Report

Outlook for Installed Capacity of Solar Photovoltaic Power Generation in Japan up to 2020

OVERVIEW: The Institute of Energy Economics, Japan has developed a model for projecting future installation of solar PV power generation capacity and has used it to estimate the installation capacity in Japan up to 2020. The institute projects that cumulative installed capacity will rise from 6,890 MW in 2012 (5,350 MW residential and 1,540 MW non-residential) to between approximately 31,200 MW and 32,500 MW in 2020 (14,900 to 16,300 MW residential and 16,200 MW non-residential). Residential system prices are anticipated to fall from 460,000 yen/kW in 2012 to between 290,000 and 300,000 yen/kW, and non-residential from 410,000 yen/kW to 260,000 yen/kW. As a result, the feed-in tariff (price paid for generated power) will fall to between 10 and 17 yen/kWh for residential generation and 25 yen/kWh for non-residential. The total cost from 2012 to 2020 is projected to be between 3 trillion and 3.2 trillion yen, with a average surcharge of between 0.37 and 0.39 yen/kWh.

INTRODUCTION

AN expansion in the installation of solar photovoltaic(PV) power generation capacity has been anticipated since the introduction in Japan of a feed-in tariff scheme for renewable energy in July 2012. Although this appears to have led to a short-term boost in installation, the long-term outlook is clouded by the potential for policy changes prompted by energy mix considerations. Despite this, projecting the extent of installation capacity over the medium-term is crucial to business strategy planning by Japan's solar PV power industry.

In response, The Institute of Energy Economics, Japan has developed a model for projecting the future installation of solar PV power generation capacity and has used it to estimate the installation capacity in Japan up until 2020. This article presents its predictions. Because installation capacity is heavily influenced by the economic benefits of installing solar PV power generation systems, the model estimates installation based on factors that include the system price and feed-in tariff.

OVERVIEW OF PROJECTION MODEL FOR SOLAR PV POWER GENERATION SYSTEM INSTALLATION

For reasons including the extensive availability of actual data and the short lead time between commencing installation and starting generation, a regression equation was used to estimate annual new residential capacity in terms of explanatory variables such as gross domestic product (GDP) and economic factors. For the non-residential case, on the other hand, the paucity of available data and the need to consider the time lag between commencing construction and starting generation led the institute to decide to use an existing model to project future installation.

The models also incorporated a "learning curve effect" to represent how the price of solar PV systems falls as more of such systems are installed. Since the

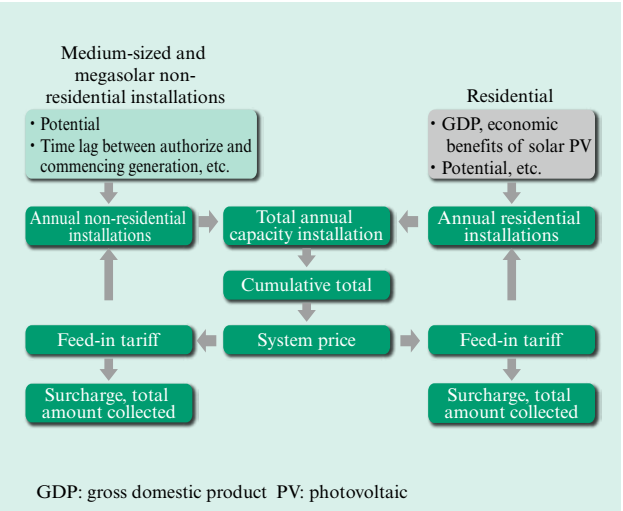

Fig. 1—Overview of Projection Model for Installation of Solar PV Power Generation Capacity.
The model treats annual installation capacity as a function of economic benefits. Independent estimates are made for residential and non-residential installations, and the combined totals are used to calculate the value for cumulative installed capacity that is used to project the fall in system price due to the learning curve effect.

cumulative installed capacity used for this purpose needs to include both residential and non-residential systems, the amount of installation for these two different types of systems are interrelated (see Fig. 1).

