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Solar Power Generation Costs in Japan

Current Status and Future Outlook

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Summary

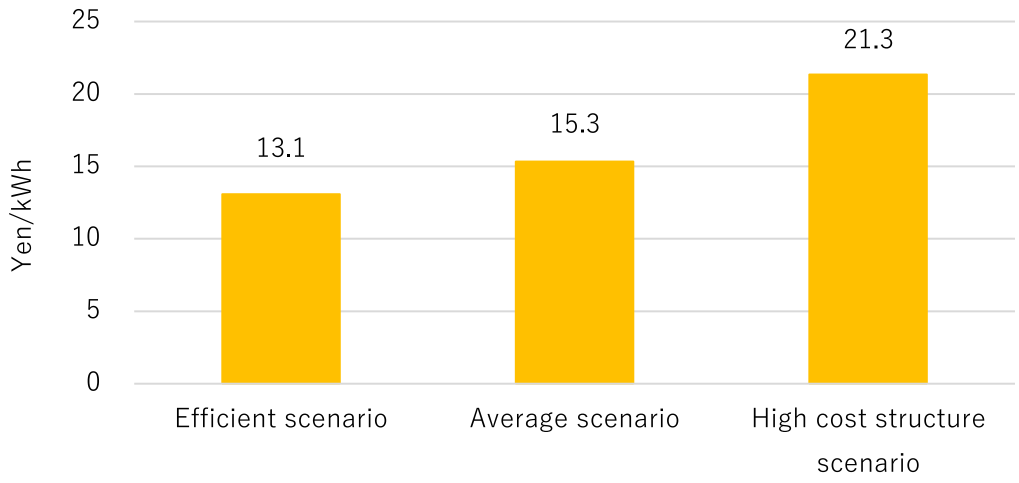
This report studies the cost structure for solar PV in recent years based on a questionnaire-centered survey, and analyzes the generation cost of solar PV in Japan. Given the fact that solar PV could potentially become one of the primary electricity sources in the future, it is important that the future cost outlook is also investigated. Accordingly, we estimated generation costs in 2030 based on the results of our analysis and recent research material.

Cost structure and generation cost of solar PV in recent years

During November and December 2018 we conducted a survey of approximately 1,676 businesses that operate solar PV power plants. The number of cost data case studies collected was 63, with the highest proportion of these - 46 - being medium size power plants (power plants with installed capacity of 50 kW or more and less than 2,000 kW). The combined total installed capacity of power plants surveyed was 89 MW. The main findings obtained from our analysis of these power plants are outlined below.

1) Regarding investment cost, we identified the possibility that the unit cost per kilowatt for hardware such as solar PV modules declined significantly from 2017 to 2018.
2) Investment cost (hereafter defined in cost per kW) and operation and maintenance costs (hereafter defined in cost per kW) varied significantly among operators. In this report's analysis, it was observed that even among power plants that commenced operation during the same period, both investment cost and operation and maintenance costs were higher for plants that were certified in the past (older). It was also found that different contract types used by generation businesses when conducting development may impact investment costs. In this report's analysis, it was observed that the investment cost for separate engagements tended to be lower than for blanket contracts. Furthermore, it was observed that although operation and maintenance costs generally tended to be lower for large-scale power plants, in the case of utility-scale power plants and above, the obligation to appoint a designated chief electrical engineer weighed on costs, resulting in operation and maintenance costs tending to be higher than for medium size power plants.
3) When we separated the data into three scenarios based on the above analysis of cost structure and calculated generation costs per kilowatt hour, it was found that there was a large variance in generation costs even among power plants that commenced operation during the same period (Fig. S-1). Particularly noteworthy is that in the efficient scenario the generation cost was 13.1 yen per kilowatt-hour (/kWh), approaching the average power exchange electricity price.

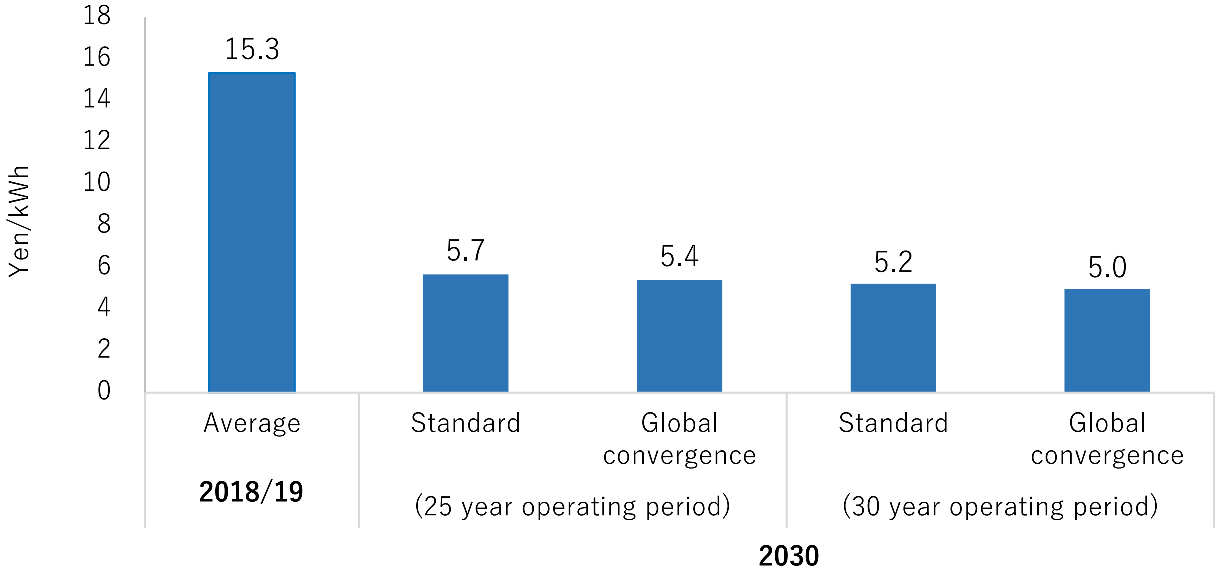
Fig. S-1 Estimated of generation cost in each scenario



Estimation of generation cost for solar PV in 2030

Based on the above cost structure analysis and findings from existing research, we estimated the generation cost for solar PV in Japan in 2030 based on several scenarios. Our estimate forecasts that generation costs will drop significantly, to the 5-6 yen/kWh level (Fig. S-2).

Fig. S-2 Estimated of generation cost in 2030



The factors behind this estimated fall in generation cost are listed below.

1. A decline in the cost of hardware, such as the unit cost of solar PV modules.
2. A decline in mounting system costs, installation costs, and ground preparation costs due to an increase in the generation efficiency of solar PV modules, which will reduce the area of land requiring ground preparation and the number of installations required per kW of generation.
3. Adoption of the ramming method of installation, which is the most cost-efficient among current installation methods.
4. Regarding grid connection costs, convergence in the unit price for connection work due to use of cost-efficient private lines.
5. Appropriate and efficient monitoring systems to reduce operation and maintenance costs, and technological advances in weed removal methods.

The estimate in this report includes currently feasible cost improvement factors such as those listed above in its assumptions. If designs and installation methods suited to Japan's geographic characteristics and new management methods can be developed, the potential for further cost reductions remains.

Regarding the potential for solar PV to function as an independent player in the wholesale electricity market, the values estimated from the findings of this report are sufficiently inexpensive even when compared against the current average day-ahead daytime power exchange price. This means that solar PV has the potential to reach a price level that is competitive in the market, even without subsidies. However, an increase in solar PV generated electricity in the market may lead to a fall in the overall market price. In order to study the potential for solar PV to actually function as an independent player, a market analysis that takes into account electricity supply and demand is required.

Introduction: Background and Purpose of the Study

The cost of solar power generation (per kWh) is rapidly declining on a global scale. The generation cost of solar photovoltaic (PV) (utility-scale solar, global weighted average unit cost) has plunged 73% between 2010 and 2017 to 8.5 US cents/kWh (IRENA, 2019). According to the latest studies from other research organizations, the global cost of solar PV (global weighted average unit cost) has fallen even further since, from 8.8 US cents[1]/kWh in 2017 to 5.7 US cents/kWh in the first half of 2019 (BNEF, 2019). As a result, solar PV costs in countries such as Germany, India, and Australia have fallen below those of fossil fuels, while in the US, UK, and China the cost has reached the same level as fossil fuels (BNEF, 2019). The country bucking this global trend is Japan.

Although the cost of solar PV in Japan is declining, it remains far higher than global standards. The average solar PV cost in 2018 calculated using the latest data from the Calculation Committee for Procurement Price, etc. was 17.6 yen/kWh (16 US cents/kWh calculated at 1 USD=110 JPY)[2].

Regarding this discrepancy in solar PV cost between Japan and the rest of the world, Kimura & Zissler (2016) conducted a quantitative analysis focusing on investment cost as of the end of 2014. This study compared the investment cost in Germany and Japan, and identified that although comparatively expensive hardware costs for modules, etc., were a factor, the primary factor was that "construction costs and other expenses" - costs other than the equipment itself - were significantly higher in Japan. In light of this finding, the study also investigated why construction costs were more expensive. A report by IRENA (2018) subsequently indicated that of the investment cost for solar PV in Japan, in addition to construction costs, margins are also high (IRENA, 2018, p.67). In light of these findings, we believe that rather than the broad category of "construction costs and other expenses," investment cost should be categorized and analyzed in more detail. Furthermore, in order to study generation cost, in addition to investment cost data operation and maintenance cost data is also necessary. From these research tasks we will review the current cost structure for solar PV and analyze the current generation cost in Japan.

Furthermore, given the fact that solar PV could potentially become a primary electricity source in the future, it is important that the future cost outlook is also studied. The Japanese government's Calculation Committee for Procurement Price, etc. has set a target cost for solar PV of 7 yen/kWh (IRR3%) by 2025 (Calculation Committee for Procurement Price, etc., 2019). Meanwhile, the government's Working Group on Generation Costs (2015) estimates the 2030 cost of solar PV (utility-scale) at 12.7-15.6 yen/kWh. As shown, there is large variance in the outlook and targets for solar power generation. This report provides an estimate of future solar PV cost levels, based on scientific knowledge, in order to provide insight that can contribute to future policymaking.

[1] Based on 2018 US dollar value

[2] An operating period of 25 years was set based on global standards. Note that this differs from the 20 year purchase period under the FiT system.

Methods of the study

During November and December 2018 we distributed a questionnaire to approximately 1,676 businesses that operated solar PV power plants in order to identify the determinant factors currently governing the cost structure of solar PV. As the study targeted businesses, solar PV facilities owned by individuals (regardless of business-level size) were naturally excluded from the scope. The scope of power plants from which we requested cost information included those that had already commenced operation between 2017 and 2018, or which planned to commence operation in 2019.

The scope of our cost analysis was investment cost and operation and maintenance costs. Each cost item was broken down into more detailed components, and survey respondents were questioned on these items (Table 1). We also asked respondents to provide a range of information that would assist in our cost analysis (the installation capacity of the power plant, etc.)

