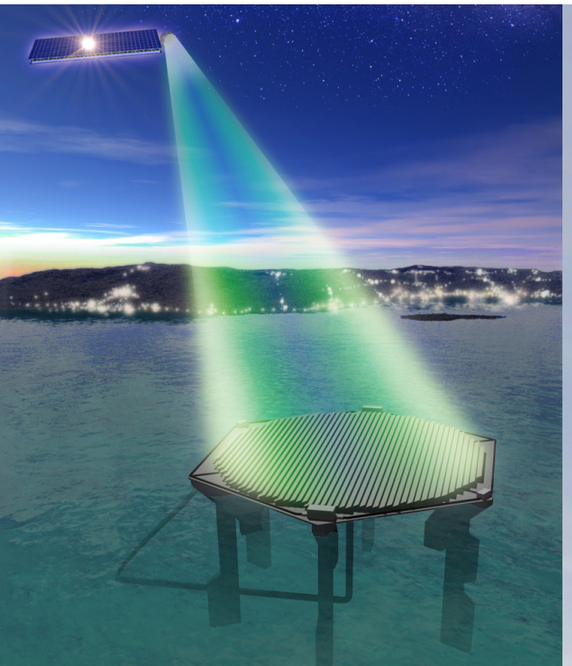
JAPAN'S LONG-PLANNED PHOTOVOLTAICS:

SPACE-BASED SOLAR POWER AND PEROVSKITE SOLAR CELLS

Solutions are emerging to conquer solar power's shortcomings, namely, limited installation sites and low-capacity utilization rates. Japan is spearheading the development of two promising technologies to make optimal use of both the Earth and space and fully harness the Sun's power as electricity: space-based solar power and next-generation flexible solar cells.

Sunlight illuminates and warms the Earth and is the ultimate source of all biological activity. Solar power, which converts the Sun's energy into electricity, is one method of generating power that the world is increasingly focusing on in the effort to create a decarbonized society.

Although solar power has been in practical use since the 1970s, it has yet to become a major source of power worldwide. That stems from the dearth of appropriate locations for installing solar panels, along with the low-capacity utilization rate as power generation falls off, such as at night, during bad weather, or when the panels get dirty.



Left: Diagram of a space-based solar power (SBSP). An antenna located at sea receives microwaves transmitted from a satellite in geostationary orbit and converts them into electricity. Microwave irradiation requires an accuracy of less than 0.001° in angular error. SHINOHARA LAB., KYOTO UNIV.
Right: Image of a perovskite solar cell (PSC) wall installation. NEW ENERGY AND INDUSTRIAL TECHNOLOGY DEVELOPMENT ORGANIZATION

Professor SHINOHARA Naoki of Kyoto University's Research Institute for Sustainable Humanosphere specializes in wireless power transmission, space solar power stations, and microwave processing. He has served as a member of the Japan National Space Policy Committee and as chair of the Wireless Power Transfer Consortium for Practical Applications. SHINOHARA LAB., KYOTO UNIV.

To maximize the use of solar energy and overcome those drawbacks, two promising technologies have been developed: space-based solar power (SBSP) and next-generation flexible solar cells. Japan is making steady progress toward the practical implementation of both.

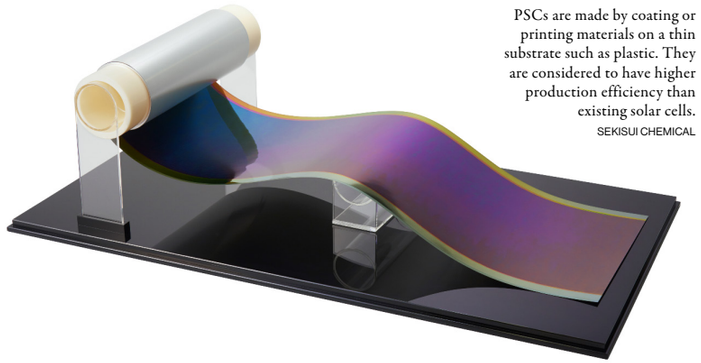
The SBSP project involves the space launch of satellites equipped with giant solar panels measuring 2 km², converting the generated electricity into microwaves that are then transmitted wirelessly to the ground. Since the satellites will be able to generate power day or night regardless of the weather, they will boast a high-capacity utilization rate of at least 90%, generating an estimated five to 10 times more power than ground-based solar panels, whose capacity utilization rate is a mere 15% or so. Each satellite will generate 1 million kW of electricity, equivalent to the output of a nuclear power plant.