PROJECTING NON-RESIDENTIAL INSTALLATION CAPACITY

Structure of Projection Model

The model uses actual data as a basis for estimating authrized as a proportion of the total potential for solar PV installation. The capacity authorized for installation each year is calculated by multiplying this proportion by that year's residual potential. The lead time is represented by calculating a time lag coefficient from the capacity authorized for installation and the capacity that actually commenced operation. The time lag coefficient is then used to calculate how much capacity commences operation each year. These calculations are performed separately for medium-sized (up to 1 MW) and large "megasolar" plants (1 MW or more). The system price is calculated based on the learning curve effect, and the feed-in tariff for each year is calculated based on a simple payback period of 10.2 years (the current period used to calculate tariffs). Table 1 lists the assumptions.

Projection

Fig. 2 shows the projection results. For non-residential generation, 1,030 MW of megasolar capacity was installed in FY2012. This is projected to increase to 7,640 MW in 2020 with an annual average of 830 MW of new capacity commencing operation. For medium-sized power plants, capacity installation in FY2012 was 510 MW. This is projected to increase to 8,580 MW in 2020 with an annual average of 1,010 MW of new capacity commencing operation. That is, total non-residential capacity is projected to rise to 16,220 MW.

However, there remains little data on the time lag between project authorize and the commencement of generation. Also, because approvals include projects where land acquisition has yet to be completed, and because it is believed that, in some of these cases, there is no genuine likelihood of or intention to acquire the land, the proportion of authorized projects that will actually enter operation remains unclear. Accordingly, there is a need to revise the projections for future installation of non-residential capacity once more data has been collected on project approvals and how much of this capacity actually commences generation.

Due to the learning curve effect, which grows along with cumulative installed capacity (including the projections for residential capacity installation described below), the system price is projected to fall from 405,000 yen/kW in 2012 to 263,000 yen/kW in 2019 (the reference period for calculating the 2020 feed-in tariff). As a result, the feed-in tariff is

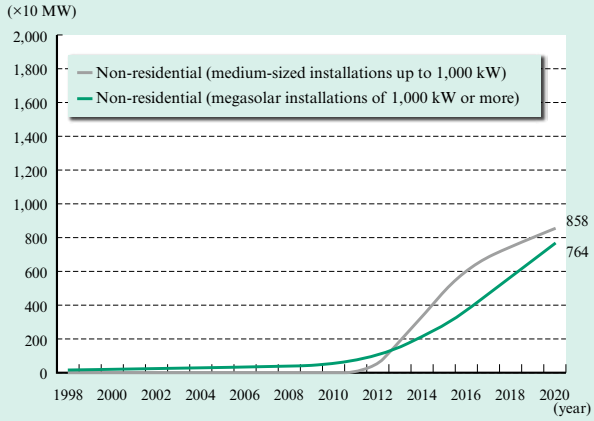

Fig. 2—Projection of Cumulative Non-residential Installation of Solar PV Power Generation.
The rate of installation of medium-sized (up to 1,000 kW) plants is projected to begin falling in late 2015 due to the reduction in residual potential (availability of potential sites). The rate of megasolar plant installation, on the other hand, is expected to remain steady. However, the projection will need to be revised to take account of factors such as how many authorized projects are cancelled.

TABLE 1. Non-residential Projections and Assumptions
The potential is calculated from Ministry of Economy, Trade and Industry figures.

