Is Japan embracing a solar future in the post-Fukushima era?

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The great earthquake and subsequent tsunami on March 11, 2011 in Japan not only disabled the power supply and cooling systems of three Fukushima Daiichi nuclear reactors, they also damaged a half-century old national nuclear program. After the accident, with the nuclear reactors out of action, the Japanese government started considering power policies in which the role of nuclear energy was severely reduced—the first time in nearly 60 years. Coal, oil, and natural gas imports skyrocketed, permitting a stable electric supply, but at the same time causing rising CO_2 emissions and electricity prices for private consumers and businesses.

Alternative energy source technologies were acknowledged as substantial contributors to the effort against climate change in the Japanese Intended Nationally Determined Contribution (INDC), said Charikleia Karakosta, an expert in energy-environmental and climate policy decisions from the National Technical Universtiy of Athens. INDC is a national voluntary pledge, in which renewables are projected to comprise 22–24% of the electricity generation, with almost 7% of it expected to be derived from solar energy.

After the disaster, a number of public and private bodies engaged in alternative energy were settled in Japan. The National Institute of Advanced Industrial Science and Technology established the Fukushima Renewable Energy Institute, which opened in April 2014 to promote R&D into renewable energy. The Renewable Energy Institute (REI), a private organization and think tank, was created to support public awareness and policies for the establishment of a society based on renewables.

Mika Ohbayashi, director at the REI in Tokyo, regards the government's targets as "clearly too low," and she thinks the expansion dynamic of renewables is underestimated. Based on REI reports, the share of renewables, including hydro, in electricity production reached approximately 21% in May 2016. Ohbayashi's annual prediction is that this percentage will stabilize around 16%. There are good reasons behind the optimism, as there are still almost 15 years for the goal to be reached.

Development of the solar, wind, geothermal, and biomass energy market was significant after the accident. In 2015, Japan was third among the G20 in clean energy investments, attracting USD$36.2 billion for alternatives. Eighty-eight percent of these investments went to small-scale solar photovoltaic (PV) projects, according to the United Nations Environment Programme's (UNEP's) 10th "Global Trends in Renewable Energy Investment 2016," by the Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance and Bloomberg New Energy Finance.

But the sky over Japan's renewable future has some dark clouds. ''Challenges depend on the types of renewables," said professor Michihisa Koyama, Unit Leader at the INAMORI Frontier Research Centre of Kyushu University in Japan. Koyama believes that unlike wind, geothermal, hydro, and biomass solutions, which must be planned and introduced gradually to maximize their resource potential in a sustainable manner, solar is in a different position. Solar is relatively easier to set up and "its short lead time has extremely accelerated its installation under a feed-in tariff (FIT) systems scheme," he said.

The FIT policy provides a guaranteed price premium to renewable energy developers for selling the electricity they produce. In July 2012, an extremely aggressive FIT for energy coming from renewables was introduced in Japan, which triggered more than 1.2 million applications, mostly for home rooftops and some mega solar power installations. The reductions in FIT that started taking place from 2014 have significantly decelerated the trend.

Furthermore, several conventional power utilities are not only prohibiting PV equipped homes to directly use their generated power (even in case of emergency), but are also blocking connection to the grid for renewables, overwhelmed by the changes taking place. Ohbayashi said that this is perhaps the biggest problem that renewables face in Japan: "A reform in the Japanese power market and power energy structure is urgently required to facilitate access to the grid and remove the barriers for solar power and other forms of clean energy technologies," she said. Additional stumbling blocks for solar come from within. It has recently been reported that a large number of megasolar initiatives are taking advantage of a loophole in policy and are delaying completion while they wait for cheaper solar panels.

But it's not only policies that slow down renewables. Several factors that depend on the materials themselves determine to what extent Japan can use solar energy to cover a larger fraction of its energy needs. Commercial PVs with improved efficiency are required for harnessing solar energy in a more cost-effective way. And the intermittent nature of PVs is a big obstacle for the desired stable power supply.

For applications with high-efficient energy use, significant efforts are under way, especially in the field of organic photovoltaics (OPVs). Professor Takashi Sagawa, expert in OPVs at the Department of Fundamental Energy Science at Kyoto University, thinks that these materials

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offer unique prospects for future utilizations. "The power-conversion efficiency of OPVs (defined as the proportion between the useful energy input and energy output) has been remarkably improved over the last decade" he said, adding that their durability has also been improved, keeping their PV performance for longer times.

