A Good Fit

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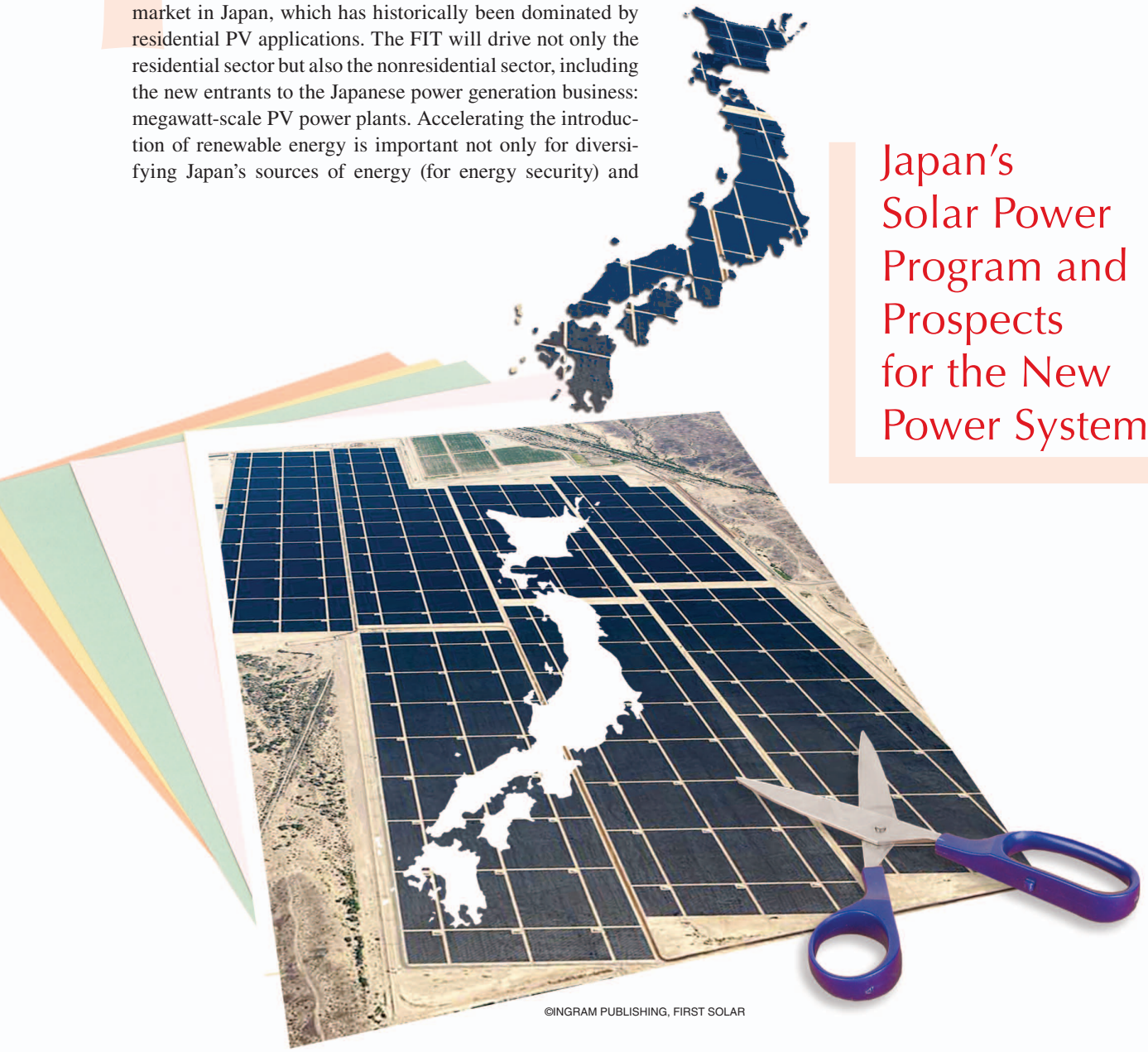
Japan's Solar Power Program and Prospects for the New Power System

THE JAPANESE EARTHQUAKE AND TSUNAMI of 11 March 2011 spurred numerous discussions and debates regarding the national energy policy of Japan. One of the outcomes of this process was a new feed-in tariff (FIT) program to promote renewable energy, including photovoltaic (PV) systems, that went into effect on 1 July 2012. This new incentive program is expected to completely change the PV market in Japan, which has historically been dominated by residential PV applications. The FIT will drive not only the residential sector but also the nonresidential sector, including the new entrants to the Japanese power generation business: megawatt-scale PV power plants. Accelerating the introduction of renewable energy is important not only for diversifying Japan's sources of energy (for energy security) and



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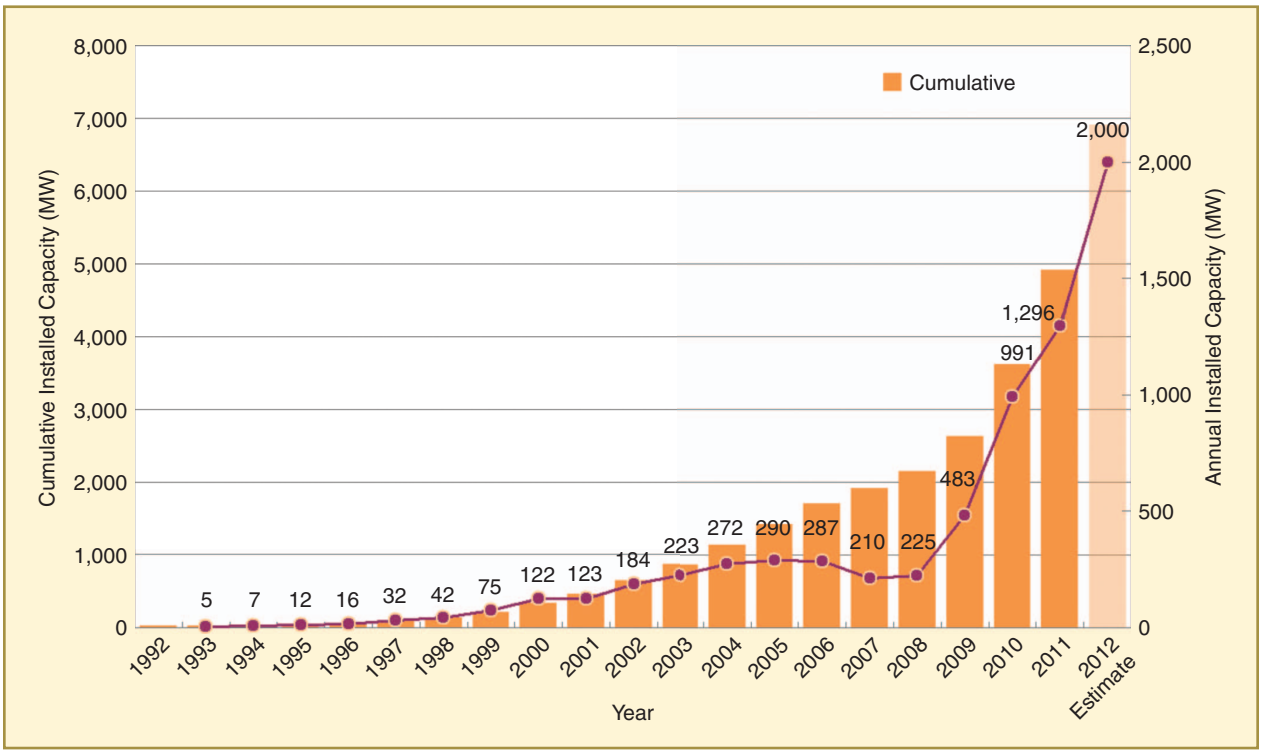