Potential installation	Medium-sized (up to 1,000 kW) 20,300 MW (public buildings, etc.)
	Megasolar (1,000 kW or more) 83,500 MW (unused/underused land + abandoned farmland, etc.)
Proportion of potential actually installed	50%
System price	• 405,000 yen/kW (2012) (87% of residential price) • Price in subsequent years calculated by modeling learning curve effect (based on total installations, including residential)
Feed-in tariff	• 42 yen/kWh (2012) → 37.8 yen/kWh (2013) • Tariff in subsequent years calculated by model
Feed-in tariff period	20 years
Simple payback period	10.2 years

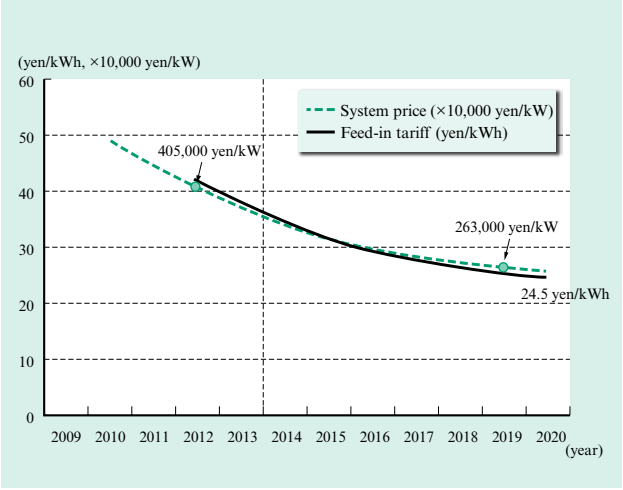

Fig. 3—Projection of Cumulative Non-residential Installation of Solar PV Power Generation.
Projections for Non-residential Feed-in Tariff and System Cost. Because the entire output of non-residential power plants is sold to the utility, the system price and feed-in tariff will remain exactly proportional to each other assuming the simple payback period remains the same. Although this graph shows a small lack of proportionality, this is a consequence of the feed-in tariff for each year being calculated based on the system price for the previous year.

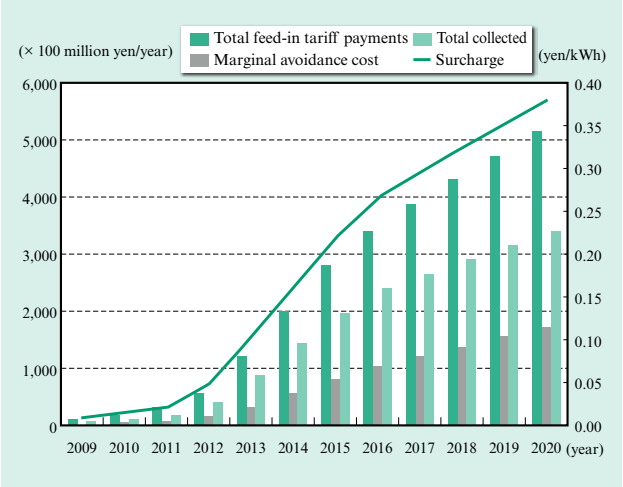

Fig. 4—Projections for Total Non-residential Feed-in Tariff Payments and Surcharge.
Based on the feed-in tariff scheme, the marginal avoidance cost is 10.4 yen/kWh. The model also assumed electricity use, excluding in-house generation, of approximately 900 TWh.

projected to fall from 37.8 yen/kWh in 2013 to 24.5 yen/kWh in 2020 (see Fig. 3). Note that, while the amount of residential installation also influences the non-residential system price, when a number of scenarios for different simple payback periods were considered for residential installation (as described below), the different scenarios did not result in large variations in system price. Accordingly, Fig. 3 shows only a single case for the above non-residential system price.

Fig. 4 shows total power purchases and the surcharge. The surcharge is projected to increase from 0.05 yen/kWh in 2012 to 0.38 yen/kWh in 2020, with the total annual cost rising from 42.2 billion yen to 340 billion yen. The cumulative total from 2012 will reach 1,900 billion yen.

