed dams now, but Malaysian activists continue to work against them.

"This remarkable turnaround victory demonstrated the importance of local community activism, along with doing and communicating the best science," Kammen wrote. — TL