Microwaves—a type of electromagnetic wave, used now daily in microwave ovens and communications equipment, that the system will use to transmit the power to the ground—can penetrate clouds and rain if the optimum frequency is selected, making them virtually free from weather interference. Since the transmission would be wireless, moreover, the target destination can be changed as needed. The SBSP concept was first proposed in the U.S. back in 1968, but research has stalled due to several technical and cost-related issues, such as the difficulty in establishing highly efficient systems for power generation and transmission and the transport and assembly of giant solar panels. With recent technological advances, however, SBSP technology has begun to garner renewed attention around the world.

Meanwhile, Japan has been continuing SBSP research for several decades through industry-academia-government collaboration. Kyoto University has already taken the lead in establishing wireless power transmission technology using microwaves, a fundamental element of SBSP. In 1990, the university's Professor SHINOHARA Naoki was inspired to enter the field by his mentor at the time, Professor MATSUMOTO Hiroshi, who said, "SBSP is a technology that will enable the human race to survive for the next 10,000 years." Looking back on his old mentor's declaration, Shinohara said, "If the Earth's population continues to grow, so will the amount of electricity consumed, and the generation capacity on the ground will be insufficient to supply the necessary power. That's why we need to go into space."

Since the 1980s, Japan has conducted many SBSP experiments in outer space and accumulated a large amount of relevant data, even when research has been suspended elsewhere. In 1983, it conducted the Microwave Ionosphere Nonlinear Interaction eXperiment (MINIX), which transmitted power from one rocket

The photo shows a microwave wireless power-transfer experiment from an airship to the ground, conducted by Kyoto University in 2009. Due to its ability to send and receive power over longer distances than other contactless power-transfer methods, the technology to wirelessly transmit power with microwaves shows promise for use in a variety of applications on the ground, such as supplying power to disaster areas where infrastructure has been disrupted.
SHINOHARA LAB., KYOTO UNIV.



PSCs are made by coating or printing materials on a thin substrate such as plastic. They are considered to have higher production efficiency than existing solar cells.
SEKISUI CHEMICAL

to another in space plasma for the first time in world history. Later, in 1993, the country conducted a successful rocket experiment using the then newly developed phased array antenna for more accurate power transmission in space plasma. Japan also has strong enough capabilities in satellite system design to maximize power generation efficiency and accurately transmit power to the ground.

Shinohara said, "SBSP has been incorporated into the Japanese government's Basic Plan on Space Policy since it was first formulated in 2009. I've been researching SBSP technology for many years, and now that there is global attention on it, I feel it will truly work out." The current plan has set a goal of conducting a space-to-ground power transmission experiment by fiscal 2025. The California Institute of Technology already successfully conducted such an experiment earlier this year, but Japan is aiming to transmit power with even greater precision, with the focus on developing beam-control technology to accurately send microwaves from a fast-moving satellite in low orbit to a receiving antenna on the ground. Progress is steadily being made toward the goal of creating a feasible SBSP around the middle of the century.

On the other hand, the social implementation of "flexible solar cells," namely perovskite solar cells (PSCs)—a technology that will expand the area available for generating solar power on the Earth—is currently being demonstrated. Utilizing the Green Innovation Fund established by the Japanese government, several companies and research institutes are working together to develop practical applications and popularize PSCs.