PROJECTING RESIDENTIAL INSTALLATION

Structure of Projection Model

Fig. 5 shows the projection model. The model projects annual installation of solar PV power generation capacity from factors that include the economic benefits of system installation, per capita GDP, and time trends. However, rather than capacity installation, the model calculates the proportion of residual potential that is actually installed. Multiplying the residual potential by this installation ratio gives the annual capacity installation, and the sum of the annual values gives the cumulative installed capacity. Adopting this model structure expresses how the falling residual potential gradually becomes a constraint on installation, causing annual capacity installation to also fall.

(1) Calculation of potential

The potential was obtained by using statistics from the Housing and Land Survey (Ministry of

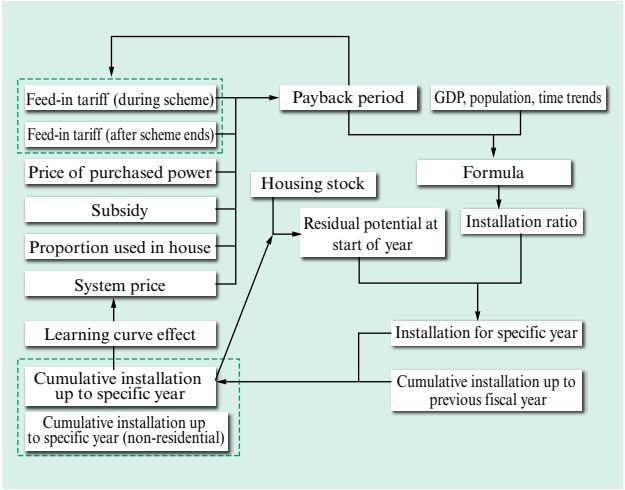

Fig. 5—Structure of Projection Model for Installation of Residential solar PV Power Generation Capacity.
The annual capacity installed is calculated by multiplying the residual potential by the installation ratio. As more capacity is installed, the residual potential falls and the rate of new installation slows.

Internal Affairs and Communications) to obtain separate figures for number of dwellings and degree of compliance with earthquake resistance standards (1981 and later) for detached house (including tenement housing) and apartment house respectively, and by estimating the total number of dwellings in the future with reference to a forecast of future dwelling numbers produced by the National Institute of Population and Social Security Research.

Based on factors such as roof shape and proportionate potential for rooftop installation, the potential for standalone dwellings was estimated to be 49,000 MW (figures from Cost Estimation and Review Committee). Although this potential is expected to increase further due to growth in the housing stock and the increasing number of dwellings that satisfy earthquake resistance standards as a result of renovations to existing houses, reaching 60,000 MW in 2030, it is expected subsequently to fall due to the falling total number of households.

While there have been cases of solar PV power generation being installed on existing collective housing, problems such as structural issues and the difficulty of getting consensus among residents mean that the numbers are very low. Similarly, while there is potential for installation on new collective housing, factors such as a jump in house prices and satisfying consumer needs remain an issue. Consequently, because of the high degree of uncertainty surrounding the outlook for installation of solar PV power generation systems on collective housing, it was excluded from this study.

(2) Calculation logic

The model estimates installation as a proportion of residual potential from per capita GDP and the simple payback period. It assumes a solar PV power generation system with rated generation output of 4 kW, 12% capacity factor, and that 40% of the generated power is used by the house. The simple payback period was calculated as follows.

Here, the equipment cost is taken from the previous period.

Annual income during feed-in tariff period (yen/year) = Tariff × Power sales + Consumer electricity tariff × Own consumption

Annual income after feed-in tariff period (yen/year) = Tariff after feed-in tariff ends × Power sales + Consumer electricity tariff × Own consumption

Simple payback period (years) = (Equipment cost - Annual income during feed-in tariff period × Duration of feed-in tariff period) / (Annual income after feed-in tariff period) + Duration of feed-in tariff period

The formula is shown below. The coefficient of determination (amount of variation explained by regression equation) is 0.92 and the t-statistic value is significant.