"OPVs are light weight, are easily printable and transparent with several hundreds of nm thickness, and are especially sensitive even against the weakest light, in comparison to conventional Si-based, copper indium selenide and CdTe devices," he said. These characteristics offer various options for applications. For example, OPV-based paints can be applied on north-faced walls or windows, where there is usually no direct solar light, as well as on the inside walls of buildings, where they can be used for recycling the room light.

"If you have seen night views of the Earth, it is striking how bright the advanced nations show, in contrast to the developing countries. Every night some parts of the world produce electricity, which is then used but also wasted in some sense. This light could be perhaps 'recycled' through OPV solar cells." For Sagawa, OPVs could offer an alternative to the conventional concept of mega-solar power plants, which require vast spaces.

Although OPV light harvesting systems seem like a promising cost-effective alternative for the use of solar energy, their relative low power-conversion efficiency, which does not exceed 11%, hinders their way to industrial production. Currently, the best commercially available solar cells have a 20% efficiency, and intense research efforts are required for novel OPV materials and device architectures, with improved electrical and optical properties.

Satoshi Ishii, a researcher at the photonics Nano-Engineering Group of the National Institute for Materials Science in Japan, and his colleagues are investigating an approach different from the sun-to-electricity materials. The team is working on methods to use solar energy by turning it directly to heat. This relatively inexpensive technology, which has been in use for years, especially in areas with abundant sunshine, is often overlooked. Ishii and colleagues demonstrated that titanium nitride (TiN) nanoparticles dispersed in water act as excellent sunlight absorbers and heat-transfer medium and can generate solar heat. The sunlight-to-heat efficiency of the TiN nanofluid was found experimentally to be higher than the efficiency of conventional solar heat concentrators. The efficiencies gained by these new materials may make this solar-thermal technology more practical in areas with less abundant sunlight, such as Japan.

Photovoltaic power plant at Miyazaki Prefecture in Japan. Credit: Shizen Energy Inc.

"Although this method cannot directly supply electricity, its advantages are critical for a sustainable society," Ishii said. Considering that 55% of energy consumption in Japanese houses is for heating water and warming rooms, Ishii believes that such a solution can be used for domestic purposes, thus reducing electricity consumption.

Finding solutions for intermittency is also the focus of several research groups. Countermeasures for this situation will also provide a viable solution for wind power generators, which are expected to be installed on a large scale, Koyama pointed out. "The present research trend will not be solely focused on renewables. Japan is strong in both battery- and fuel-cell (or hydrogen) technology, and both of them, along with solar cell technologies and emerging energy management systems, will help to realize its energy plans," Koyama said.

Cost-effectiveness is another primary concern when it comes to implementation of solar PV technologies. In March 2016, a study conducted by the REI at Tokyo showed the prices of solar PV systems in Japan were relatively high compared to global standards and double in comparison to Germany, a country with a long tradition in renewables that was in favor of a nuclear power phase-out after the Fukushima disaster. In September, a newly established bi-national German–Japanese Energy Transition Council (GJETC) held its first meeting in Tokyo. The collaboration aims at strengthening the international competitiveness of both countries.

"GJETC work is focused on the scientific exchange of knowledge in the field of energy sector issues and mutual learning, and although the main scientific work has not started yet, solar energy is on the list, and it will be discussed while analyzing scenarios and energy systems, costs, and technologies," according to Maike Venjakob, project coordinator for the establishment of the council at the Wuppertal Institute, which supports the council's work.

With an eye to the future, experts believe that renewables and especially solar power have a big role to play. Koyama thinks that R&D investments for non-conventional technologies are essential to realize the drastic low-carbonization and sustainable development of domestic industries.

Ishii thinks it is remarkable that although many Japanese acknowledge the importance of solar energy, mainly PVs, the government still wants to rely on nuclear power plants to keep electricity cheap and stable. "Everyone should recall what we have seen in Fukushima," he said.

Ohbayashi believes that despite the problems, Japan is undergoing a big transformation and is gradually moving in the right direction. "If we catch up with the drastic expansion of renewables, which is happening in other parts of the world, that remains to be seen." □