Next-Generation Energy

Roadmap for Commercialization of Perovskite Solar Cells

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Industry Research Department
Mizuho Bank

Summary

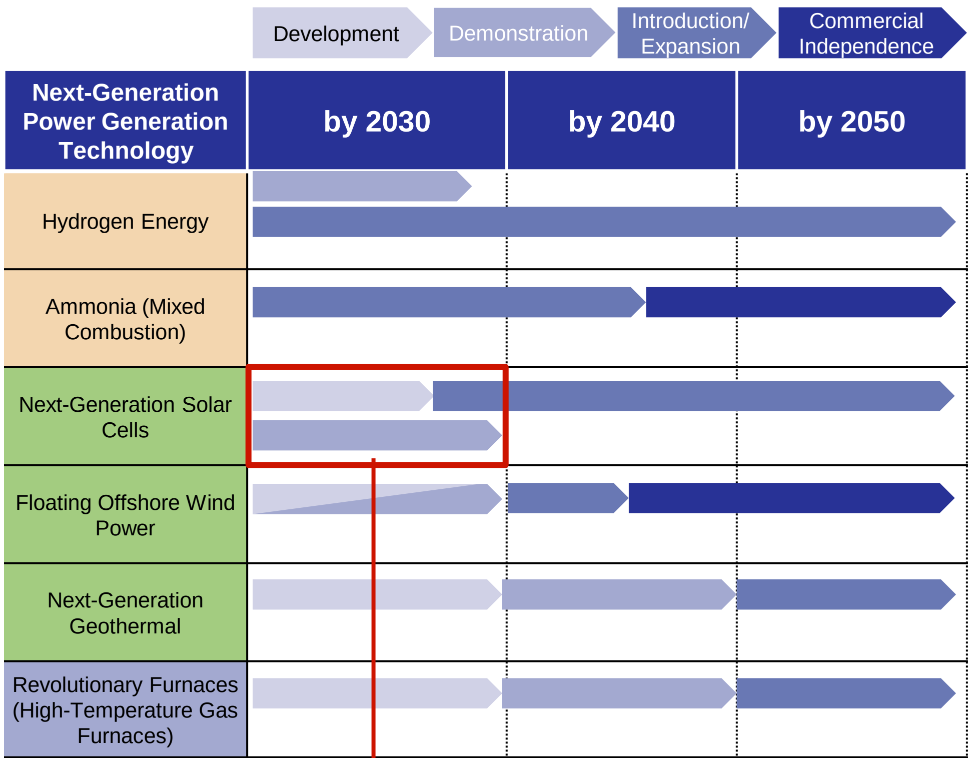
- Among next-generation power generation technologies, expectations are gathering around next-generation solar cells as a way of responding to increasing electricity demand and power source decarbonization. These cells are expected to transition to an introduction and expansion phase by 2030. Japan faces the challenge of limited suitable sites for solar power generation due to the small proportion of flat land area relative to its total territory. With the need for new approaches toward further introduction and expansion, perovskite solar cells, which have shown remarkable improvement in conversion efficiency in recent years, are attracting attention from two perspectives: "expansion of new installation locations" and "improvement in power generation per unit area."
- In terms of approaches aimed at increasing new installation locations, module development is progressing, including film-type modules that leverage lightweight and flexible properties, and glass building material-integrated type modules that utilize transparency. Integrated public-private efforts are advancing, led by SEKISUI CHEMICAL's mass production plan for film-type modules. On the other hand, tandem-type solar cells, which aim for significant improvement in conversion efficiency by stacking two types of solar cells (perovskite and silicon), are important as an approach focused on improving power generation per unit area, though commercialization efforts are still in progress.
- Film-type and glass-type modules aimed at new installation locations and tandem-type modules targeting improved power generation per unit area are all important from the perspective of increasing Japan's energy supply. For tandem-type modules, considerable scale is expected in both the domestic and international solar panel equipment markets, and, as with film-type modules, it is necessary to conduct technology development and industry development from a long-term perspective through public-private partnerships.
- The challenges for tandem-type commercialization can be broadly categorized into three points: 1. economic rationality, 2. dependence on China for the silicon supply chain, and 3. global competition. Conceivable measures to address these challenges include accelerating research and development with government support and supply chain reconstruction and large-scale production in collaboration with like-minded countries (countries that desire increased solar power generation and attract manufacturing investment)
- An important point for tandem-type (perovskite/silicon) solar cells is the need to integrate materials, structures, and manufacturing processes (fine tuning) to meet the quality requirements desired by the demand side. Therefore, demand for domestic rooftop and ground-mounted (mega-solar) installations should be secured by first establishing technology at an early stage in collaboration with material and manufacturing equipment manufacturers and commercializing ahead of competitors from other countries.
- For overseas expansion, larger-scale mass production investment and channels will be required, so expansion should be carried out utilizing collaboration with like-minded country partners while there is still an advantage in early commercialization. In the market maturity phase, Japan's winning strategy would be to aim for a virtuous cycle of using profits gained thus far to invest in the next technologies.