figure 1. Installed capacity of PV systems in Japan.

combating global warming (for the environment) but also for the development of green industries (for the economy). It is essential that Japan create an environment conducive to the expansion of renewable energy in Japan by identifying the appropriate mix of regulatory measures (e.g., FITs), public support, and private-sector voluntary efforts best suited to each energy source. This article describes the current status of the PV market in Japan; the new FIT program and its impacts on the PV market; and further institutional, technical, and R&D challenges for PV dissemination.

The Japanese PV Market in 2011

In 2011, for the first time, the annual installed capacity of PV systems in Japan surpassed 1 GW, reaching 1.3 GW, which represents a 31% increase from the 991 MW of capacity in 2010 (see Figure 1). The Japanese PV market was activated in 2010 by a subsidy program for residential PV systems and a program to purchase surplus power, at a preferential price, from PV systems with a capacity of less than 500 kW. The cumulative installed capacity of PV systems in Japan in 2011 reached about 4.9 GW, as shown in Figure 1. The market share of each segment is depicted in Figure 2.

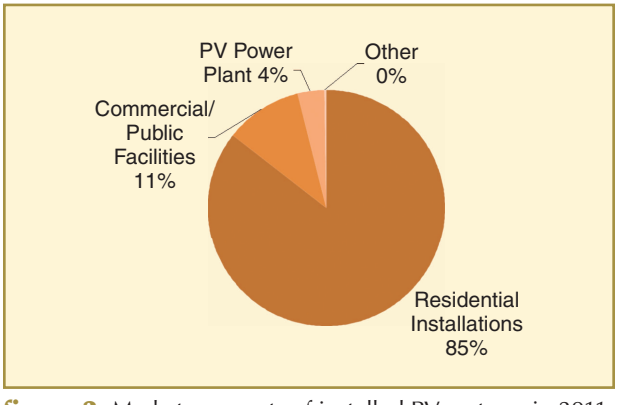

figure 2. Market segments of installed PV systems in 2011.

Residential PV Market

The major application in the market has been residential PV systems. The cumulative number of residential PV systems in Japan topped 1 million in April 2012. As shown in Figure 3, the annual installed capacity of residential PV systems in 2011 was 1 GW. In grid-connected applications, residential PV systems accounted for 85.4% of the total in 2011. The key drivers of this market are the national subsidy program, which provides 48,000 yen/kW for a PV system with less than 10 kW of installed capacity (in 2011), and the Surplus PV Power Purchase Program in which individual PV owners can sell surplus PV power at ¥42/kWh. In addition to the national government, more than 800 local governments have been continuing subsidy programs, and individuals are able to apply to both programs at the same time. After the 2011 earthquake and the failures of the Fukushima Daiichi nuclear power plants, demand for residential PV systems has increased because of the anticipated shortage of electricity and the perceived threat of rolling blackouts, which occurred right after the earthquake.

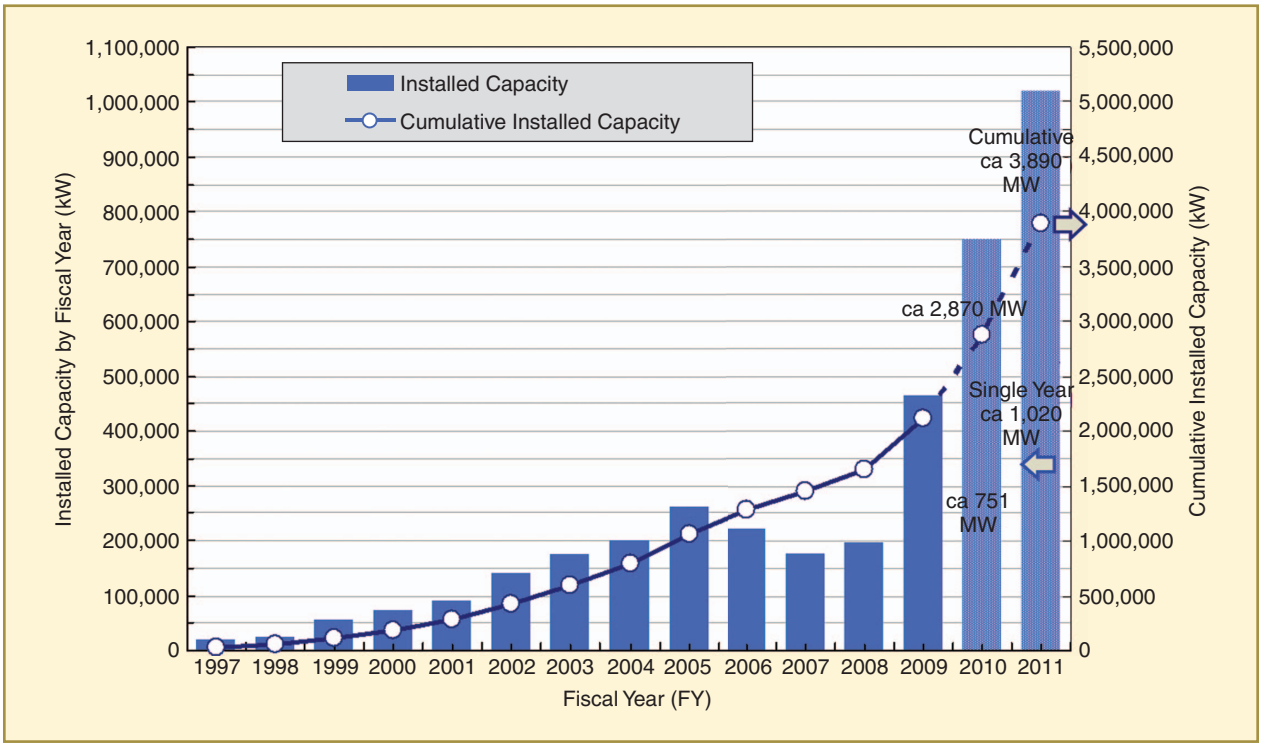

figure 3. Installed capacity of residential PV systems in Japan.