Installation as proportion of residual potential = -0.018912 + 0.000152 × (per capita GDP) - 0.001382 × (payback period)

Projections

(1) Assumptions

A figure of 0.7% was used for annual real GDP growth from 2013 to 2020 based on the Asia/World Energy Outlook 2012 published by the Institute of Energy Economics, Japan. Based on predictions from the National Institute of Population and Social Security Research, population is expected to fall from 128 million in 2010 to 124 million in 2020. As a result, growth in per capital GDP up to 2020 is expected to average 1.0%.

The consumer electricity tariff (price charged by utility) was assumed to remain at its most recent actual level of 22.3 yen/kWh. Similarly, it was assumed that the feed-in tariff period would remain 10 years in the future.

Although government subsidies for solar PV power generation are falling, it was assumed they would remain at their current levels (17,500 yen/kW as of 2013).

Based on material from the Cost Estimation

Table 2. Assumptions for Residential Projections
The purchase-related assumptions are based on the current feed-in tariff scheme.

Population	128 million (2010) → 124 million (2020) (approx.)
Economic growth	0.7%/year (2013 to 2020) ・Average annual increase in per capita GDP up to 2020: 1.0%
Consumer electricity tariff	Remain constant at FY2011 price (22.3 yen/kWh).
Subsidy	Assume current 17,500 yen subsidy will continue.
System price & learning effect	・464,000 yen/kW (2012) (cells: 290,000 yen, associated equipment: 99,000 yen, installation: 75,000 yen) ・Future prices are calculated based on learning curve effect for each component (80%, 80%, and 100% respectively) (includes non-residential total)
Feed-in tariff	・42 yen/kWh (2012) → 38 yen/kWh (2013) ・Subsequent tariffs calculated by model
Scheme duration	10 years
After scheme ends	Assume excess power purchased at same rate as consumer tariff. Adjust if feed-in tariff falls below consumer tariff.
Simple payback period	14 to 18 years (various scenarios are modeled)

and Review Committee, the learning curve ratios that represent the cost reductions resulting from economies of scale were assumed to be 80% for cells and associated equipment, and 100% for equipment installation (see Table 2).

The future levels of mandated feed-in tariffs were calculated based on the assumption that the payback period assumed below will continue to apply. The feed-in tariff reverts to the consumer electricity tariff after the scheme period ends, and if the feed-in tariff falls below the consumer electricity tariff while the scheme is still in effect, the prices during and after the scheme will be adjusted so as to maintain the payback period and keep the two prices the same.

(2) Scenarios (targets for economic benefits)

An analysis was conducted in which the economic benefits of installing solar PV power generation capacity were varied in order to look at how future changes to the design of the feed-in tariff scheme would affect the amount of capacity installed. Given the likely fall in the price of solar PV power generation systems, future studies are likely to consider ongoing reductions in the feed-in tariff. Another possibility is to reduce the degree of favorable treatment to minimize the increases in the surcharge imposed on consumers that experience from Germany indicates are likely. Accordingly, anticipating that brakes will be imposed on any sudden increase in installation, alternative scenarios were considered with longer simple payback periods of 16 and 18 years (in contrast to the FY2013 period of 14.2 years) (see Fig. 6). However, because the feed-in tariff scheme states that "for the three year period after the law is enacted, special consideration shall be given to the profits of renewable energy suppliers to expand concentrated use of renewable energy," it was assumed that the simple payback period for FY2013 (14.2 years) will remain up until FY2014.

(3) Capacity installation

Fig. 7 shows the projection results. For the case when the simple payback period is kept the same as in FY2013 (14.2 years), it is projected that cumulative installation of residential solar PV power generation capacity will rise from 5,350 MW in 2012 to 16,300 MW in 2020. For the scenarios in which the simple payback period is raised to 16 years and 18 years, this projected total falls to 15,600 MW and 14,900 MW respectively. The projections for average annual capacity installation under the three scenarios are 1,370 MW, 1,290 MW, and 1,200 MW respectively, indicating that each year added to the simple payback period will reduce installation by 44 MW.

