SUSTAINABILITY

Will Space-Based Solar Power Finally See the Light of Day?

A satellite that reaps the sun's energy in space and beams it down to Earth for use as electricity may leave the realm of sci-fi and edge closer to reality this week following an energy deal in California

By Adam Hadhazy on April 16, 2009

Pacific Gas & Electric Co. (PG&E) has long invested in renewable energy sources, including geothermal, wind and solar. Earlier this week, the utility company reached for the stars in announcing the first-ever deal of its kind: The California power utility, says spokesperson Jonathan Marshall, plans to purchase clean energy generated by a satellite beaming solar power from orbit.

The agreement between PG&E and Solaren Corp., an eight-year-old company based in Manhattan Beach, Calif., still hinges on state regulatory approval. If the deal gets the green light, Solaren must then privately raise billions of dollars to design, launch and operate a satellite as well as an energy-receiving ground station slated for the Fresno County area, says Cal Boerman, director of energy services for Solaren.

The challenges of building this satellite (due to be completed in 2016) and introducing so-called space-based solar power (SBSP) remain formidable. But driven by the urgency of climate change and the lowering costs of solar technology, a growing number of countries and companies believe an energy revolution could be in the offing.

Why bother harvesting solar energy directly from space? It is abundant, and "you can get [this] power 24/7," says Marty Hoffert, an emeritus professor of physics at New York University. Sunlight is some five to 10 times stronger in space, and its shine would reach energy-gathering satellites placed into geostationary (fixed) orbits—the realm of many currently deployed communications spacecraft—more than 99 percent of the time.

SBSP could, according to energy experts, provide constant, pollution-free power—unlike intermittent wind and cloud cover–sensitive ground-based solar, and without the emissions of fossil fuels or radioactive waste from nuclear power. "[SBSP] is a disruptive technology [in that] it could change the whole energy equation," says Frederick Best, director of the Center for Space Power (CSP) at Texas A&M University in College Station, Tex.

The premise (and promise) of SBSP has been considered scientifically feasible since the late 1960s. The basic concept of beaming microwave frequencies to Earth from orbit has already been proved: A fleet of solar-powered communication satellites routinely beam various electromagnetic frequencies to ground receivers, linking cell phone calls or relaying TV signals to rooftop dishes, for example. Converting solar energy beamed from space into electricity in a power grid, however, has not yet been demonstrated.

Space Energy, a Switzerland-based SBSP start-up, aims to change that by deploying a prototype orbiter in the next several years, possibly before Solaren's pilot plant reaches orbit. "You can argue the physics [of SBSP] all day, but you'll only know with a prototype," says Peter Sage, a co-founder of

Space Energy, started in 2008.

Last year, U.S. and Japanese researchers crossed an important SBSP threshold when they wirelessly transmitted microwave energy between two Hawaiian islands about 90 miles (145 kilometers) apart, representing the distance through Earth's atmosphere that a transmission from orbit would have to penetrate, says Frank Little, associate director of the CSP.

Many other technologies relevant to SBSP have made "enormous progress" in recent years, says John Mankins, who led the Hawaiian island test as chief operating officer and co-founder of Ashburn, Va.–based Managed Energy Technologies, LLC. A little over a decade ago, the best photovoltaic efficiency, or sunlight conversion into electricity, was 10 percent, Mankins says; now it can reach 40 percent. And satellite technology has also improved: Autonomous computer systems as well as advanced, lightweight building materials have also made leaps and bounds, he says.

Despite such progress, and spending some $80 million, SBSP has not gotten past the U.S. government's drawing board so far. A key reason, Little says: NASA does not do energy, and the U.S. Department of Energy (DoE) does not do space.

The U.S. Department of Defense, however, has recently shown interest in SBSP. Air Force Colonel M. V. "Coyote" Smith cites high fuel costs, along with risks to personnel when supplying petroleum to U.S. combat theaters and bases. A 2007 Defense report (pdf) from the Pentagon's National Security Space Office (NSSO), viewed the commercial development of SBSP quite favorably, especially as traditional, fossil fuel energy sources get ever scarcer in the years ahead. "We've got to identify sources of safe, clean energy in order to help us prevent energy wars in the future," says Smith, one of the authors of the 2007 report.

The NSSO report said it would be in the fed's interest to encourage the commercial development of SBSP, but that the government should not design or operate the eventual orbiting power plants.

The previous government work, including a joint NASA and DoE report from the 1970s about SBSP, has left its mark on many current architectural schemes, though. This textbook approach calls for a massive, microwave-beaming satellite several miles wide that would sport multiple enormous solar arrays connected to a central hub *[like the artist's conception on the first page of the article]*. The craft would be perched in orbit about 22,400 miles (36,050 kilometers) above Earth, or a tenth the distance to the moon. There, the satellite would maintain a geostationary, or fixed, position relative to a point on Earth's surface while its solar panel arrays bask in the constant sunlight.

Captured solar energy then gets converted on board the satellite into electromagnetic carrier waves, specifically microwaves, ideally at a frequency of either 2.45 or 5.8 gigahertz (both fall on the spectrum between infrared and FM/AM radio signals) for subsequent beaming back to the ground. At that frequency, the waves pass easily through the atmosphere, although some energy—physicists do not know exactly how much yet—would be lost during the transfer, Smith says.

This invisible column of microwave energy, measuring perhaps a mile or two (two to three kilometers) across, would be beamed at an oval-shaped, ground-based rectifying antenna, or a "rectenna," of similar size, and from there the energy would flow into the traditional electrical grid.

Despite the clear analogy to a science fiction death ray, scientists believe the diffuse energy beam from above would not pose a health threat to people or wildlife, even at its most intense center.