Commercial and Industrial PV Markets

As for medium-scale to large-scale PV systems for public and industrial facilities, installed capacity in 2011 was 139 MW, accounting for 10.7% of total grid-connected applications. In 2011, there were no new projects awarded by the Project for Promoting the Local Introduction of New Energy and the Project Supporting New Energy Operators, which means there was no national support program in 2011 in this category. After experiencing the rolling blackouts that followed the earthquake and the subsequent power shortages in east Japan, however, local governments and municipalities installed PV systems in schools and other public facilities that could be used as evacuation sites in emergency situations.

Large-Scale PV Plant Market

As of 2011, large-scale PV plants with a total capacity of 46 MW were installed for grid-connected, centralized applications, mainly by power utilities. The Federation of Electric Power Companies (FEPC) also announced a plan for ten electric utilities to construct 30 PV power plants with a total capacity of 140 MW across the nation by 2020. Most of these projects were originally scheduled to get under way by 2012, but construction of megawatt-scale PV power plants proceeded ahead of schedule, and 15 such PV plants have actually been completed across Japan as of November 2012, as shown in Table 1. A small number of large-scale PV projects were deployed by entities other than power utilities in 2011. But in preparation for the new FIT program that started in July 2012, many organizations began working on market development of a wide variety of PV systems, including megawatt-scale PV power plants.

The New FIT Program

The FIT program is based on the Bill on Special Measures Concerning Procurement of Renewable Energy–Sourced Electricity by Electric Utilities (also known as the Renewable Energy Law), which was passed by the Japanese national legislature on 26 August 2011. The law requires utilities to purchase as much electricity from renewable sources as possible so as to intensively expand the use of renewable energy. In November 2009, before the new FIT program started, Japan's Ministry of Economy, Trade, and Industry (METI) implemented the Purchase Program for Surplus PV Power (an FIT program for surplus PV power), based on the Law on the Promotion of the Use of Nonfossil Energy Sources and Effective Use of Fossil Energy–Source Materials Energy Suppliers, which had been enacted in July 2009. Under this law, electric utilities were obliged to purchase surplus PV power. Under the new FIT program, the electricity from PV, wind, geothermal, biomass, and small-sized hydropower generation is eligible for FITs. In the case of PV, all the generated power can be sold if the installed capacity of the PV system is 10 kW or larger. While the former program limited the PV system capacity to systems under 500 kW, the new FIT has not set a maximum output capacity. Figure 4 shows the difference

table 1. Large-scale PV projects of various power utilities.

Company	Scale (MW)	Prefecture	Operation (Year/Month)
Hokkaido Electric Power	1	Hokkaido	2011/6
Tohoku Electric Power	2	Miyagi	2012/5
	1.5	Aomori	2011/12
	1	Fukushima	2015/1
Tokyo Electric Power	7	Kanagawa	2011/8
	10	Yamanashi	2012/1
	13	Kanagawa	2011/12
Chubu Electric Power	8	Shizuoka	2015/2
	1	Nagano	2011/1
	7.5	Aichi	2011/10
Hokuriku Electric Power	1	Ishikawa	2011/3
	1	Toyama	2011/4
	1	Fukui	2012/9
	1	Ishikawa	2012/11
	4	Miyako Island	2010
Kansai Electric Power	10	Osaka	2011/9
	0.5	Fukui	FY 2014
	0.5	Fukui	FY 2013
	2	Osaka	2013/4
Kansai E.P./Sharp	18	Osaka	TBD
Kansai E.P./Kyoto Pref.	2	Osaka	2013/4
Chugoku Electric Power	3	Fukushima	2011/12
	3	Yamaguchi	2014/12
	TBD	Hiroshima	TBD
Shikoku Electric Power	4.3	Ehime	2020
Kyusyu Electric Power	3	Nagasaki	2013
	10.5	Nagasaki	2013
	3	Fukuoka	2010/11
Okinawa Electric Power	1	Okinawa	2011/3

between the former surplus PV power purchase program and the new FIT program.

Purchase Price and Period

Following the passage of the Renewable Energy Law, the Purchase Price Calculation Committee of METI finalized the purchase price and the period for electricity generated by renewable energy sources, as stipulated by the law. The committee studied the costs and conditions of eligible renewable energy technologies, compiled a final proposal by 27 April 2012, and submitted it to METI. METI solicited public comments on tariffs and purchase periods. This was followed by discussions among the minister of economy; the minister of the environment; the minister of land, infrastructure, transport, and tourism; and the minister of agriculture, forestry, and fisheries. Subsequently, and with reference to an opinion by the minister of state for consumer affairs, the minister of METI announced the tariff and purchase period.

As shown in Table 2, FITs and purchase periods for 100% of the electricity generated by PV systems with capacities of at least 10 kW were set at ¥40/kWh, plus a consumption tax, for a period of 20 years. The consumption tax is excluded from the table because the consumption tax rate will probably change in the future. The purchase price is set so as to achieve a 6% internal rate of return (IRR) before tax.

For PV systems with capacities below 10 kW, surplus electricity will be purchased at ¥42/kWh, including a consumption tax, for ten years. Because residential consumers, who are the main owners of such PV systems, are not obliged to pay a consumption tax for the sold PV power, FITs are the same for both tax-included and tax-excluded tariffs. For residential PV systems, the actual FIT is equivalent to ¥48/kWh if the 2012 governmental subsidy of ¥35,000/kW is taken into account. The assumed IRR is 3.2% before tax. This scheme, which provides incentives for surplus PV power, was based on several factors. Owners of residential PV systems are motivated to conserve energy because the less power they consume, the more power they can sell to the utilities from their PV systems. Shifting to the gross FIT scheme (which provides incentive for the entire amount of generated energy) will increase the surcharge which will be charged to all of the electricity users in accordance with their electricity usage to compensate for the cost of FIT.