(4) System price, feed-in tariff

Fig. 8 shows a breakdown of income from residential solar PV power generation in FY2013 (calculated using the FY2012 system price as a base) and FY2020 (calculated using the FY2019 system price as a base) for the case when the simple

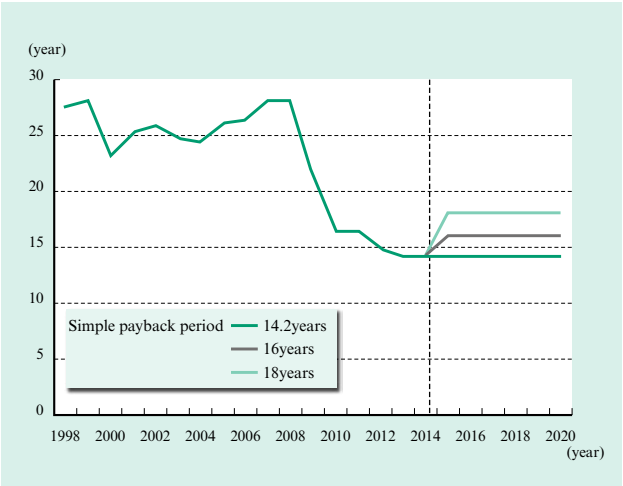

Fig. 6—Simple Payback Period Scenarios (Targets for Economic Benefits).
Although the current simple payback period is 14.2 years, 16 and 18 year scenarios were also considered. However, all scenarios assumed that the simple payback period of 14.2 years would remain in force until 2014.

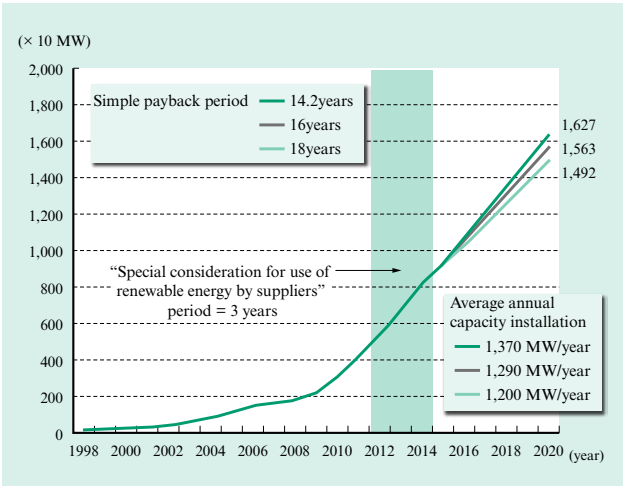

Fig. 7—Projections for Cumulative Installation of Residential solar PV Power Generation Capacity.
The study projected that cumulative installation of residential solar PV power generation capacity would reach between 14,900 MW and 16,300 MW in 2020.