Table 1: Components of each cost item

Investment Cost	
	Development costs (land acquisition, FiT certification, etc.)
	License acquisition costs
	Design costs
	Ground preparation costs (including tree felling)
	Solar PV module
	Inverter
	Mounting system
	Materials such as cables, junction box, etc.
	Installation costs
	Transforming equipment and installation costs
	Grid connection costs
	Other costs
Operation and Maintenance Costs	
	Day-to-day operation management/monitoring costs
	Weed removal
	Regular inspection costs (including legal inspections)
	Accident response/repair costs (including reserves for this purpose)
	Insurance costs
	Land leasing fees

Overview of data

The data obtained from the questionnaire is outlined below (Table 2). In total, 63 cost data case studies were collected, with the highest proportion of these - 46 - being medium size power plants (power plants with installation capacity of 50 kW or more and less than 2,000 kW). The combined total installed capacity of power plants surveyed was 89 MW. Regarding generation capacity, utility-scale power plants (2MW and over) were the most prevalent, comprising approximately 56 MW of the total with an average installed capacity of 11 MW. Medium size power plants were the most prevalent plant type by number of data items, generating a total of approximately 33 MW at an average of 714 kW per plant. In addition, there is a trend among solar PV power plants to install solar cells greater than the plant's installed capacity. Overall, solar cells with a generation capacity 122% that of the plant's capacity were installed (hereafter referred to as "overload ratio"). The overload ratio was highest in small-sized power plants, reaching 147% in low voltage power plants. For power plants classified as medium size or greater, the overload ratio was generally around 120%.

Table 2: Overview of data collected

	Total	Small size	Medium size	Utility-scale
No. of valid data items	63	12	46	5
Generation capacity (kW)	89,296	479	32,855	55,962
Average capacity (kW)	1,417	40	714	11,192
Generation capacity of solar cells (kW)	108,575	704	41,832	66,039
Overload ratio	122%	147%	127%	118%

As shown, the installed capacity of the power plant and the generation capacity of its solar cells differ. Due to this fact, when discussing the unit price per kilowatt of electricity generation, it is necessary to clarify whether the discussion at hand is based on the unit price for installed capacity or the unit price for solar cell capacity. As outlined above, solar cell overload is a standard practice implemented at power plants of all sizes, and solar cell module costs, mounting system costs, installation costs, and other costs are closely proportional to solar cell capacity. Accordingly, unless otherwise stated, analyses performed in this study refer to the unit cost for solar cell capacity.

1. Analysis of Solar PV Cost Structure in Recent Years

This chapter identifies the current cost structure for solar PV based on cost data obtained from the questionnaire relating to power plants which commenced operation between 2017 and 2019 (including plants slated to commence operation).

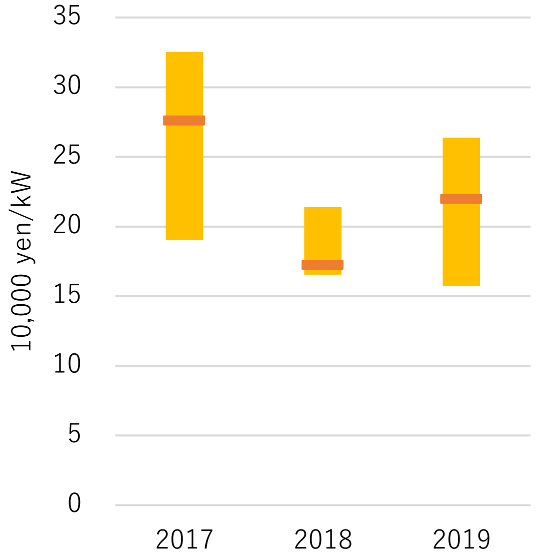
1.1. Characteristics of investment cost structure

Firstly, the most prominent cost trend seen in recent years is a continued fall in the investment cost for solar PV (Fig. 1). From 2017 to 2018 the median investment cost has plunged. Although investment costs for power plants which plan to commence operation in 2019 have risen from 2018 levels, they remain approximately 20% lower than 2017 levels. Looking at the average cost, 2018 and 2019 levels are almost identical, and represent a significant decline in investment cost compared to 2017 levels. In consideration of the above, we believe that as a trend, the investment cost of solar PV is declining.

Reviewing the data by cost item shows that the unit cost of the main hardware such as solar PV modules and inverters has declined significantly (Fig. 2).

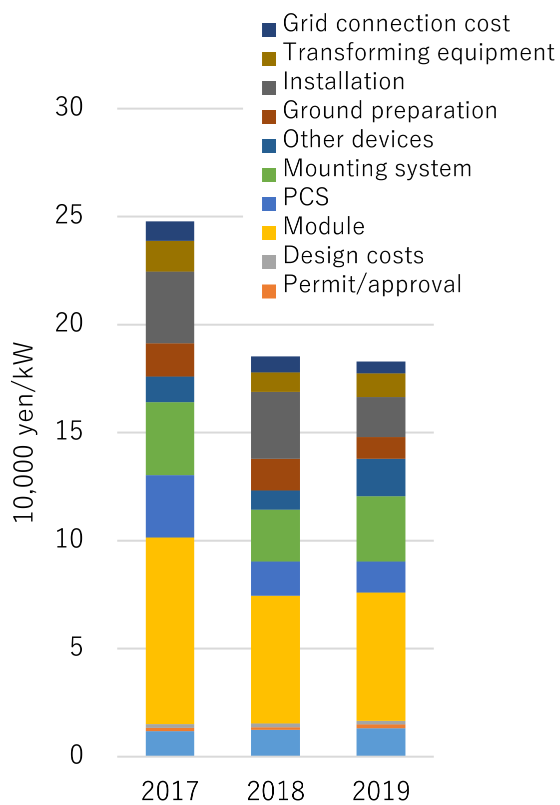
In particular, the unit price of solar PV modules has fallen 32% in one year. The largest contributor to this decline in cost for solar PV modules is a fall in the price of modules produced by overseas manufacturers. Particularly distinctive is the fact that the price for modules produced by overseas manufacturers fell significantly from 2017 to 2019. During the 2017-2019 period, the average price of Chinese and Taiwanese manufacturers declined by 39%, while that of other overseas manufacturers dropped by 52% (Fig. 3). In the case of "other" overseas manufacturers, the average price level in 2019 has fallen below 40,000 yen/kWh in what could almost be considered a price rout. Meanwhile, Japanese manufacturers have been unable to keep pace with the fall in module prices, and may be losing their cost competitiveness.

Fig. 1 Investment cost annual trend



Note: The bar graph in the above figure shows quartiles from 25% to 75%. The gradient lines in the bar graph denote the median values.

Fig. 2 Average unit price by cost item



A similar trend is occurring in inverter pricing. A review of annual pricing trends by size shows that a significant decline in price occurred from 2017 to 2018. The average price of high voltage inverters has almost halved from the 2017 level of 24,000 yen/kW to 14,000 yen/kW. This decline has occurred across virtually every size range, making it likely that some sort of major shift has taken place in the overall market (Fig. 4).

This trend may by attributable to the following two factors. Firstly, the increasing market share of cheap overseas inverter manufacturers. Indeed, the import ratio (unit number base) for inverters for the domestic non-residential market rose from 29.6% in the first half of fiscal 2017 to 38.1% in the first half of fiscal 2018 (The Japan Electrical Manufacturers' Association, 2018). In this way, the ratio of imported inverters in the Japanese market is increasing year by year - a comparison of the current level against the 6.5% ratio in the first half of fiscal 2014 illustrates the extent of this trend.

The second factor is that distributed inverters are increasing. In particular, conventional high voltage or greater modules typically employed a central inverter system that incorporated a small number of large-sized inverters. In the case of central inverters, although the number of inverters installed is small, a separate junction box was required, requiring foundation work to install the system, facilities to house it, and related construction work. In comparison, although distributed inverters have a large number of inverters, no junction box is necessary, the inverter can be installed together with the mounting system, and there is no need to construct a unit to house the inverter.

Fig. 3 Average unit price for solar modules by region of manufacturer

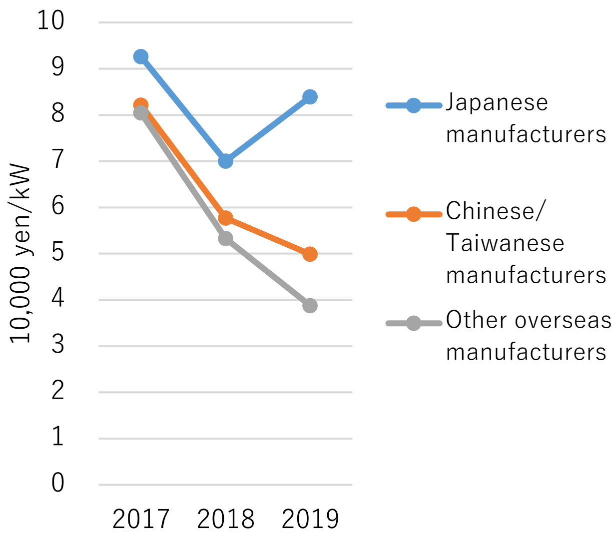
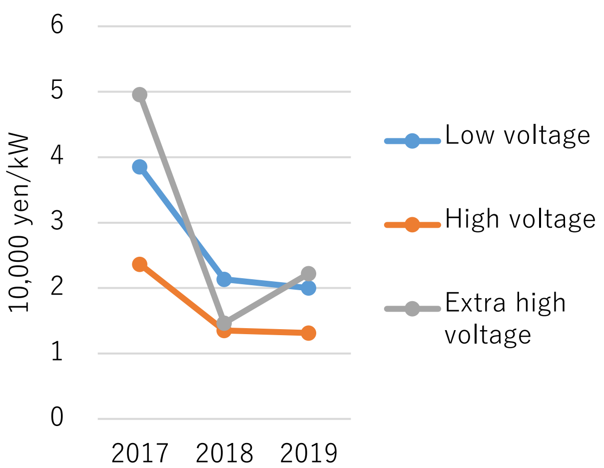


Fig. 4 Trend of average inverter unit price by scale of generation

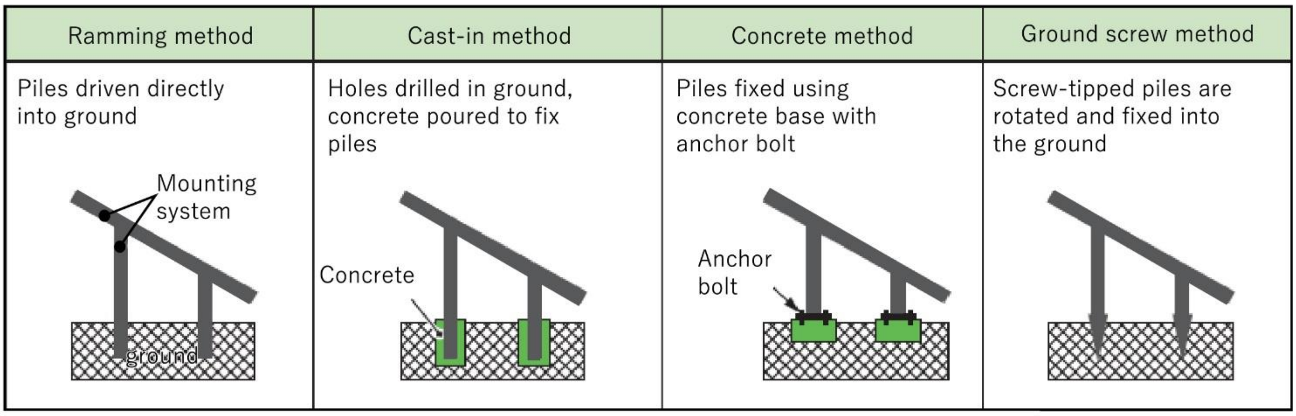


Reviewing trends in mounting system costs, although there is variance according to the type of mounting unit, a general decline in prices can be observed. As shown in Fig. 5, mounting systems can be classified into four main types. The average price for each system type is shown in Fig. 6, and an overall decline in price levels for each type can be confirmed[3]. Although the unit price for ramming type and concrete type systems has declined, it is evident that ground screw type systems remain the cheapest.