These tariffs and periods will be effective until 31 March 2013, the end of fiscal year 2012 (FY 2012). New tariffs and periods for FY 2013 will be effective beginning 1 April 2013. METI will track the cost of PV projects, and the Purchase Price Calculation Committee that calculates the FIT will submit its proposal in early 2013. The FIT program applies to PV systems that have already been installed, as long as owners submit applications. For the PV systems that receive a subsidy, FITs are deducted according to the amount of the subsidy. For the purchase period, the years in which a PV system operated in the past are deducted. For existing PV facilities, however, the applicable purchase program has changed from the surplus PV power purchase program to the new FIT program (100% purchase of generated power).

Requirements for the FIT-Eligible PV System

To be eligible for an FIT, the cell technologies in PV modules must satisfy minimum conversion efficiencies: 13.5% for crystalline silicon (Si), 7.0% for thin-film Si, and 8.0% for a compound semiconductor. Flexible and concentrator solar cells are excluded from these requirements. Building-material-integrated PV modules, however, must meet the efficiency requirements.

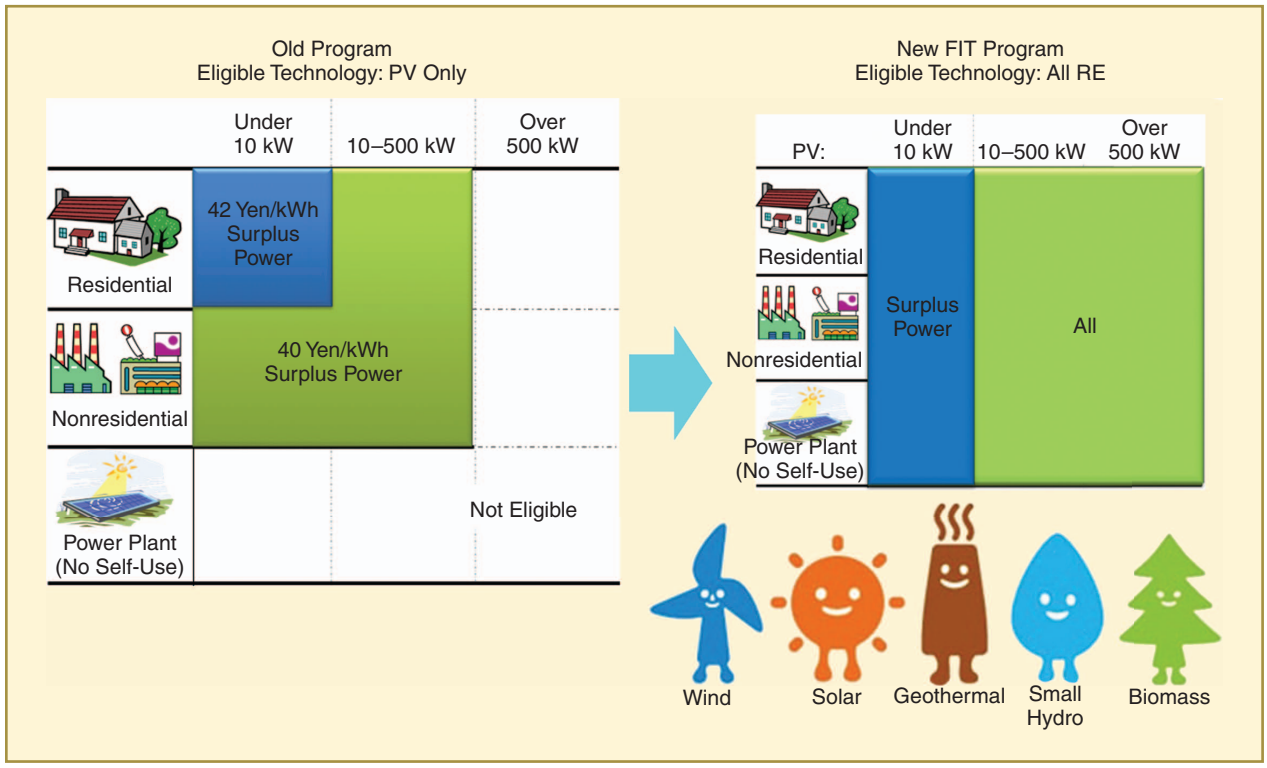

figure 4. Difference in eligible technologies between the former surplus PV power purchase program and the new FIT program.

PV systems with a capacity less than 10 kW (including building-material-integrated PV systems) are required to obtain certification equivalent to that given by the Japan Electrical Safety & Environment Technology (JET) Laboratories or the International Electrotechnical Commission (IEC). This qualification is also required in order to obtain the subsidy for a residential PV system from the Japan Photovoltaic Expansion Center (J-PEC). PV systems with a capacity of 10 kW or larger are not required to be certified. They therefore only need to meet the conversion efficiency requirements of PV modules. In general, however, PV system owners and financial institutions are the most likely to request certification for PV modules. Only the modules must be certified for small systems. This is to make sure the homeowners are getting reliable products. For systems greater than 10 kW, the modules do not need to be certified. It is usually assumed that, for larger systems, the installer will have much more knowledge and flexibility to make decisions than a homeowner. Made-to-order PV modules, such as those on glass louvers and facades, also qualify for the FIT program, even though they cannot acquire certification.

The PV Market Under the New FIT Program

METI estimates that new installation of residential PV systems until the end of the third quarter in FY 2012 will increase by 40% from the entire FY 2011, and cumulative

table 2. Purchase rates, purchase periods, and other cost information for PV systems in Japan.

Category		Capacity: 10 kW or Larger (Nonresidential)	Capacity: Below 10 kW (Residential)
Electricity to be purchased		100% of generated electricity	Surplus electricity
Feed-in tariffs per kWh		40 yen/kWh + tax (0.39 €/kWh)	42 yen/kWh (0.41 €/kWh) (include tax)
Purchase period		20 years	10 years
Assumption for calculation	Construction cost	325,000 yen/kW (3,199 €/kW)	466,000 yen/kW (4,587 €/kW)
	Annual operation/ maintenance cost	10,000 yen/kW (9.84 €/kW)	4,700 yen/kW (46.2 €/kW)
	Internal rate of return (IRR)	6% before tax	3.2% before tax