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

Next-Generation Solar Cell Installation Expected by 2040 to Achieve Carbon Neutrality

- To achieve carbon neutrality (CN) in the power sector, the development of next-generation power generation technologies is needed for thermal power decarbonization, renewable energy, and nuclear power. Among these technologies, next-generation solar cells are expected to transition from the development phase to the introduction phase by 2030.
- According to the energy supply and demand outlook for fiscal 2040 presented in the The 7th Strategic Energy Plan, electricity demand is expected to increase. In this context, further introduction and expansion of solar power generation is anticipated based on the policy of maximizing the use of decarbonized power sources.

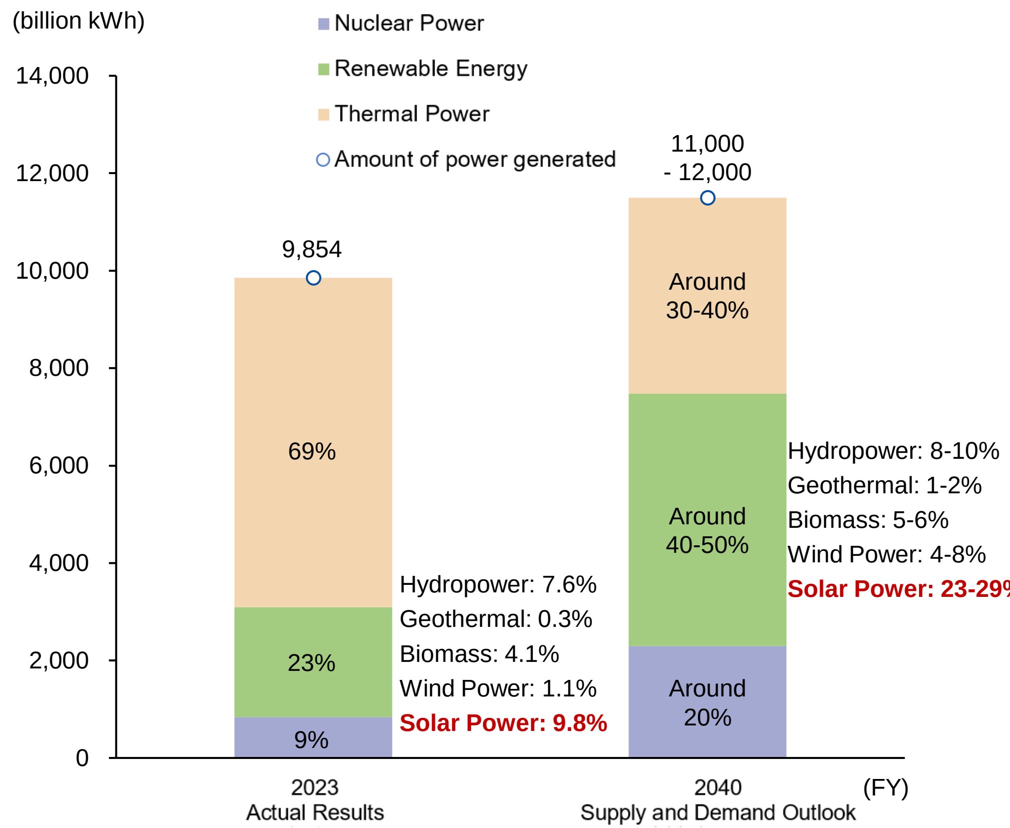
Next-Generation Power Generation Technology Development Roadmap



From development to introduction/expansion phase by 2030

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd based on Ministry of Economy, Trade and Industry "Green Growth Strategy for Carbon Neutrality by 2050"

Energy Supply and Demand Outlook for Fiscal 2040 (The 7th Strategic Energy Plan)