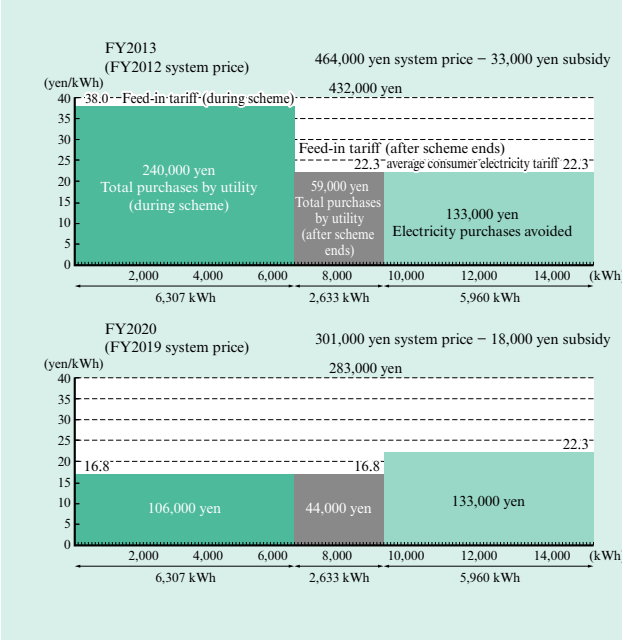

Fig. 8—Income from Residential Solar PV Power Generation. The feed-in tariff will fall significantly by 2020 because the falling system price will mean that electricity purchases avoided will represent a higher proportion of the system price.

payback period is 14.2 years.

Assuming a feed-in tariff of 38 yen/kWh in FY2013, and its subsequent fall to the level of the consumer electricity tariff after the feed-in tariff scheme ends (after 10 years), the system price of 432,000 yen/kW (full price of 464,000 yen/kW less subsidy of 33,000 yen/kW) will be paid back over the 14.2-year simple payback period with income during the feed-in tariff scheme (240,000 yen), income from the scheme's end until the end of the payback period (59,000 yen), and avoided electricity purchases (133,000 yen). In 2020, the system price will have fallen to 301,000 yen/kW due to higher installation volumes, including non-residential systems (cumulative non-residential total of 16,220 MW by 2020), and the feed-in tariff will be 16.8 yen/kWh both during and after the feed-in tariff scheme. In this case, the price of 283,000 yen/kW (after deducting the 18,000 yen/kW subsidy) will be paid back over the simple payback period of 14.2 years with income during the feed-in tariff scheme (106,000 yen), income from the scheme's end until the end of the payback period (44,000 yen), and avoided electricity purchases (133,000 yen). Because the amount of electricity purchases avoided is independent of the system price, being dependent solely on the house's power use and the consumer electricity tariff, and because reductions in the system price will mean that these avoided purchases will be equal to a larger proportion of the system price, the feed-in tariff will drop significantly. That is, assuming a simple payback period of 14.2 years, the subsidy and the feed-in tariff scheme will no longer be needed once the system price falls to 133,000 yen/kW.

Fig. 9 shows the projections for feed-in tariff and system price. Because the installed capacities under the different scenarios are similar, the projected system prices remain roughly the same, falling from 460,000 yen/kW in 2012 to 300,000 yen/kW in 2019 (the reference period for calculating the 2020 feed-in tariff). The projected 2020 feed-in tariff is 16.8 yen/kWh for a payback period of 14.2 years and 10.3 yen/kWh for a payback period of 18 years.

(5) Total surcharge collected

Fig. 10 shows the feed-in tariff totals and surcharge amounts. The surcharge is projected to increase from 0.10 yen/kWh in 2012 to 0.16 yen/kWh, 0.13 yen/kWh, or 0.11 yen/kWh in 2020 under the 14.2-, 16-, and 18-year simple payback period scenarios respectively. The total annual surcharge collected under the three scenarios is projected to increase from 87.9 billion yen to 145.2 billion yen, 120.2 billion yen, and 102.4 billion yen respectively. Similarly, the cumulative total surcharge collected from 2012 is projected to increase to 1,200 billion yen, 1,100 billion yen, and 1,100 billion yen respectively.

Note that the reason why the total annual feed-in tariff decreases from 2019 to 2020 is because the