[3] Due to small sample sizes, the 2018 value for the ramming method, the 2019 value for the concrete method, and all values for the cast-in method have been excluded.

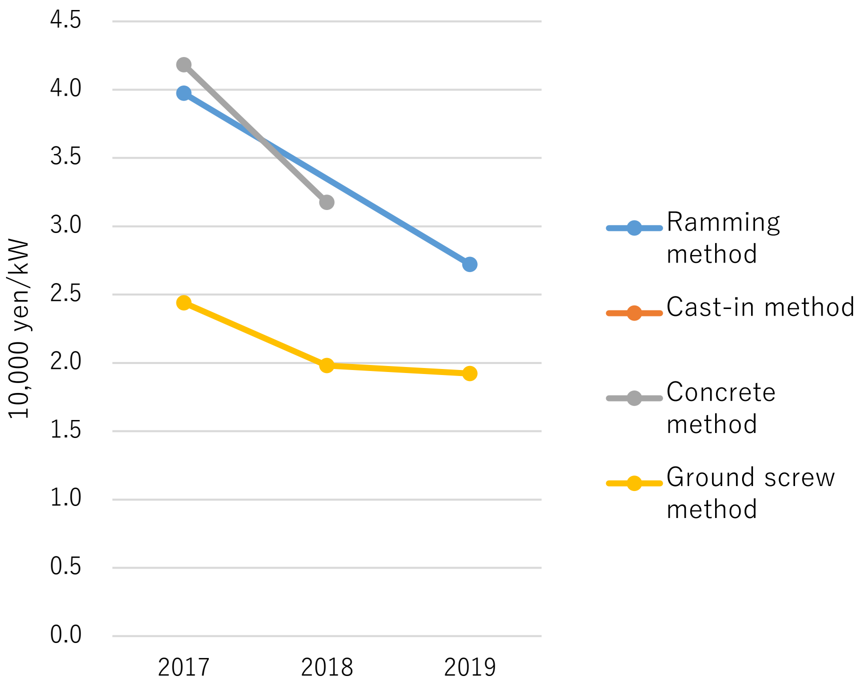
However, as mounting system design has a large impact on the workload and the difficulty of the installation, when considering investment cost, coming to a judgement based on mounting system unit cost alone is hasty. In actuality, with regard to installation costs concrete type systems are the cheapest to install, followed by ramming type systems. Furthermore, looking at the annual change in installation costs, although trends differ by system type, a general decline is evident.

Fig. 5 Typical mounting system designs and installation methods



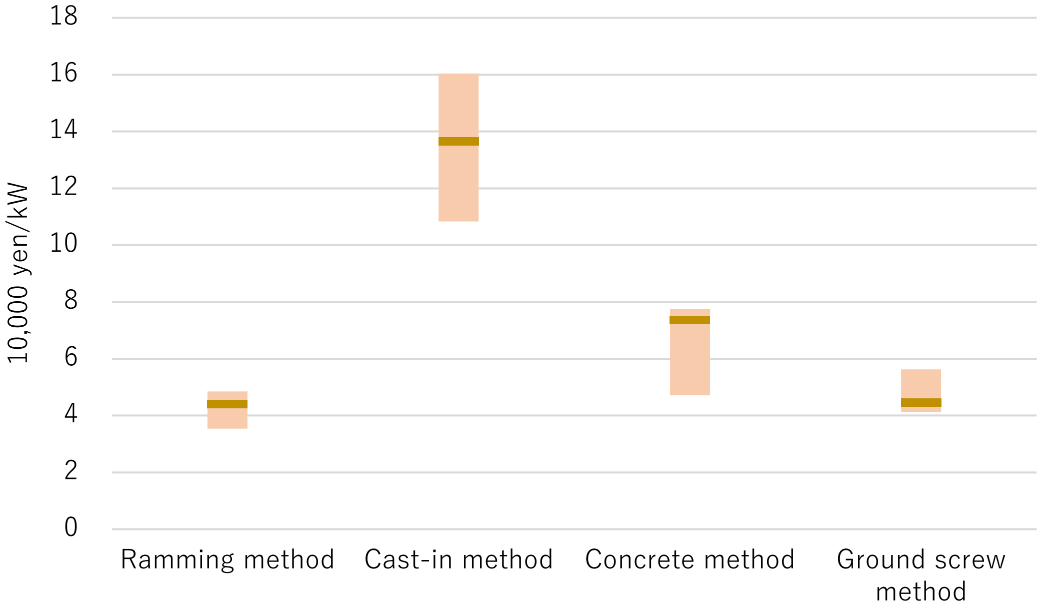
Source: Inaba, Watanabe (2012)

Fig. 6 Average unit cost of mounting system by type



Based on the above, we studied the total installation-related cost, including mounting system unit cost, installation unit costs, and the cost of other hardware such as cables, junction box, etc. As the change in mounting system unit costs was dramatic, we used data from plants which commenced operation between 2018 and 2019 (including plants slated to commerce) for our comparison scope. As outlined in Fig. 7, results showed that the median values for ramming type and ground screw type systems were of an equivalent level, while ramming type systems were cheaper on a quartile range basis. This is believed to be because installation costs for ramming type systems can be kept lower than for ground screw type systems.

Fig. 7 Quartile values of installation-related costs by mounting system type



Note 1: Data from systems which began operations in 2018 and 2019 was included in the comparison scope.
Note 2: The bar graph in the above figure shows quartiles from 25% to 75%. The gradient lines in the bar graph denote the median values.

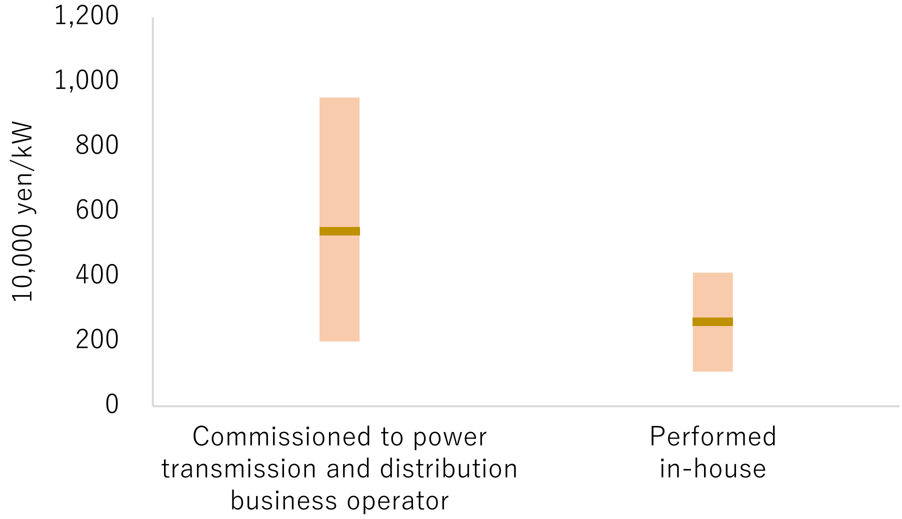
Grid connection costs

Grid connection costs vary significantly due to a range of factors. Factors believed to have a major impact on the grid connection cost include voltage level connected and distance to the connection point. In the data gathered, almost all voltage levels of 7.7 kV or lower had a short grid connection distance of less than 100 meters. Although the sample size over 7.7 kV was small, all had a grid connection distance of 1 kilometer or greater. This would indicate that when considering the grid connection costs for systems 7.7 kV or lower (low voltage/high voltage), the distance of the power lines is not a significant problem.

Regarding grid connection unit cost (yen/kW) by voltage class, costs for 6 kV and above are cheaper than for 0.6 kV and below, and costs are cheaper for power plants that are mid-sized or larger. However, there is significant variance in grid connection unit costs in each voltage class. A large variance in grid connection unit costs despite a short grid connection distance indicates that other factors are at play.

Accordingly, as one possibility we studied the variance in cost according to the party performing the connection work. In many cases, the electricity-generating business commissions the connection work to a power transmission and distribution business operator, pays electricity charges, and has the power line installation work conducted on their behalf. On the other hand, there are also cases where the electricity-generating business performs the work required to install power lines to the grid connection point by themselves. An investigation of the grid connection costs according to the party performing the connection work for power plants in the voltage class from 0.6 kV to 7.7 kV showed, as outlined in Fig. 8, that costs were significantly lower when the generation business operator performed the work themselves. As the grid connection costs shown here all involve grid connection distances of less than 100 meters, we believe that any differences in connection costs due to distance can essentially be disregarded.

Fig. 8 Comparison of grid connection costs for high voltage connections with a connection distance of less than 100m



Note: The bar graph in the above figure shows quartiles from 25% to 75%. The gradient lines in the bar graph denote the median values.

1.2. Factors affecting investment cost

In the previous section we analyzed year by year investment cost trends for each component element. In this section, we will study other factors that may affect investment cost.

1) Investment cost by year of certification

The first factor is a difference in investment cost according to the fiscal year of certification under the feed-in tariff (FiT) system. Under Japan's FiT system, the purchase price differs based on the timing of certification. For the certification from fiscal 2012 to fiscal 2014 the purchase price is 32 to 40 yen/kWh, declining to 21 yen/kWh in fiscal 2017 and almost halving to 18 yen/kWh in fiscal 2018. It is possible that this difference in purchase price is impacting investment cost.

As shown in Fig. 9, 25% of the data obtained during this study related to power plants that were certified between fiscal 2012 and fiscal 2014, directly after the introduction of the FiT system. Meanwhile, comparatively new power plants that were certified during fiscal 2017 and fiscal 2018 comprised 48% of the sample.