"Microwave radiation is nonionizing, just like visible light or radio signals," says Jim Logan, former chief of medical operations at NASA's Johnson Space Center and an expert on aerospace medicine. That means it lacks sufficient energy, like x-rays and gamma rays, to remove an electron from an atom or a molecule to make a charged particle that can damage DNA and biomolecules, he says.

Birds passing through the heart of the carrier wave from space might feel some warmth, Logan wrote in a February white paper on SBSP safety for Space Energy, but not at elevated levels. And should the beam stray from its rectenna target, it would be designed to defocus, Logan says, and not "run amok all over the landscape." Sage of Space Energy says: "We won't be frying birds or turning clouds to steam."

Space Energy's first operational array, which adheres to the typical SBSP setup just described, would be designed to generate one gigawatt almost continuously, about the same output as a large nuclear plant. Pursuant to a successful prototype experiment in several years, Space Energy expects that investors would pony up the billions estimated to make a full-scale commercial plant a reality.

Building segments of the plant's solar arrays on Earth, along with supports and a central transmitter, would take two years or so, says Stephan Tennsel, CEO and co-founder of Space Energy. Some 40 to 60 launches would boost all the components for the first SBSP satellite into a low Earth orbit (LEO) where a combination of automatic panel unfurling ("like an umbrella," Tennsel says) and robots would assemble and integrate them.

Dangers and engineering challenges abound, however: Space junk like that which recently threatened the International Space Station, for example, could collide with the skeletal space solar satellite during assembly. And keeping the satellite's huge beam and the distant rectenna reliably synced up also stands as an unsolved technical issue, says CSP's Little.

Overall, the *how* may be much easier to overcome than the *how much*. "Technically, we're a lot closer to space-based solar power than we are economically," Little says. The biggest obstacle, he says, continues to be launch costs. "Large structures in space are not showstoppers, but the cost of getting up into space is the real hang-up [for SBSP]," CSP's Best says. In Space Energy's business plan, for instance, half of the $250 million allotted for their communication satellite–size prototype goes toward just lofting the approximately 1,760-pound (800-kilogram) craft into orbit.

Though Solaren is tight-lipped about what its pilot power plant will look like, a 2005 patent retained by the company indicates that the firm intends to use mirrors—another oft-explored SBSP element—to gather and focus sunlight prior to converting it to microwaves. According to the patent, Solaren also looks to eliminate many of the structural connectors on its craft—that is, some or all of the satellite's components, including the mirrors, power module and microwave emitter could be "free-floating" in space, orbiting in tandem. "The big thing is to get the weight down so the weight costs don't kill you," says Solaren's Boerman.

Backers of SBSP hope that the rising commercialization of space—sparked by the allure of space tourism and the economics of cheaper access—will bring down the expense of rocketing into orbit. Some of the best-known entrepreneurial ventures include Richard Branson's Virgin Galactic and Elon Musk's SpaceX, but almost 20 companies are trying their hand at lowering launch overhead. "These organizations could potentially change the picture of launch costs," Best says.

Many other obstacles stand in the way of commercially viable SBSP. A crucial regulatory matter: getting clearance from the U.N.'s International Telecommunication Union (ITU) that allocates use of the electromagnetic spectrum. SBSP's ideal microwave frequencies are already used by wireless systems such as Bluetooth, according to Smith. "Even if we could narrow the beam [from space] down and ensure complete signal integrity in the broadcast wave area," the ITU may deem the possible interference from SBSP as too disruptive to some extant technologies, he says.

Some think that SBSP efforts should zero in on lasers rather than microwave transmission to avoid this and other confounding issues. "I think an approach using microwaves is doomed," N.Y.U.'s Hoffert says. Given the necessary size of microwave transmitters and their solar arrays, "it's a huge capital investment before you get one kilowatt of power," he adds.

A higher efficiency, laser-based approach would require far smaller satellites and transmitters, perhaps requiring just one launch, Hoffert notes. One proposal involves capturing sunlight in space via photovoltaics, converting the energy into a visible or an infrared laser and then beaming this concentrated light onto existing solar panel arrays in the desert around the clock. Weather can disrupt laser transmissions, however, and Hoffert says other technical hurdles remain for both microwave and laser light approaches.

The Japan Aerospace Exploration Agency (JAXA) is covering all bases as

Scientific American magazine reported last year. JAXA hopes to have a one-gigawatt satellite in geostationary orbit around 2030 that may use either microwaves or lasers to send its energy back home.

Yet another school of thought involves placing solar-power generators and microwave transmitters on the surface of the moon, or even using a lunar base to construct the satellites before launching them (with relative ease, due to the moon's far weaker gravity) into a geostationary orbit. Many of the raw materials for crafting the satellites could be mined from the moon as well.

If these and other far-flung, future missions ever come to pass, their creators may look back on PG&E's faith this week in Solaren as a key moment in the history of SBSP development, Logan predicts. "If [Solaren] is able to deliver this energy, you're talking about the first time space-based resources have ever been imported to Earth," he says. "It's a significant breakthrough in the awareness of the fact that we're not limited to just the resources on the planet."

Auspiciousness aside, Solaren has a long road ahead of it in terms of raising capital and constructing the first-of-its-kind SBSP operation. Soothing local fears of death rays from space will also take some finessing, Logan admits.

In the end, PG&E has not invested its customers' or shareholders' finances in the deal, says Marshall, the company spokesperson; rather, Solaren is on the hook to deliver the power first. Over 15 years, Solaren has agreed to provide 200 megawatts of electricity almost continuously, enough for a quarter million homes, starting in June 2016.

"Even though PG&E took pains to assure the public they were not investing and that it was only a supply contract, it is still a big step," says CSP's Little.

"If another energy supply contract is signed in the near future, I expect interest in space solar will really accelerate."

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