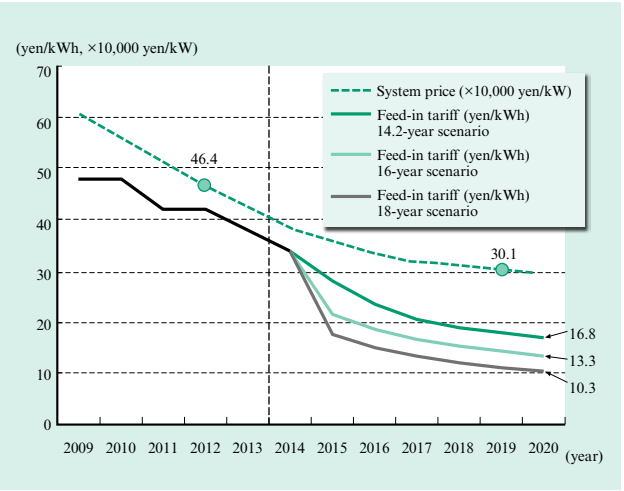

Fig. 9—Projections for Residential Feed-in Tariff and System Price.
The system price is projected to fall from 460,000 yen/kW in 2012 to 300,000 yen/kW.

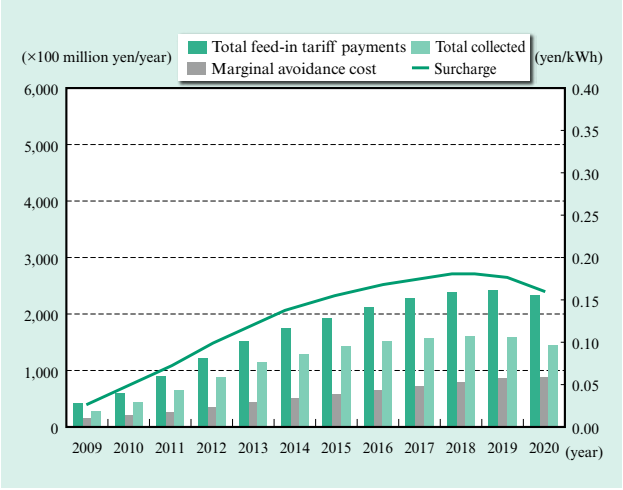

Fig. 10—Projection for Total Residential Feed-in Tariff Payments and Surcharge.The cumulative total cost from 2012 is projected to exceed one trillion yen.

amount for systems for which the (10-year) feed-in tariff scheme has ended (and for which the higher feed-in tariff applied) will exceed the amount for newly installed systems (for which a lower feed-in tariff applies).

CONCLUSIONS

Assuming that feed-in tariffs will continue at a level that guarantees a payback period of between 14 and 18 years for residential installations and 10 years for non-residential installations, it is projected that cumulative total installation will increase from 6,890 MW in FY2012 (5,350 MW residential and 1,540 MW non-residential) to between approximately 31,200 and 32,500 MW in 2020 (14,900 to 16,300 MW residential and 16,200 MW non-residential). Residential system prices are anticipated to fall from 460,000 yen/kW in 2012 to between 290,000 and 300,000 yen/kW, and non-residential from 410,000 yen/kW to 260,000 yen/kW. As a result, the feed-in tariff will fall to between 10 to 17 yen/kWh for residential generation and 25 yen/kWh for non-residential. Assuming the simple payback period remains the same, the system price and feed-in tariff will remain in proportion for non-residential installations because these involve the sale of all power generated. For residential installations, on the other hand, which only sell excess power, the falling system price will result in avoided electricity purchases making up a larger proportion of the payback, and therefore cause a rapid fall in the feed-in tariff.

Also, the total cost from 2012 to 2020 is predicted to be between 3 trillion and 3.2 trillion yen, with a average surcharge of between 0.37 and 0.39 yen/kWh.

This article has used a model to project the future installation of solar PV power generation capacity up until 2020. Although the results show a steady increase in non-residential installations, caution is required as a number of factors remain that could stall this progress, including the cancellation of authorized projects, falling availability of land for plant construction, and constraints on grid connection. Similarly, while the results indicate that residential installations will also increase up until 2020, there is a potential for this to slow subsequently due to a falling number of dwellings suitable for installation. Given the inevitability of increases in the surcharge imposed on the public, another reason for caution is the potential for revisions to the feed-in tariff scheme.

This study was conducted under contract to Hitachi, Ltd.

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