Fig. 9 Percentage by fiscal year of certification

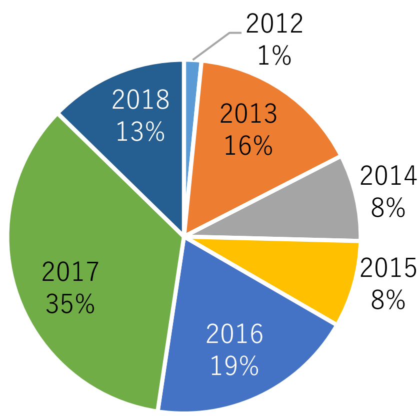
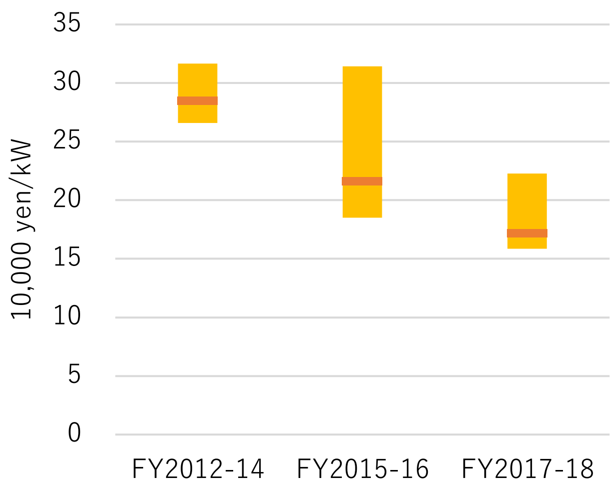


Fig. 10 Investment cost by fiscal year of certification: quartiles



Note: The bar graph in the above figure shows quartiles from 25% to 75%. The gradient lines in the bar graph denote the median values.

As the sample size of power plants certified in certain years was small, we organized the data into bands spanning multiple fiscal years, and analyzed the investment cost for each group. Power plants which were certified from fiscal 2012 to fiscal 2014 were classified as "older certified plants." In addition to older certified plants, we also classified plants certified in fiscal 2015 and fiscal 2016, and 'newly certified plants" that obtained certification in fiscal 2017 and fiscal 2018. Based on these classifications, we collated the investment cost for each group (Fig. 10)

This analysis found that even among power plants which commenced operation during the same period, the older the certification year, the higher the investment cost tended to be.

2) Investment cost by contract type

Secondly, we analyzed the difference in investment cost according to contract type. This analysis was performed because there is a possibility that differences in the management process and level of involvement of the generation business operator in the design, procurement of supplies, construction, and other processes may vary according to contract type, ultimately affect cost.

The management of the processes for design, procurement of materials, and construction, etc., of solar PV can be broadly categorized into three contract types. The first is a package contract in which a vendor (EPC contractor) handles all processes, including design, procurement, and construction. In this report, we will refer to such an arrangement as a “blanket contract." Under such an arrangement, the business operator commissions all processes, including system design, procurement of materials, hiring of various subcontractors, and supervision of the work process, to an EPC contractor. The second is a system in which the business operator procures all the main materials for the solar PV plant on their own, before outsourcing all other detailed design and construction work to another vendor under a blanket contract. In this report, we will refer to such an arrangement as a "BOP." The third is a system in which the business operator handles all design, procurement, and construction related to the solar PV plant on their own, including handling all outsourced work on a case-by-case basis. In this report, we will refer to such an arrangement as a "separate engagement."

Comparison of the investment cost for each contract type revealed that the investment cost for blanket contracts tended to be higher, while that for separate engagements tended to be lower (Fig. 12). The cost for BOP fell in between the aforementioned types.

Fig. 11 Percentage by contract type

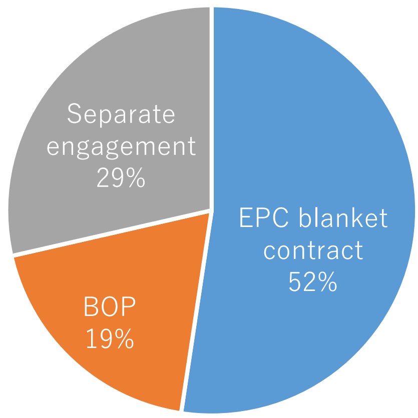
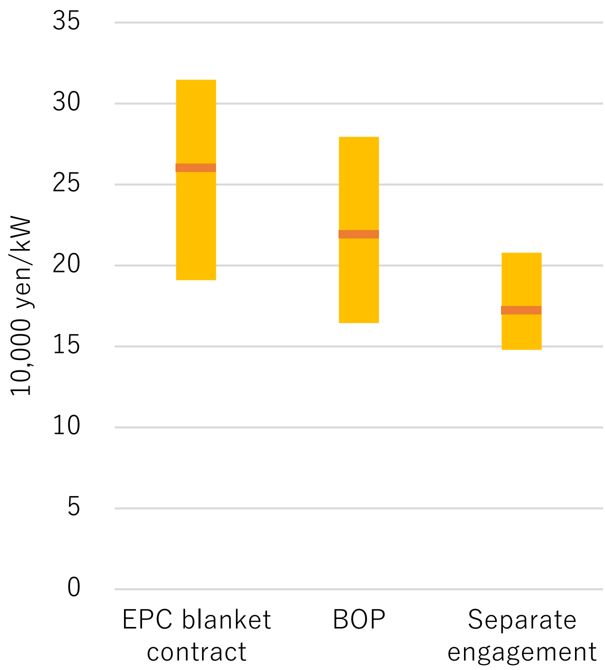


Fig. 12 Investment cost by contract type: quartiles



Note: The bar graph in the above figure shows quartiles from 25% to 75%. The gradient lines in the bar graph denote the median values.

The blanket contract allows the construction process to be commissioned to a single company. This eases the burden on the business operator, as the EPC contractor bears responsibility for managing the construction process as well as risks during construction. However, costs under this arrangement are higher, likely due to the premium that the EPC contractor demands for taking on this risk burden as well as a desire to maximize profits. Lower costs in the case of separate engagements are likely due to the fact that the generation business operator has control over the process, and is able to consider the optimal arrangement for the overall design or each individual cost item, as well as place orders with cheaper contractors.

1.3. Operation and maintenance cost structure

Operation and maintenance costs vary significantly according to the size of the plant. Operation and maintenance costs for high voltage power plants tended to be significantly lower compared to low voltage power plants (Fig. 13). Comparison by cost item showed that for most costs, including operation management costs, weed removal costs, repair costs, and insurance, the larger the size of the plant, the lower the unit cost tended to be (Fig. 14).

Fig. 13 Operation and maintenance unit cost by size of plant

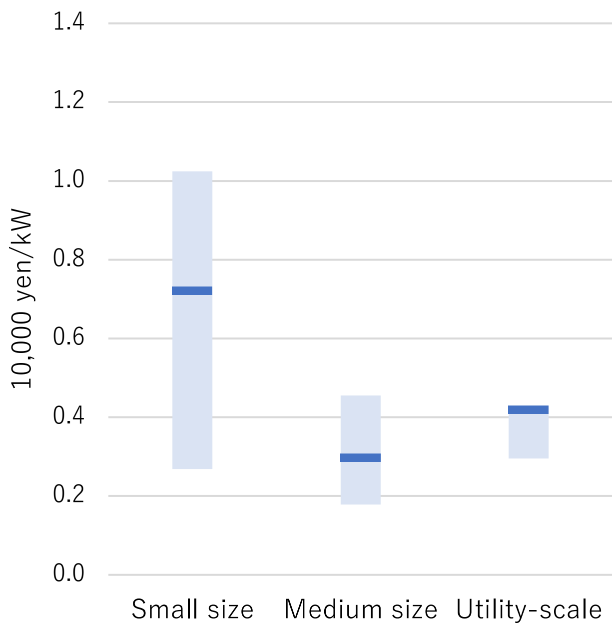
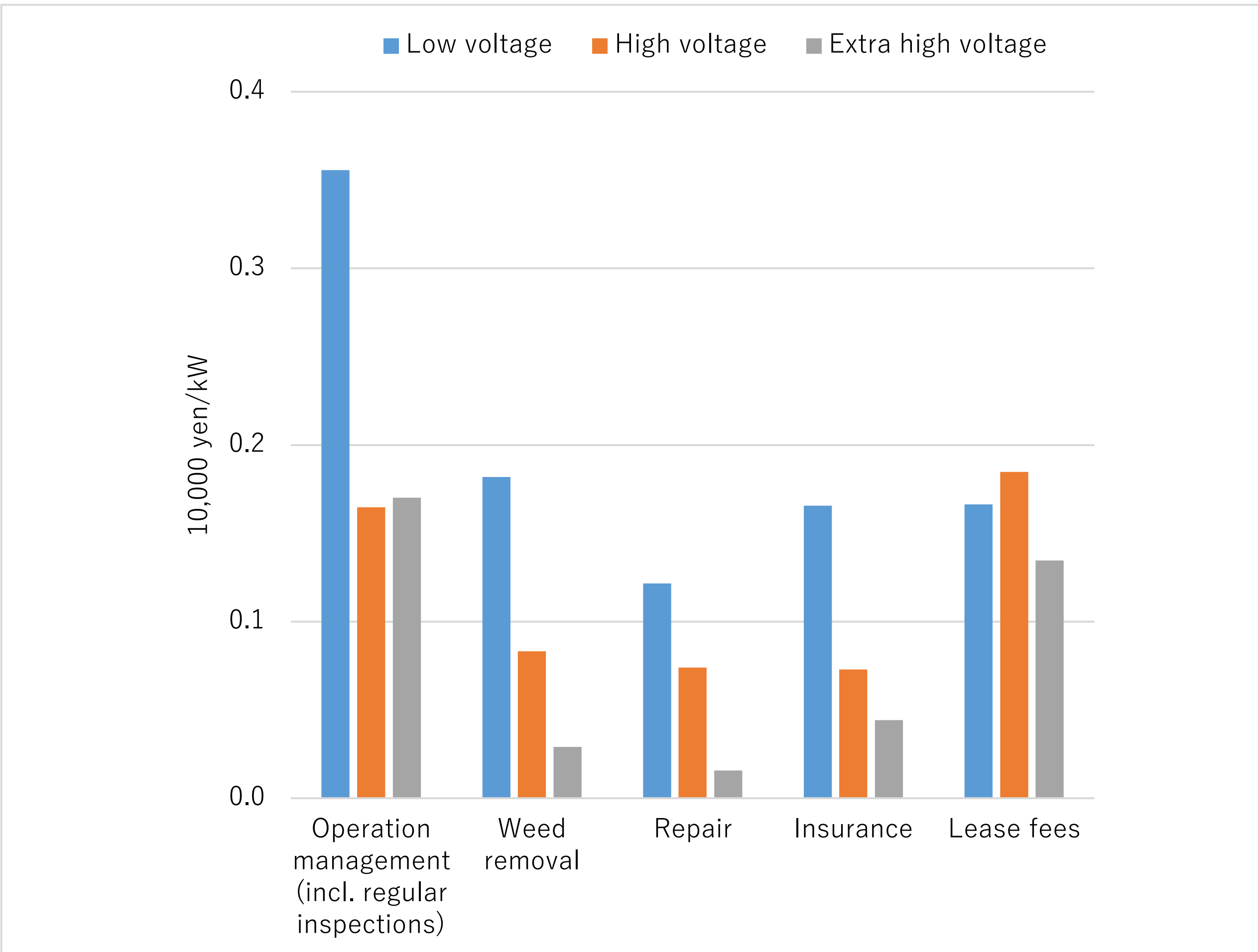