Note: 1 JPY = 0.009843 Euro

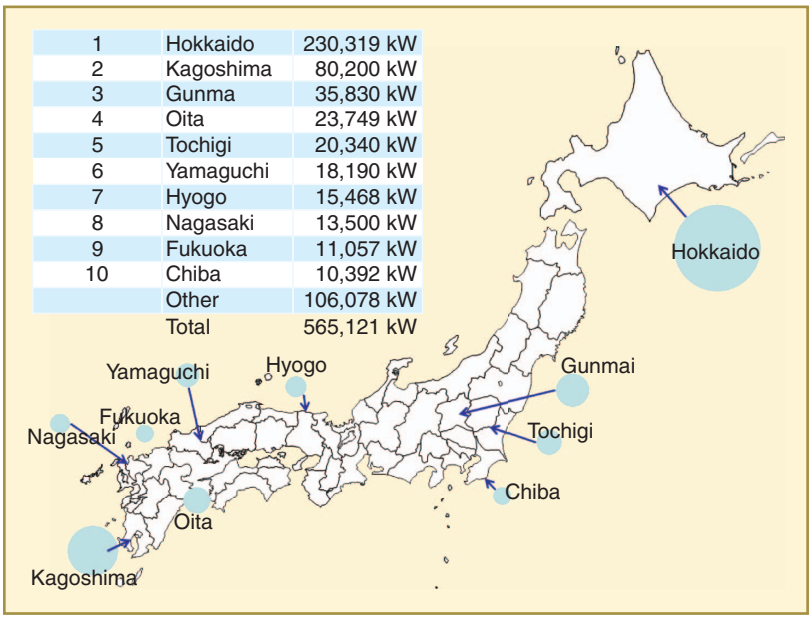

figure 5. Approved capacities of megaWatt-scale PV projects in the top ten prefectures.

installation of nonresidential PV systems will increase by about 500 MW by the end of FY 2012. The total additional capacity in calendar year 2012 is thus likely to reach the 2-GW level, compared with 1.3 GW added in 2011, as shown in Figure 1. In 2011, residential PV accounted for 85% of newly installed PV capacity in Japan, as shown in Figure 2. With the new FIT program, nonresidential applications, including utility-scale PV power plants, are expected to increase significantly (see Figure 5).

The growth trend in nonresidential installations was clear from the first METI report to list approved, FIT-eligible PV facilities, dated August 2012. There were 32,659 approved PV systems with capacities of less than 10 kW; these were mostly residential installations, with a total installed capacity of 144 MW. There were 946 PV systems with capacities of between 10 kW and 1 MW; these were mainly installed on the roof tops of public, commercial, and industrial facilities, and had a total installed capacity of 57.6 MW. And there were 81 so-called "megasolar" PV systems with capacities of 1 MW or more, mainly for large-scale PV power plants, with a total installed capacity of 243 MW.

The new FIT program has created PV business opportunities in Japan and, by involving local governments, is also providing a strong impetus to revitalize local economic activities. In developing large-scale PV power plants, owners and operators can effectively use spaces at industrial complexes that were developed by local governments and idle land owned by private companies. Companies from various industrial sectors are entering the business of PV generation. Furthermore, some electric utilities have established subsidiaries specifically for the PV power generation business.

table 3. Japanese government's acts related to PV power plant development.

Ministry	Acts Related to Large-Scale PV Projects
MLIT[1]	City Planning Act
MLIT	Building Standards Act
MAFF[2]	Agricultural Land Act
MAFF	Forest Act
MOE[3]	Soil Contamination Countermeasures Act
MOE	Natural Parks Act
MOE	Wastes Disposal and Public Cleansing Act
METI[4]	Electricity Business Act

[1]Ministry of Land, Infrastructure, Transport, and Tourism.
[2]Ministry of Agriculture, Forestry, and Fisheries.
[3]Ministry of the Environment.
[4]Ministry of Economy, Trade, and Industry.

Challenges for PV Dissemination

In March 2011, the Government Revitalization Unit of the Japanese cabinet office held a subcommittee meeting on regulatory and institutional reforms and compiled a draft final report on the energy sector, including 183 items relating to energy sector regulatory reform. Many of the reform items had to do with the acceleration of various kinds of renewable energy, including PV generation, to enable the evolution of Japan's energy system after the March 2011 earthquake. Various ministries are responsible for the reform items, many of which mitigate regulatory and institutional barriers, such as those in the procedures for renewable energy integration, siting, and approval.

Currently, developers constructing large-scale PV power plants face many challenges. Successful implementation depends on the effectiveness of full-fledged deregulation and the timing of the changes. Unnecessary regulations will increase investment costs, thus reducing the profit of the power generation businesses that install PV systems. Among the obstacles, regulations on land use are key. Several ministries involved in land use are greatly affected by the legislation listed in Table 3, which have been passed, and subsequently, PV project planning and approval are also greatly affected. For example, approval for converting agricultural land into a site for PV power generation requires many time-consuming steps.

Generally, it takes a large amount of time to achieve deregulation because it requires coordination among many

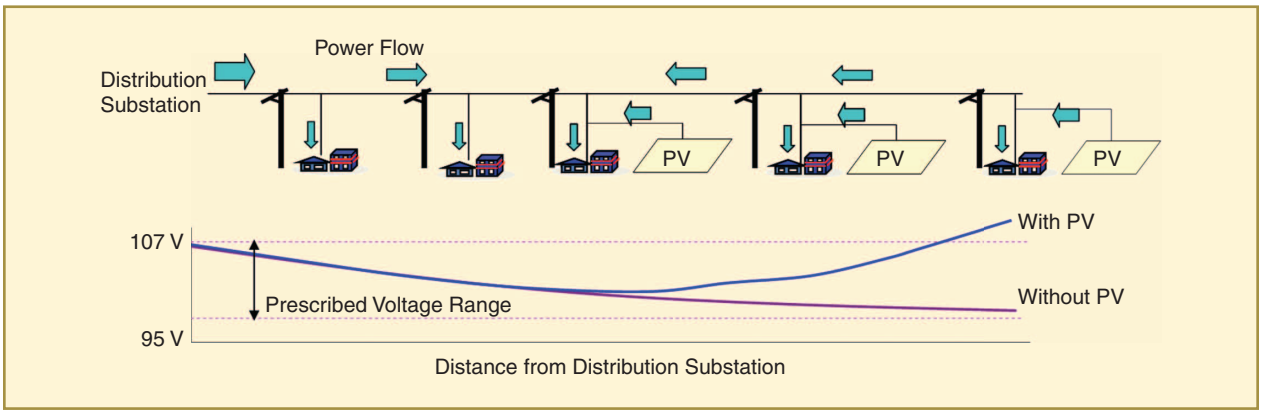

figure 6. Power flow and voltage profile in a distribution line with a significant number of PV systems.

entities to confirm compliance with existing laws and ordinances, to coordinate stakeholders, to conduct safety checks, to work with many different ministers and agencies, and more. To effectively deregulate, persistent efforts must be made to clarify issues under current regulations, and continued appeals must be directed to concerned parties. It is therefore important for the Japanese PV industry to work hard to identify irrational regulations by means of industrial associations.