PSCs were invented in Japan, with the first research paper published in 2009. PSCs are film-shaped solar cells made of a material whose crystal structure resembles that of a mineral called perovskite. The cells are thin, lightweight, and flexible, in contrast to today's mainstream silicon solar panels, which are thick and rigid, and thus face restrictions on where they can be installed. Meanwhile, the power-generating layer of a PSC is less than 1μm thick, more than 100 times thinner than a traditional silicon solar cell. PSCs, which are about one-tenth the weight of ordinary solar cells, can thus be installed in places where conventional solar panels cannot, such as on the exterior walls of a building or on curved surfaces.

One company currently developing PSCs is SEKISUI CHEMICAL CO., LTD., a major chemical manufacturer. One problem with PSCs is their poor durability; outdoors, they quickly degrade owing to moisture, oxygen, and ultraviolet light. This is where SEKISUI CHEMICAL's technological expertise comes into play. MORITA Takeharu, Director of the Perovskite Solar Cell Group at the company's R&D Center, said, "Our strengths lie in our sealing technology that protects precision equipment from dust and moisture, as well as our film sheet manufacturing. We have the largest global share of liquid crystal sealants, as well as interlayer films for automotive laminated glass. We are also working with customers and suppliers to develop construction and installation techniques. Our development now is geared toward future maintenance and replacements."

MORITA Takeharu (right), Director of SEKISUI CHEMICAL's R&D Center Perovskite Solar Cell Group, is shown holding a PSC along with KOGA Meiko (left), Executive Officer of the company's Corporate Communications Department. SEKISUI CHEMICAL

With more than 30 companies and local governments collaborating, many demonstration tests and joint-research projects are underway. In April 2024, a major IT company in Tokyo plans to install PSCs on the walls of a data center for a demonstration test. In order to control their indoor temperature and prevent intrusion, data centers normally have few windows, which makes a substantial portion of their wall surfaces suitable for installing PSCs. Data centers also consume a lot of power because they operate many servers, so decarbonization is an important issue. After the conclusion of the demonstration tests, the IT company intends to install PSCs at 16 of its data centers across Japan.

Other pilot projects are in the planning and implementation stages at sewage treatment plants, thermal power plants, railroad facilities, public facilities, and elsewhere to investigate durability and power-generation efficiency under various conditions. After the trials are completed, the PSCs will be deployed to other similar facilities nationwide. KOGA Meiko, Corporate Communication Department Head and Executive Officer at SEKISUI CHEMICAL, said, "For over 75 years, we have been working to solve environmental issues through our businesses and products, but perovskite solar cells seem to hold particularly great promise. Through this technology, we hope to contribute to the building of social infrastructure that helps give people around the world peace of mind."

This April, at the Ministerial Council on Renewable Energy, Hydrogen and Related Issues, Prime Minister Kishida announced that Japan aims to introduce PSCs to society as soon as possible, instead of waiting until 2030. Commenting on that announcement, Morita said, "It is beyond anything I ever expected that our company and our country would be pursuing the same goal," but added, "We have to make a nationwide effort to develop feasible PSCs as quickly as possible and spread them across the globe."

The search for more sustainable and efficient methods of power generation is indispensable for humanity's survival over the next 10,000 years and beyond. Moreover, given the unstable state of global affairs, energy security has become an urgent issue for every country. It will become increasingly important to introduce renewable energy sources that do not require fuel, and to diversify energy sources. Japan's efforts to harness the potential of solar power, a well-known renewable energy source, will shine a light on humanity's future.

In May 2023, a PSC test measuring the power-generation efficiency of PSCs and verifying their corrosion resistance performance began at the Morigasaki Water Reclamation Center, a sewage treatment facility in Tokyo and the largest water reclamation facility in Japan. Tokyo Governor KOIKE Yuriko (foreground, left) and SEKISUI CHEMICAL President and Representative Director KATO Keita (foreground, right), who is a co-researcher, mount a PSC to a pipe.
TOKYO METROPOLITAN GOVERNMENT

PSCs produced by SEKISUI CHEMICAL, which were also exhibited at the International Media Center (IMC) at the G7 Hiroshima Summit. SEKISUI CHEMICAL