Fig. 14 Average operation management unit cost by item

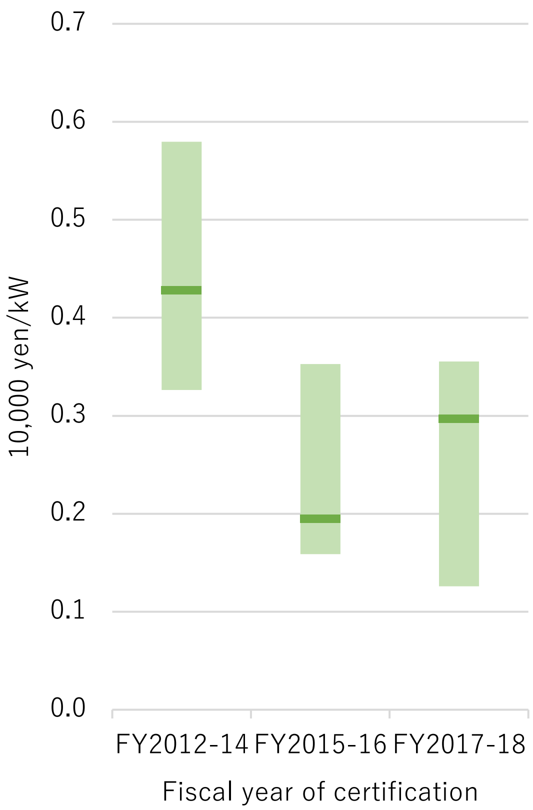


However, operation management costs (including regular inspections) were higher at utility-scale power plants than at medium size power plants. Conventionally, as most duties related to operation management involve monitoring operations and responding in the event of trouble, economies of scale tend to be involved. The fact that utility-scale power plants had high operation management costs may be due to the cost of appointing a dedicated chief electrical engineer. Solar PV power plants generating 50kW or greater are required under Japan's Electricity Business Act to appoint a dedicated chief electrical engineer. In particular, power plants generating 2000 kW (utility-scale) or greater are not allowed to appoint a chief electrical engineer serving a concurrent role at another power plant, nor outsource this role to a contractor - a specialist, dedicated engineer must be employed. The cost of this employment is an extremely heavy burden on solar PV power plants. If the labor cost of a dedicated chief electrical engineer is 10 million yen per year, this equates to a burden of 2,000 yen/kW/year for a solar PV power plant with generation capacity of 5,000 kW. The appointment of a chief electrical engineer alone accounts for half of the overall operation and maintenance costs for an utility-scale power plant. Accordingly, we believe that in order to operate an utility-scale generation power plant in an economically rational manner, a generation capacity of at least 10 MW is necessary.

1.4. Operation and maintenance costs by fiscal year of certification

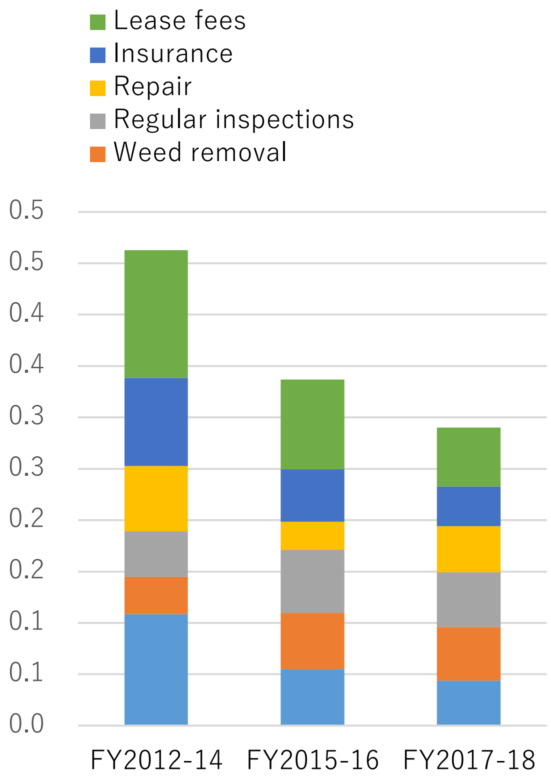
We studied whether operation and maintenance costs differed according to the fiscal year in which plants were certified. As operation and maintenance costs differed significantly according to plant size, we included only plants with a classification of medium size or greater in the scope. As shown in Fig. 15, it is evident that plants which obtained certification from fiscal 2012 to fiscal 2014 have higher operation and maintenance costs. Studying the difference by cost item, older certified plants trend toward higher costs in three categories: operation management costs, insurance fees, and land lease fees (Fig. 16). We hypothesize that these business operators spend generously on thorough operation management, and return the profit enjoyed from the higher purchase price to landowners in the form of lease fees.

Fig. 15 Operation and maintenance costs by fiscal year of certification: quartiles



Note: The bar graph in the above figure shows quartiles from 25% to 75%. The gradient lines in the bar graph denote the median values.

Fig. 16 Average unit cost by fiscal year of certification per cost item



2. Estimating Generation Cost of Solar PV

In this chapter, we use the cost structure analysis for solar PV investment cost and operation and maintenance costs, which we performed in the previous chapter, to estimate generation costs in recent years. The main points identified as a result of the analysis in the previous chapter are, firstly, that the investment cost for solar PV is declining on a year-to-year basis, and secondly, that investment costs vary according to contract type. The analysis performed as part of this study identified that separate engagement can potentially reduce investment cost compared to blanket contracts. Thirdly, we identified that both investment cost and operation and maintenance costs tended to differ according to fiscal year of certification. Older certified plants tended to have higher costs, even when compared to other plants that commenced operating during the same period. Based on these analysis results, we will estimate the generation cost for solar PV in Japan as of 2018/2019.

2.1. Considering criteria for estimation

In order to estimate generation cost, in addition to investment cost and operation and maintenance costs it is also necessary to define capacity factor and discount rate. The manner in which operating period is defined is also important. In this section, we examine three variables: capacity factor, discount rate, and operating period.

1) Capacity factor

According to the Calculation Committee for Procurement Price, etc. (2019), the average capacity factor for power plants generating 10kW or greater from June 2017 to May 2018 was 14.4%. This figure denotes the capacity factor (AC end capacity factor) on an inverter output basis (authorized capacity). As this report analyzes cost on the basis of solar cell capacity, the capacity factor used to calculate generation cost must also be defined on a solar cell capacity basis (in other words, DC end capacity factor).

According to the Calculation Committee for Procurement Price (2019), the AC end capacity factor is increasing due to an increase in the overload ratio. For power plants generating 1,000 kW or greater, the average capacity factor has reached 15.8%. The year-upon-year increase in the AC end capacity factor is likely occurring in line with a corresponding year-upon-year increase in the overload ratio of the plants operating. In fact, while the overload ratio of plants operating in 2013 (50 kW or greater) was 110%, for plants operating in 2018 this ratio had risen to 128%. The overload ratio for small size power plants has risen particularly rapidly since 2017, exceeding 135% in 2018.

In light of these circumstances, we will estimate the DC end capacity factor based on materials released by the Calculation Committee for Procurement Price. As the overload ratio is increasing year-upon-year, we will use the original capacity factor and overload ratio at time of FiT commencement. According to the Calculation Committee for Procurement Price (2016), the AC end capacity factor for power plants generating 1,000 kW or greater between October 2013 and September 2014 was 14.2%. As the overload ratio for power plants generating 1,000 kW or greater from 2013 to 2014 is found to be 115%, the DC end capacity factor can be calculated at 12.3%. From the above, we will set the value for DC end capacity ratio to be used during our estimation of generation costs at 12.3%.

2) Discount rate

The Japanese government's Working Group on Generation Cost states that the discount rate is "based on a general societal uncertainty surrounding future finances," and systematically uses the same discount rate in its calculations, regardless of electricity generation technology (Working Group on Generation Cost, 2015). However, the above definition is the general definition of discount rate, and how this is applied in the calculation of generation cost depends on the purpose of the calculation at hand.

During actual investment in electricity generation, factors such as the interest rate of borrowed investment capital at the time or the expected profit rate on own capital become important, and factors such as the soundness of the companies invested in and risks related to the generation business must also be taken into account. In order to estimate generation costs that are as close as possible to reality, it is important to factor in a realistic discount rate that takes into account this range of elements. Accordingly, regarding the discount rate in the solar PV generation business, this report uses the minimum investment capital procurement cost necessary for investment as the discount rate. We will calculate investment capital procurement cost using the weighted average investment cost (pre-tax) when procuring investment capital.

Weighted average investment cost = cost of borrowed investment capital × borrowing ratio + cost of own investment capital × (1 - borrowing ratio)/ (1 - effective corporate tax rate)

In order to calculate the weighted average investment cost, for each parameter related to investment cost and borrowing ratio, etc., we used 2018 first half benchmark values for Japan compiled by Bloomberg NEF (BNEF, 2018). For the effective corporate tax rate, we referenced the Secretariat of the Study Group on the Capacity Market (2018). As a result, weighted average investment cost was set at 3.2%.

3) Operating period

Under the FiT system, the purchase period for commercial solar PV power plants is set at 20 years. However, in the calculation of overseas generation costs, in most cases the operating period of solar PV power plants is assumed to be 25 years (IEA/NEA, 2015; Fraunhofer ISE, 2015; IRENA, 2018), and in some cases 30 years (NREL, 2018). In light of this, in this study we will set an assumed operating period of 25 years.

2.2. Results of estimate

Based on the analysis results outlined in Chapter 1 and the criteria set out in the previous section, we will estimate the generation cost of solar PV. We will study fiscal year of certification and contract type as the main elements affecting cost. In line with the different factors involved, we will separate our assumptions into three scenarios: 1) an efficient scenario, 2) an average scenario, and 3) a high cost structure scenario. The conditions and specifications for each scenario are outlined in Table 3. For example, investment costs in the efficient scenario are based on our analysis thus far and reference the average value for a power plant which received certification from 2017 to 2018 and applied the separate engagement type during construction.

As our study thus far has observed a significant declining cost trend from 2017 to 2018, in order to identify more recent generation costs we will exclude power plants which commenced operation in 2017 from the calculation scope. For plant size we will set medium size power plants, for which we obtained the greatest number of data samples, as our scope.