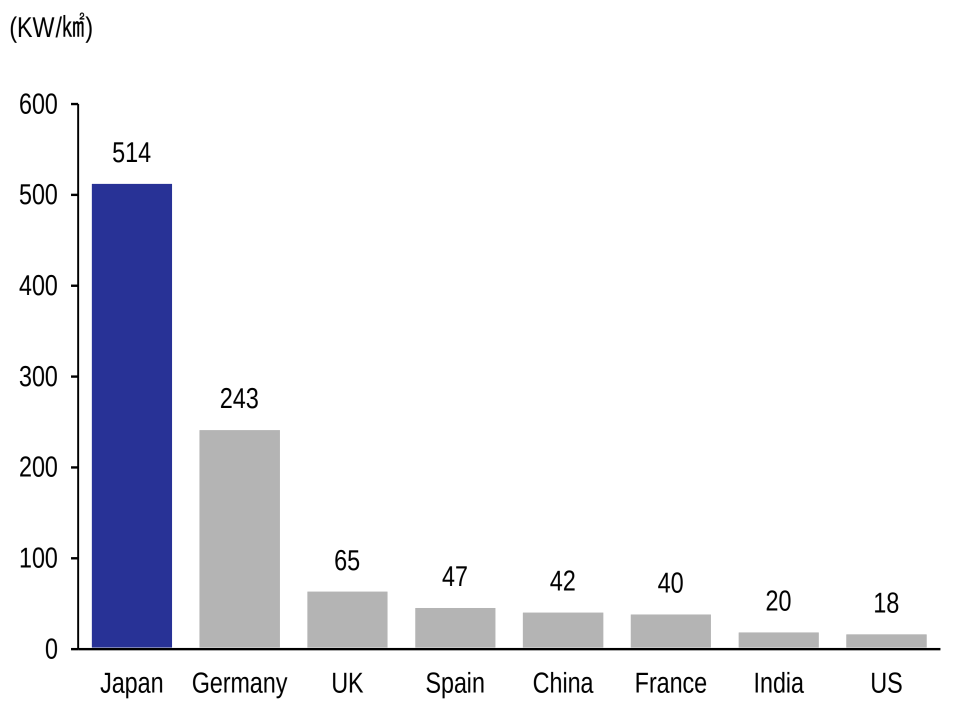


Source: Compiled by Industry Research Department, Mizuho Bank, Ltd based on Ministry of Economy, Trade and Industry "The 7th Strategic Energy Plan"

Solar Power Generation in Japan Faces the Challenge of Limited Suitable Sites, Requiring New Approaches for Further Installation

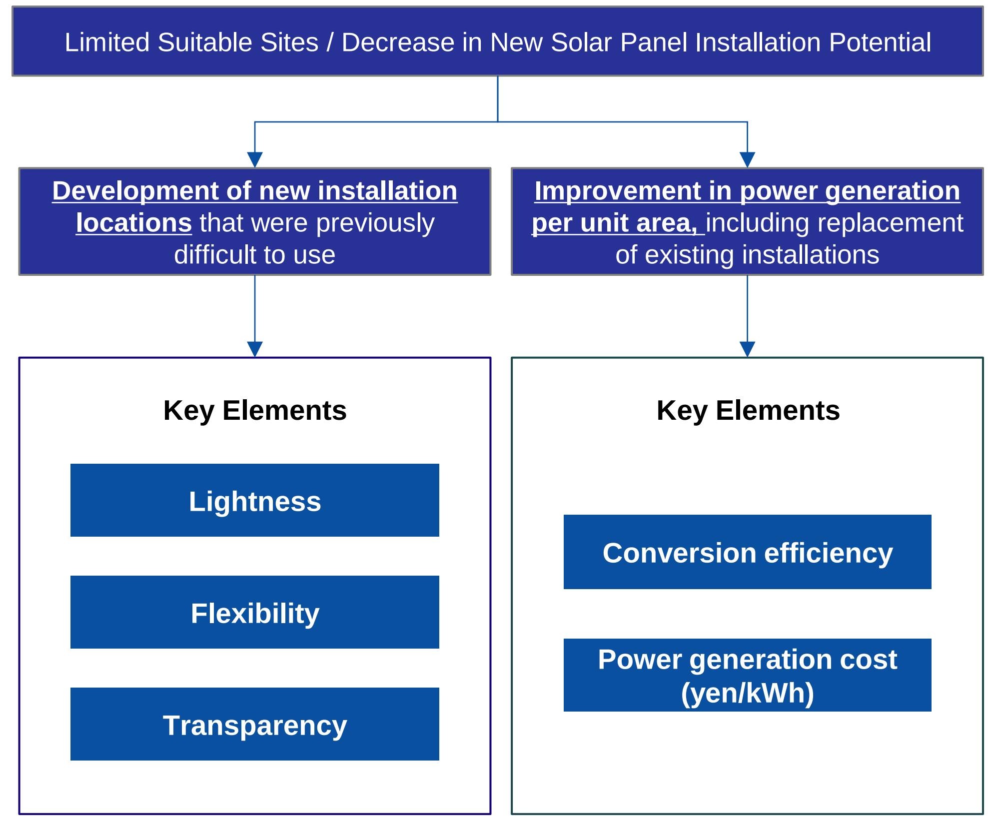
- In Japan, solar power facility capacity relative to the area of flat land has become the largest among major countries as a result of promoting the introduction of solar power generation in a country with a small proportion of flat land area relative to the total territory. The limited number of suitable sites for solar power has become a major challenge for further installation.
- Under these circumstances, two approaches can be considered to further increase solar power generation through technology development: (1) "development of new installation locations" that were previously difficult to introduce, and (2) "improvement in power generation per unit area" through enhanced conversion efficiency.