Grid Connection

Japan's Renewable Energy Law stipulates that electric utilities must not refuse grid connection for electricity generated from PV systems, except for the conditions stipulated by the ministerial ordinance under the subsection "Securing of Preferred Grid Connection Right." PV generators must, however, agree to curtail generation when power generation is reasonably expected to exceed the demand-supply balance limit or transmission-distribution capacity limit after the necessary operational efforts and procedures have been taken. When PV and other variable renewable generation systems are installed at high penetrations in a power system, the voltage and power flows on the local distribution system can be affected. Task 14 of the Photovoltaic Power Systems (PVPS) program of the International Energy Agency (IEA) consists of studying these issues and identifying potential solutions. To make large shares of PV and wind generation a reality, the flexibility of a power system must be enhanced. This additional flexibility will come not only from the traditional generator, but also from demand activation (automatic demand response), PV and wind generation forecasting and curtailment, and enhanced power system operation.

In Japan, there are many research and technology development projects being conducted relating to the integration of variable renewable generation.

METI's Demonstration Projects for Next-Generation Optimal Control of the Power Transmission and Distribution Network (FY 2010–FY 2012) address the two major issues regarding PV integration into a power system. One issue is related to voltage in distribution networks (see Figure 6); the other concerns the power supply and demand balance across the entire power system (see Figure 7). The METI projects deal with these issues by establishing the following four groups:

- ✔ Group 1 deals with the optimal allocation and control of voltage-regulating devices.
- ✔ Group 2 is addressing the development of high-performance power electronic devices for distribution networks.

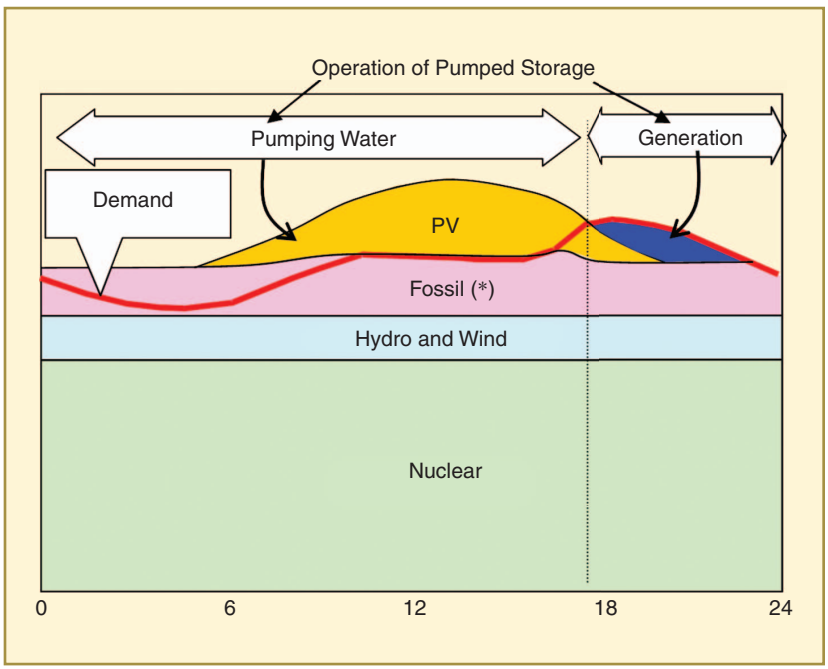

figure 7. Schematic of the supply–demand balance over 24 h in a system with a large number of PV systems. (*) Minimum output required for LFC.

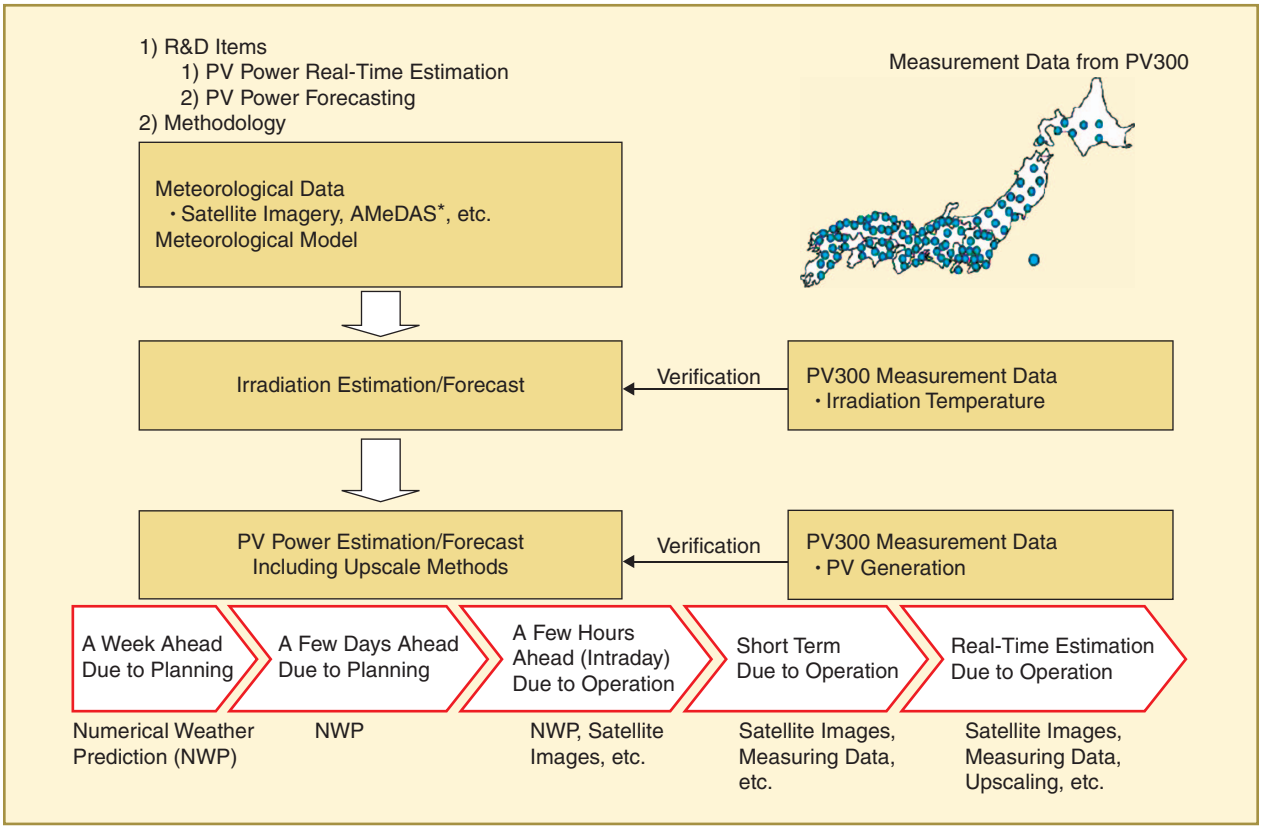

figure 8. METI's Demonstration Project of Forecast Technologies for PV generation. *Automated meteorological data acquisition system.