Table 3: Conditions and specifications to calculate generation cost

		Efficient scenario	Average scenario	High cost structure scenario
Conditions	Fiscal year of certification	FY 2017~2018	All	FY 2012~2014
	Contract type (investment cost only)	Separate engagement	All	Blanket contract
Specifications	Investment cost (yen/W)	172	200	284
	Operation and maintenance costs (yen/W/y)	2. 9	3.5	4.5

Fig. 17 Estimated unit cost for generation in each scenario

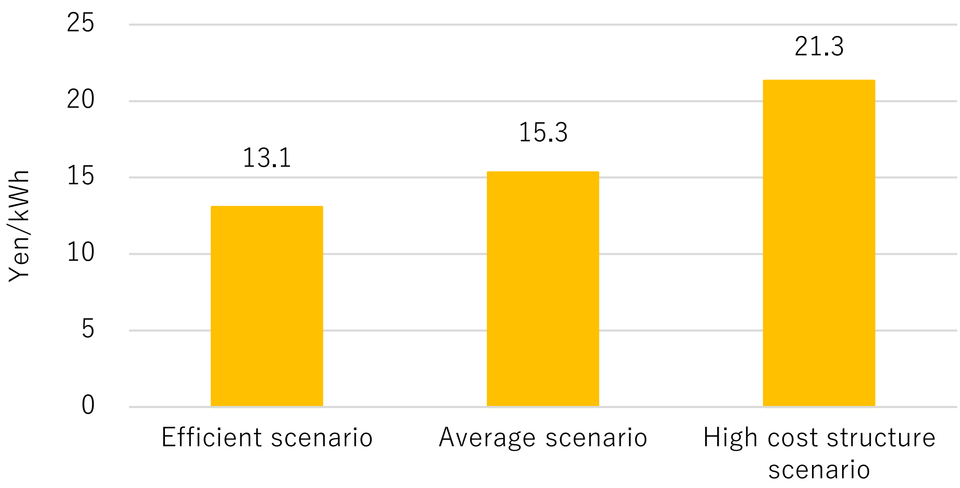


Fig. 17 shows the results of our estimate. The unit cost for generation in the respective scenarios were 13.1 yen/kWh (11.9 US cents/kWh) in the efficient scenario, 15.3 yen/kWh (13.9 US cents/kWh) in the average scenario, and 21.3 yen/kWh (19.4 US cents/kWh) in the high cost structure scenario. However, it should be noted that the criteria for the efficient scenario are not particularly difficult for business operators to achieve. As shown in Table 3, the criteria for the efficient scenario are simply: the power plant obtained certification in 2017 or 2018; designed and developed the business efficiently using a separate engagement; and was able to commence operation swiftly. We believe that this development is not necessarily difficult for an experienced electricity generator to perform. On the other hand, the high cost structure scenario assumes that generation costs match conditions under the initial introduction of FiT when the purchase price was high, as well as a contract type in which the process is a package outsourced to an EPC contractor, reducing development risk but incurring higher costs. Including these types of plants, the assertion that Japan's solar PV costs are high may simply be an overstatement of the country's solar PV generation costs. To the contrary, the efficient scenario may in fact be closer to the real economic performance of Japan's solar PV.

Finally, we will also examine the generation cost in the event that further improvements in cost efficiency are made in the efficient scenario. To this end, we calculated generation costs using upper quartile values (referred to as the "leader values") for investment cost and operation and maintenance costs for power plants that met efficient scenario criteria. Under this scenario, the unit cost for generation using leader values was 10.8 yen/kWh (9.8 US cents/kWh). As the average unit price in the power exchange market in Japan in fiscal 2018 was 9.8 yen/kWh (the average day-ahead unit price [8:00-17:00] was 9.9 yen/kWh), in the case that leader values are realized, the cost of solar PV would draw almost level with wholesale electricity prices. Although circumstances will depend on wholesale electricity prices going forward (particularly daytime pricing), we can conclude that the potential for solar PV to shift from the FiT system to an economically independent business model is growing. Additionally, generation costs under a leader value scenario has approached a level not far off the 2018 global weighted average unit cost for solar PV of 8.5 US cents/kWh (IRENA, 2019). Given these factors, we believe that Japan's high cost structure for solar PV is not ingrained, and can be resolved.

3. Estimating Solar PV Generation Costs in 2030

Based on the current generation cost circumstances examined in the previous chapter, we will next estimate generation costs for solar PV in Japan in 2030. According to Obane et al. (2017), the methods for estimating future costs can be broadly classified into three types. The first method uses a learning curve to estimate the future cost of solar PV systems (hereafter "learning curve method"). The second estimates future cost levels for each cost item taking into account factors such as technological advances, manufacturing processes, and future market size, and stacks these in a bottom-up manner to estimate the total cost. The third estimates future cost by assessing the possibility for cost reductions based on interviews with experts.

As this study targets 2030 and considers costs in 11 years' time (from the time of writing) - a comparatively short-term future outlook - we will use the bottom-up method rather than the learning curve method to conduct our estimation. This is due to the fact that the learning curve method requires estimates regarding future cumulative installation volume, and estimates of solar PV installation vary widely across a range of research institutions. For this reason, the value used in the calculation has the potential to significantly shift the output value, casting a high degree of uncertainty across results. The bottom-up model also has a certain degree of uncertainty as it is necessary to take into account changes in technology and manufacturing methods, however we can consider a realistic outlook of technology currently exists. For this reason, we judged the bottom-up model to have a higher degree of reliability when examining an outlook of approximately 10 years.

3.1. Study of criteria

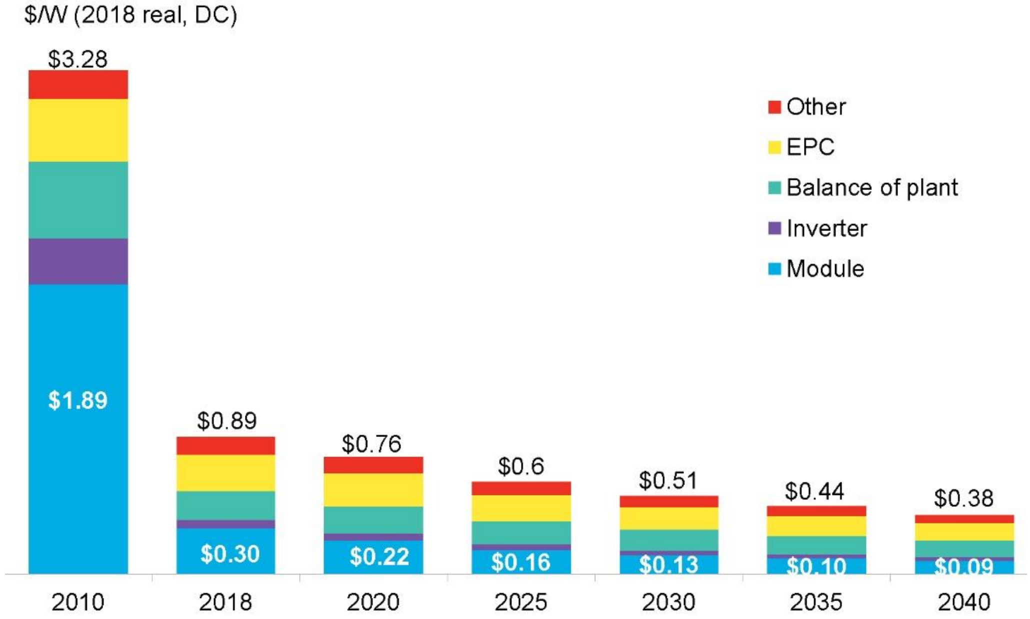
1) Solar cell modules

An estimate for the procurement cost of solar cell modules and inverters in 2030 based on the bottom-up method already exists (BNEF, 2018b; JST-LCS, 2019). According to BNEF (2018b), the global cost for modules in 2030 is estimated at USD1.25[4]/W (USD 125/kW) (Fig. 18). At the 2018 exchange rate of 110 yen to the US dollar, this is equivalent to 13,800 yen/kW. This cost decline is attributed to a decrease in wafer thickness, which results in less silicon used per 1W of output, as well as the use of cheaper raw materials. This estimate also takes into account cost reductions stemming from greater efficiency in the production process through utilization of technology such as automatic assembly machines, and lower margins due to increasing cost competition between manufacturers.

Meanwhile, based on the assumption that production takes place in Japan, JST/LCS (2019) estimates the 2030 unit cost of single-crystal silicon modules at 21,600 yen/kW (21.6 yen/W) (Fig. 19). JST/LCS (2019) takes into account the module conversion efficiency, reduction in wafer thickness, improvements in productivity, and lower raw material and manufacturing machinery costs due to market expansion.

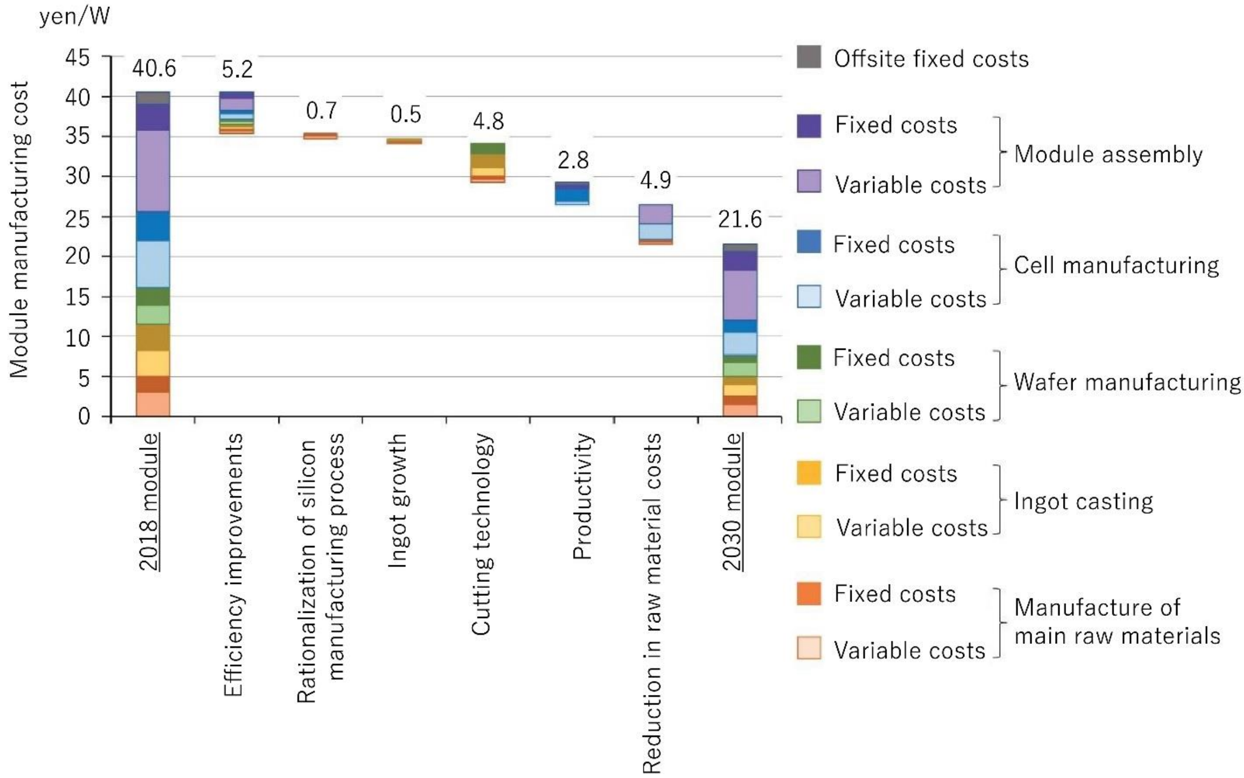
[4] Actual 2018 US dollar value

Fig. 18 Estimated investment cost for large-scale solar PV power plant



Source: Bloomberg NEF (2018b)

Fig. 19 Estimated cost of single-crystal silicon solar cells



Source: JST/LCS (2019)

As the generation efficiency of modules is increasing year by year, we can also anticipate these sorts of improvements in efficiency. According to Fraunhofer (2018), the average generation efficiency of silicon modules commercialized in the past 10 years has risen from 12% to 17%. BNEF (2018b) estimates that module generation efficiency will rise to 21% in 2025, and 24.4% in 2040. Regarding the generation efficiency in 2030, for the purpose of this study we will adopt a factor of 22.1%, representing a straight-line increase in module efficiency from 2025 to 2040. Meanwhile, JST/LCS (2019) estimates that the generation efficiency level of single-crystal silicon modules will reach 25% in 2030.