- ✔ Group 3 is concerned with the optimal control of customer appliances for demand-supply balance.
- ✔ Group 4 is developing solutions for the optimal planning and operation of a power system that take into consideration generation forecast and demand.

Japan's power utilities, with the support of METI, have also been accumulating and analyzing the synchronized ten-second irradiation data from more than 300 sites across Japan to understand the variability of the solar resource. This effort is taking place as part of METI's Demonstration Project of Forecast Technologies for PV Generation (2011–2013), which is a joint project of weather service companies, manufacturers, research institutes, and Japan's ten power companies, as shown in Figure 8. The other project for developing forecasting technologies is called R&D for the High-Performance PV Generation System of the Future and is being conducted by Japan's New Energy and Industrial Technology Development Organization (NEDO). The Japan Meteorological Agency has joined the project along with other collaborators, including weather service companies, universities, and national institutes; together they are studying PV system technologies, as shown in Figure 9. The project also aims to improve the numerical weather prediction model for PV system operations. As for the grid code and standards of power conditioning, the Japan Electrical Manufacturers Association (JEMA) has spelled out a standard anti-islanding protection method for a single-phase inverter in low-voltage use. JEMA is currently holding discussions about three-phase inverters. The current Japanese grid code includes a fault ride-through requirement for all voltage levels.

R&D for Cost Reduction and Life Cycle Management of PV Systems

Further enhancement of sustainability and cost reductions are necessary in order for PV systems to become a major generation source in Japan. To reduce the cost of PV systems, efficiency improvement and reliability enhancement are essential. To this end, many Japanese universities, research institutes, and manufacturers are collaborating on R&D efforts to study PV materials and modules. Specific entities conducting this research include NEDO, with two projects: R&D for the High-Performance PV Generation System of the Future, and R&D for the High-Performance PV Generation System of the Future. The Ministry of Education, Culture, Sports, Science, and Technology (MEXT), under the Japan Science and Technology Agency (JST), is also conducting research within three programs: Exploratory Research for Advanced Technology (ERATO), Core Research for Evolutional Science and Technology (CREST),

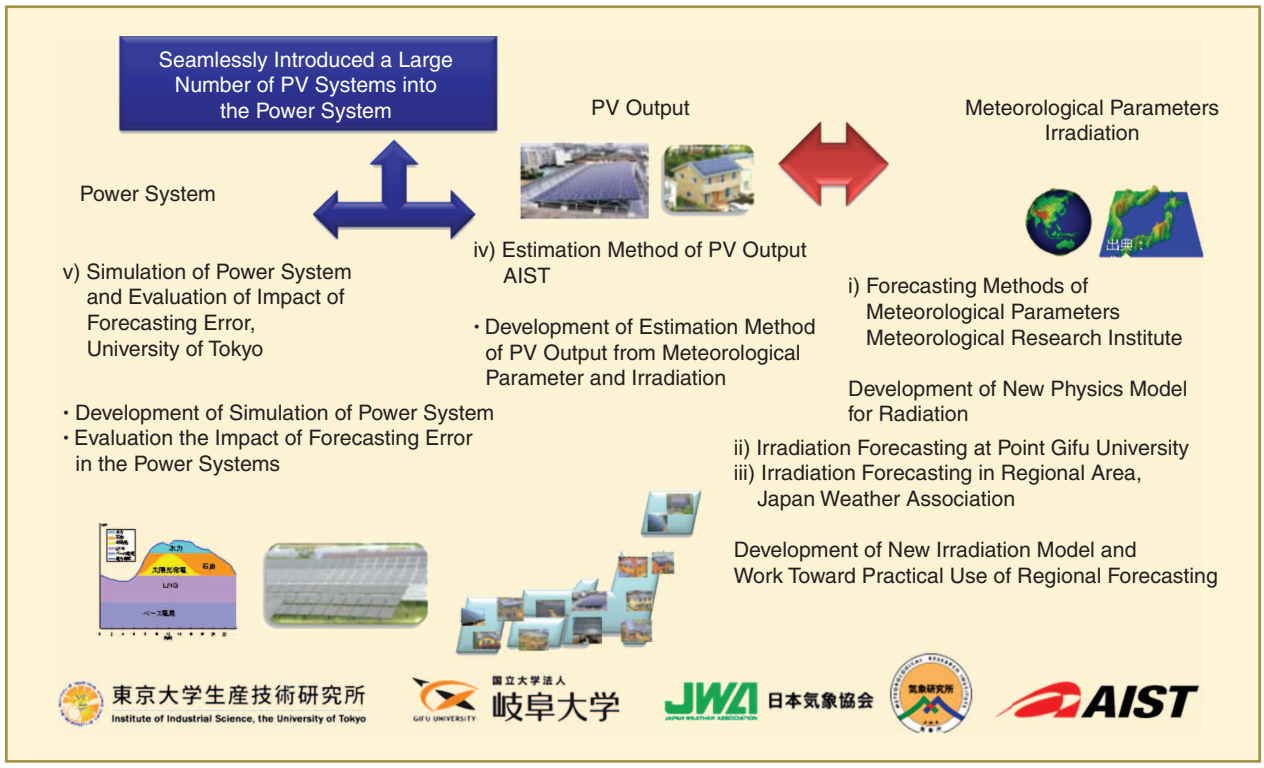

figure 9. NEDO's R&D project for PV output power forecasting.

and Precursory Research for Evolutional Science and Technology (PRESTO).

There are also several projects aimed at life cycle management of PV, which are focusing on reliability management, waste management, and material reuse of PV systems. These projects include NEDO's R&D for the High-Performance PV Generation System of the Future, the PV remote failure management project of the Ministry of the Environment (MOE), and METI's Asia-Pacific Industrial Science & Technology and International Standardization Cooperation program. The National Institute of Advanced Industrial Science and Technology (AIST) has conducted several projects addressing PV reliability, including collaborative research with more than 40 companies.