Next, we will use the 2030 cost estimates for single-crystal modules in Japan by JST/LCS (2019), and globally by BNEF (2018b), to forecast 2030 solar PV module cost in Japan. According to module shipment statistics released by the Japan Photovoltaic Energy Association, of the total volume of modules shipped to generation businesses in the 2017 and 2018 calendar years, the shipment volume ratio of Japanese companies was 43%. Based on our interviews with solar PV business operators, the majority were of the opinion that using modules produced by Japanese companies was difficult from the perspective of economic efficiency. Given this situation, there is a possibility that Japanese companies' share of the domestic market may decline in future.

From the above we will envision two scenarios. The first scenario is one in which the shipment ratio for Japanese companies in 2030 is 20%, with overseas companies' shipment ratio at 80%. Using this ratio and the allocating the cost estimates by JST/LCS (2019) and BNEF (2018b) therefore establishes a unit cost for modules in the Japanese domestic market of 15,300 yen/kW. We will set this as our "standard scenario". The second scenario is one in which the price of Japanese manufacturers converges with that of overseas manufacturers (global convergence scenario). Using the unit cost estimated by BNEF (2018b), the 2030 unit cost for modules in the Japanese market under this scenario is 13,800 yen/kW.

2) Inverters

According to IRENA (2016), based on the bottom-up method the cost for inverters in 2025 is estimated at 0.09 USD/W for centralized inverters, and 0.12 USD/W for distributed inverters (2015 USD value base). However, NREL (2018a) indicates that in the first quarter of 2018 the unit cost of centralized inverters in the US fell to 0.04-0.05 USD/W, while that for distributed inverters declined to 0.08 USD/W, raising a strong possibility that costs have already reached the 2025 levels estimated by IRENA (2016). As shown, it is evident that the cost trend for inverters is shifting dramatically. BNEF (2018b) estimates the 2030 unit cost for centralized inverters at 0.03 USD/W - a fall of 43% from the 2018 level.

Next, we will compare the domestic versus overseas price for the unit cost of inverters in 2018. While the median value for medium size power plants in Japan was 13,500 yen/kW (REI data), the US price for distributed inverters was 0.08 USD/W, which equates to 8,800 yen/kW (NREL, 2018a). Compared to distributed inverters, the unit price for inverters in Japan is approximately 50% higher. However, the upper quartile value for inverter unit price in Japan is 9,800 yen/kW, close to the global standard.

From the above, we will envision the following two scenarios for the unit price of inverters in 2030. In the standard scenario, we will set the domestic upper quartile price as the standard, then subtract the 43% fall in price indicated by BNEF (2018b) to give 5,600 yen/kW. In the second, global convergence scenario, prices will converge to the 3,300 yen/kW level indicated by BNEF (2018)

3) Installation-related and ground preparation costs

The primary factor affecting installation-related costs and ground preparation costs is solar cell efficiency. If generation efficiency is low, a larger surface area is required, leading to higher ground preparation and installation costs. On the other hand, if efficiency is high, the same output can be achieved using a smaller area, reducing the aforementioned costs. As described above, solar cell efficiency is improving with each passing year. In this study, we will presume that solar cell efficiency will increase further, leading to a decrease in the land area required and consequently lower ground preparation and installation-related costs.

The second factor with a major impact on installation-related costs is the mounting system design and their prescribed installation methods (see Chapter 1). Analysis conducted during this study revealed that the ground screw method and ramming method were most effective in lowering installation costs. In particular, when upper quartile values are examined the ramming method is the most cost-efficient, and it is possible that employing this method may be effective in reducing costs. Although in the lead-up to 2030 there may be further developments in cost-efficient mounting system design or installation methods, in this study we will use the upper quartile value for the ramming method, which is believed to be the most cost-efficient method available for minimizing installation-related costs, as our reference value when estimating installation-related costs in 2030.

We have estimated installation-related costs and ground preparation costs in light of two key points: the cost reduction effect of improvements in solar cell efficiency and the promotion of efficient installation methods. Under the standard scenario, 2030 installation-related costs and ground preparation costs are 26,200 yen/kW and 9,400 yen/kW respectively. Under the global convergence scenario, these values are 26,900 yen/kW and 9,700 yen/kW respectively.

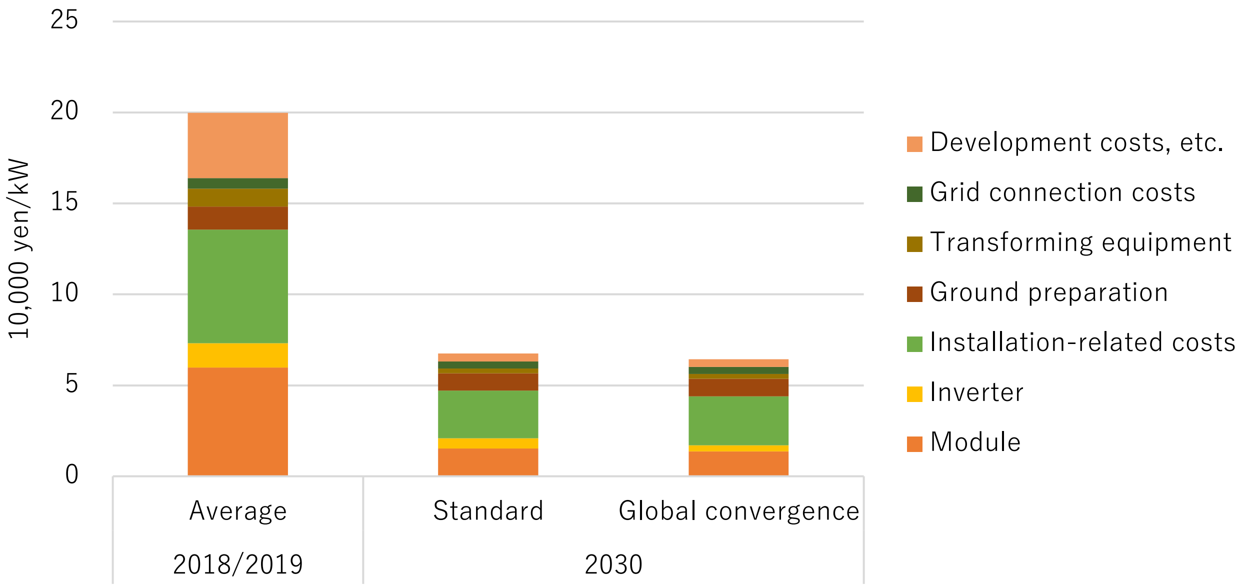
4) Transforming equipment and grid connection costs

Although transforming equipment technology is mature and there is a limited outlook for technological innovation, there are large differences in cost even at the same voltage level. Furthermore, a reduction in costs from 2017 to 2019 has been observed. Accordingly, we have set the value for 2030 at 2,700 yen/ kW (medium size power plants), representing the upper quartile value from the latest 2019 data.

Meanwhile, an increase in grid connection costs is expected as the future increase in power plants is likely to lead to gird constraints. On the other hand, grid connection costs can be reduced by the operator performing the line work on their own. In other words, when connecting solar PV power plants to the grid, rather than outsourcing the work to a general power transmission contractor the business operator performs the work to connect the system to the connection point. Data from this study also indicates that this has the potential to reduce grid connection costs significantly. Accordingly, we assume that in 2030 it will be standard practice for business operators to perform the grid connection work themselves, and set the current median unit cost for connection via private lines as our input value.

Collating the 2030 investment cost for each cost item as above gives a total of 67,500 yen/kW under the standard scenario, and 64,300 yen under the global convergence scenario (Fig. 20). Compared to the average investment cost in 2018/2019 (average scenario in Table 3), these results represent a 66% reduction in cost in the standard scenario, and a 68% reduction in the global convergence scenario. Although this indicates that a significant reduction in costs from the present level is possible, it should be noted that ground preparation costs vary significantly by location. In areas where ground preparation costs can be minimized, solar PV systems can be installed at an even lower cost.

Fig. 20 Estimated investment cost for onshore medium size power plants in 2030



5) Operation and maintenance costs

Operation and maintenance costs can be broadly categorized into three types: (1) costs required to conduct day-to-day management of the power plant (operation management costs and regular inspection costs), (2) payment costs related to risk response, such as repair costs and insurance costs, and (3) land lease fees.

Regarding (1), we believe that plant monitoring technology will play a key role. Excluding regular inspections, the use of remote monitoring technology to perform necessary monitoring in most situations could potentially reduce labor costs. As the number of power plants increases going forward, it is possible that remote monitoring costs for each plant will decrease. Monitoring is currently conducted on a string basis, and although both the average and median for operation and maintenance costs were 600 yen/kW (upper quartile value: 300 yen/kW), in the case that visual inspections can be eliminated, we believe that greater efficiency can be achieved in future, and therefore estimate that costs will converge to the upper quartile value of 300 yen/kW in 2030. The same applies to regular inspection costs.

Weed removal costs are another important item. The current unit cost for weed removal in Japan is 500 yen/kW for medium size power plants. However, ride-on mowers are beginning to gain traction as an efficient method of cutting grass. This reduces a workload of 4-5 person-days in the case of handheld movers to 1 person-day, significantly reducing labor costs. Furthermore, in addition to human-operated technology, automated robot mowers are also beginning to be developed (Solar Power Plant Business, 2018). Although the conditions in which they can be used are limited at present, it is predicted that with advances in technology the types of sites in which they can be utilized will grow and that the cost of introduction will decline. As detailed above, weed removal technology is still in the development stage. Accordingly, we will set weed removal costs in 2030 at 100 yen/kW based on the assumption that, for example, ride on mowers and automated robot mowers will become commonplace.

(2) Repair costs and insurance costs are generally calculated based on the investment cost at the time. Accordingly, we will set repair costs, assuming costs for one inverter replacement during the operating period, at 200 yen/kW in the standard scenario, and 100 yen/kW in the global convergence scenario. Meanwhile, we will set insurance costs at 300 yen/kW, 0.5% of investment cost, based on the cost data obtained in this study.

(3) Land lease fees per unit of output may decline as generation efficiency improves, meaning that a smaller land area is required. On the other hand, there is a possibility that the supply of favorable land that can be developed may decline, driving up lease fees per square meter. In light of the above, we opted to set the value for lease fees at the current median level for medium size power plants of 800 yen/kW.

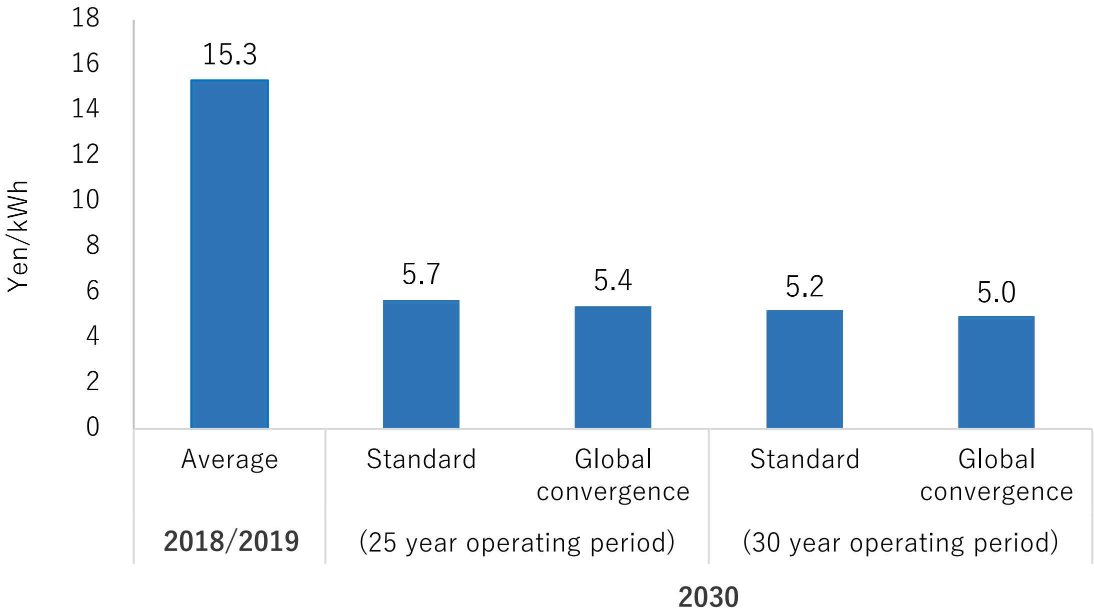
From the above, total operation and maintenance costs amount to 1,900 yen/kW. This represents a significant decline from the current level of 5,700 yen/kW indicated by the data obtained during this study.

3.2. Results of estimate and discussion

Based on the above 2030 investment cost and operation and maintenance cost levels in Japan, we will estimate solar PV generation costs in 2030. In doing so, assumptions regarding operating period and discount rates must also be considered. Regarding discount rates, we hypothesize that there will be no change from the current level. Regarding operating period, we forecast two scenarios: one in which the current operating period of 25 years remains unchanged, and one in which the operating life lengthens to 30 years due to technological advances. This is because in their estimation of 2030 generation costs, NEDO (2014) and RTS Corporation (2018) assume that the operating period will extend to 30 years due to improvements in solar cell life.

Calculating 2030 solar PV generation cost based on these assumptions gives 5.7 yen/kWh in the standard scenario (25-year operation) and 5.4 yen/kWh in the global convergence scenario. An increase in the operating period would further lower generation costs, decreasing to 5.2 yen/kWh in the standard scenario and 5.0 yen/kWh in the global convergence scenario. All of these values represent a further significant reduction in cost compared to the efficient scenario discussed in Chapter 2 (13.1 yen/kWh). Furthermore, these levels are sufficiently cheaper than the 2018 day-ahead daytime power exchange price, making it increasingly plausible that solar PV can function independently in the electricity market as a cost-competitive energy source.

Fig. 21 Estimated 2030 generation cost for solar PV: results



From 2030 onward, the potential for cost reductions expand further. Reduction in hardware costs and further improvements in efficiency are predicted. In addition, from the early-2030s the purchase period under the FiT system will end for many solar PV power plants. In the case that these plants are replaced, we can surmise that obtaining permits and approval for the related development will be simple, plus grid connection, ground preparation, and other processes will already be complete. Therefore, compared with investments in new development, replacement facilities can potentially save significant outlay on development costs, grid connection costs, and ground preparation costs. Thus, the replacement of these existing power plants by new ones can further lower generation costs. As described, although commercial solar PV started out at 40 yen/kWh in fiscal 2012 under the FiT system, when these facilities are replaced in 2035 and beyond, it is possible that some plants may achieve generation costs around one tenth of the fiscal 2012 purchase price.

Meanwhile, when considering the potential for solar PV to function as an independent player in the electricity market, there are other factors that must be taken into account. Firstly, the possibility of curtailment. The above generation costs do not take into account the effect of curtailment, instead representing the value in the case that all electricity generated can be sold. In the case of a 30-year operating period, a solar PV power plant which commenced operation in 2030 will operate until 2059. At this time, it is likely that the scale of solar PV generation in Japan will be significantly larger. In this situation, it is possible that a frequent oversupply of electricity will occur during daytime hours. In these circumstances, if a power plant is subject to a 10% curtailment, the volume of electricity generated will decline by 10% accordingly. A 10% curtailment would increase generation cost to 6.3 yen/kWh in the standard scenario, and 6.0 yen/kWh in the global convergence scenario.

Secondly, there is also the issue of whether operators will be able to obtain sufficient revenue to justify generation costs. The generation costs that we estimated during this study are certainly significantly lower than even the current daytime wholesale electricity price. However, it is possible that from 2030 and 2059 the daytime wholesale electricity price level may fall even further. This is because, in the case that daytime solar PV generation exceeds demand as described above, the wholesale electricity price should, in theory, become 0 yen/kWh. In the event this occurs, solar PV business operators would earn zero revenue during this time period. Even in the case that supply does not exceed demand, if a significant portion of demand is met by solar PV, the wholesale electricity price will decline, reducing the revenue of solar PV business operators.

On the other hand, lower electricity prices may also drive further demand for electricity. Cheap wholesale prices could create new demand for electricity through applications such as electric vehicles or heat pump water heaters. Alternatively, new businesses or innovations that transfer consumption demand, such as storing cheap electricity to sell or consume at times when the wholesale rate is higher, could potentially be conceived. Although such developments depend on trends in the overall market, this may be one important point that should be taken into account when considering the penetration of renewable energy.

4. Conclusion

In this report, we gathered actual cost data from solar PV businesses that commenced operation from 2017 to 2019, identified their cost structure, and estimated generation costs based on this information. Results showed that a dramatic reduction in the costs of hardware such as solar PV modules, inverters, and mounting systems is occurring. In particular, the influx of cheap equipment from overseas is not only reducing overall costs, but also spurring domestic manufacturers to increase their competitiveness. In light of these analysis results, we will outline the policy-related issues identified from this study.

(1) Flaws in system may lead to high-cost structure

The study found that the development method (differences in contract type) and differences in the fiscal year of FiT certification impacted costs. Despite hardware costs falling significantly compared to when the FiT system was introduced, as described above, a large number of older certified plants remain in operation, with their initial electricity purchase price unchanged. These plants tended to have higher component procurement costs, as well as inflated costs across a range of areas. The same applied to components of operation and maintenance costs such as land lease fees and operation management costs.

The electricity purchase price for older power plants certified between fiscal 2012 and fiscal 2014 is 32-40 yen/kWh, two to three times the purchase price for plants certified between fiscal 2017 and fiscal 2019 (14-21 yen/kWh). The purchase price for these older certified plants means that they can anticipate latent high profitability. It is possible that in addition to the business operator, this latent profitability is being distributed to a range of associated players, such as component suppliers, EPC contractors, landowners, and those holding FiT certification rights. Through the tariff, Japanese electricity consumers are paying for these additional costs in the form of higher prices, leading to a structure under which “renewable energy is high cost".

This structure is a result of a failure in the initial system design, namely negating to set a time limit for commencing operation. In June 2013, the Renewable Energy Institute issued a press release entitled "Japan's Feed-in Tariff System Achievements and Issues One Year On," in which it identified the problems outlined below. However, it was not until after August 2016 that an effective time limit for commencement of operation was put in place.

"In the current operation of plant certification under the FiT system, changes in solar panel manufacturer, changes in component model, changes in business operator, and changes in location are all regarded as small changes. In addition, there are no standards that indicate when the business operator must commence operation. This operating system enables operators to obtain plant certification at a high purchase price, wait for the price of solar PV systems to fall before installing equipment cheaply, then reap a high profit margin. Urgent action is required to ensure that this system is not abused."

If any lessons are to be learned from these experiences, it should be to ensure efforts are made to prevent similar problems occurring with other renewable energy sources. The key is to reduce the potential for costs to remain high, despite the fact the cost reduction efforts can reduce expenses due to purchase price providing a significant latent profit potential, which does not incentivize the operator to optimize cost competitiveness, with profit instead allocated to various associated parties. As other types of renewable energy differ from solar PV in that the electricity purchase price is largely unchanged, the extent of this problem cannot be studied empirically in the same way as solar PV.

However, the problem can be resolved to a certain extent by incorporating the following systematic measures: setting an “appropriate” time limit for commencing operation, promoting cost reductions by setting long-term cost reduction targets which are lowered incrementally, or operating a corridor system. Although a time limit for commencing operation has already been introduced, each of the above measures can be applied to the current FiT system. Making improvements to address these systematic problems will help promote the permeation of cost-efficient renewable energy.

(2) Future generation costs need to be re-verified

This study indicated that the cost of solar PV generation can potentially be reduced significantly in the lead-up to 2030, to around the 5 yen/kWh level. This is meaningful as it indicates that solar PV would be the cheapest option among newly constructed power plants. However, the Generation Cost Verification Working Group (2015) estimates the 2030 generation cost of solar PV (mega solar) at 12.7-15.6 yen/kWh. The energy mix in the Japanese government's long-term energy supply/demand outlook was determined based on this type of estimate. During the study process for the Fifth Basic Energy Plan that was subsequently released in 2018, verification of generation cost was not performed, only a change in framework - in the form of verification of costs and risks related to overall energy systems - was implemented. Although the cost of the overall system is important, without verification of the generation cost of each individual electricity source it is impossible to perform a cost analysis of what constitutes an appropriate overall system. In any case, generation cost is an extremely important element of energy policy, and correct policy decisions cannot be made unless relevant generation cost data is up to date. In this regard, regular verification of generation costs is essential, and future energy mix should be reconsidered in light of the latest information in a flexible manner.

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