Future Prospects

The FIT program has brought about a significant change in the expansion of PV system installations in Japan. PV system deployment, originally led mostly by the supply side, is now mostly led by users. Japanese financial institutions are actively supporting the PV industry. Advances by PV system integrators, PV-utilizing industries, and users are enabling downstream sectors of the PV industry to flourish, broadening the scope of the PV business. Installations of PV systems for public, industrial, commercial, road and railroad, and agricultural applications, which have lagged behind residential applications, have become more easily achievable. These applications are establishing a new core market in addition to the residential PV market. Meanwhile, overseas manufacturers are increasingly entering the Japanese PV market by emphasizing the lower prices of their products.

In July 2008, the Japanese government set a national target for the introduction of PV systems with a cabinet decision on an action plan to create a low-carbon society. This plan specifies targets and measures regarding innovative technological development and the deployment of existing advanced technologies. Among other things, the plan establishes a framework for transforming the entire nation into a low-carbon society. The national targets are to increase PV power generation to ten times its 2008 level, to 14 GW, by FY 2020 and to 40 times the 2008 level, or to an estimated 53 GW, by 2030. In April 2009, the government formulated an economic stimulus measure named the J-Recovery Plan. This plan set a new 2020 PV power target: 20 times the cumulative installed capacity (as of 2009), to a level of 28 GW. Figure 10 shows the prospects for PV power installation as presented by the J-Recovery Plan. In this plan, the target for 2030 was kept at 53 GW.

Following the nuclear power plant failures in Fukushima after the March 2011 earthquake, the Japanese government began formulating a new energy strategy from scratch. It is called the Innovative Energy and Environment Strategy and was discussed in the cabinet on 14 September 2012. The strategy stipulates that all available efforts and resources are to be used to reduce the generation share of nuclear power, including maximum deployment of all types of renewable energy.

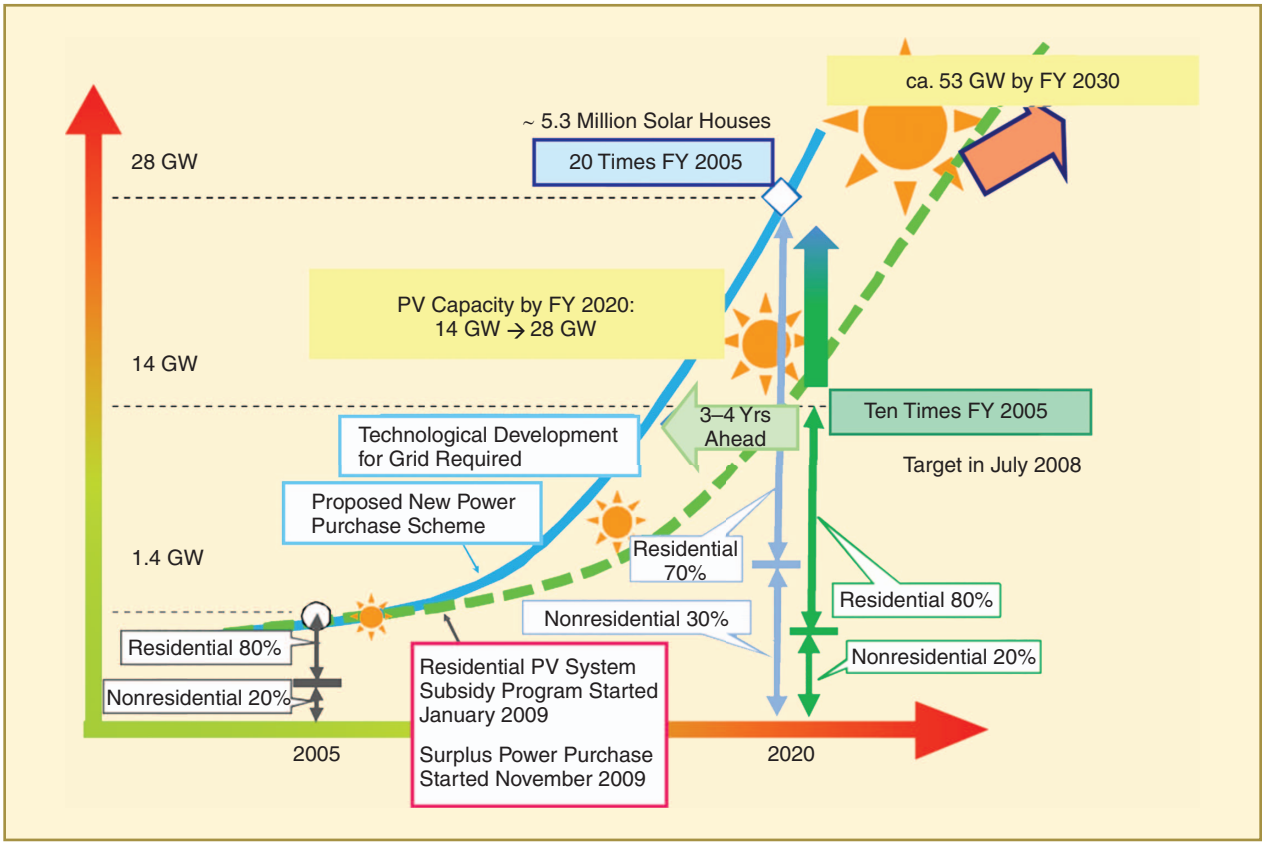

figure 10. Target PV capacity in Japan.

Before the announcement of the strategy, the National Policy Unit issued its outlook for the energy mix in 2030. According to that document, the government expects renewable energy to supply 25–35% of the nation's total generation, and PV and wind, whose generation is variable, should supply 9–18% with the rest coming from hydropower and geothermal plants. In this scenario, the national 2030 PV target will be raised from the current 53 GW to about 60 GW or more. To achieve such a generation mix, the Japanese PV research institutes, industry, planners, project developers, end users, and customers need to successfully address all the challenges of regulation, institutional, integration, costs, and reliability. The government has announced that its energy plan will be revised, based on the Innovative Energy and Environment Strategy, by the end of 2012. In parallel with PV deployment in Japan, the Japanese PV industry will also able to contribute to the deployment of PV in foreign countries. Japan's PV industry must enhance its global competitiveness by continuing to shift its business structure, based on the technologies, engineering, and services that support the life cycle of PV systems.

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