Solar Power Facility Capacity Relative to Flat Land Area by Country



Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on Ministry of Economy, Trade and Industry “Future Renewable Energy Policy (May 29, 2024)"

Approaches to Increase Solar Power Generation

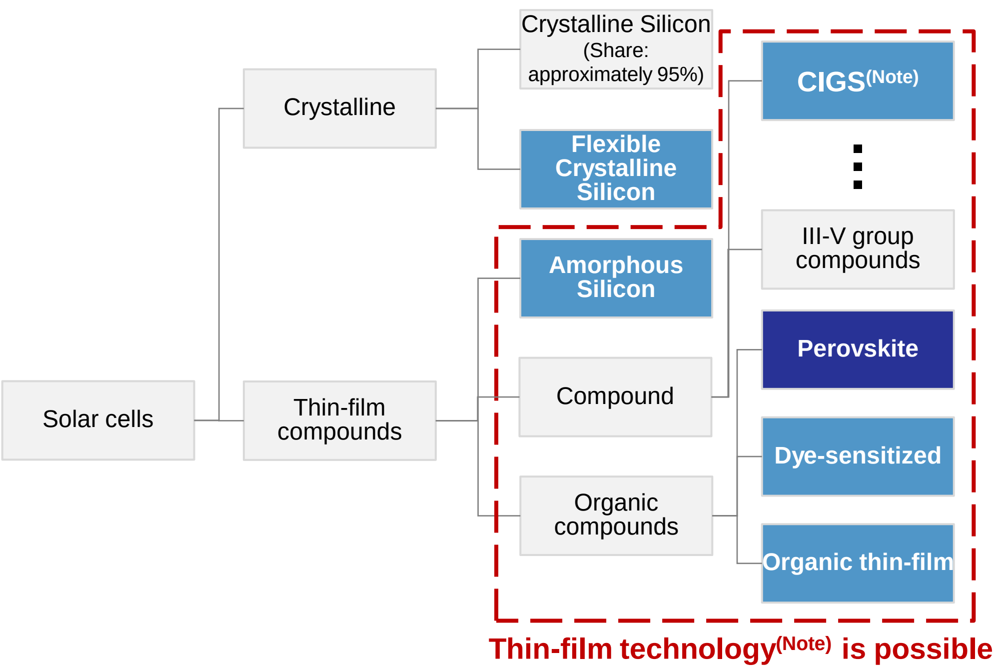


Note: "New installation locations that were previously difficult to use" refers to low load-bearing roofs, wall surfaces, window glass (building-integrated type), etc.
Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

Perovskite is Attracting Attention Due to its High Potential for Remarkable Improvement in Conversion Efficiency and Use in the Development of Tandem-type Solar Cells

- "Lightness" and "flexibility" are among the important elements in approaches aimed at the "development of new installation locations" that were previously difficult to use. Research on solar cells that combine these characteristics has existed before now.
- Among these, perovskite solar cells have shown remarkable improvement in conversion efficiency in recent years, and competition in development and commercialization is accelerating globally, including for tandem-type solar cells (described later).

Solar Cell Candidates When Emphasizing Lightness and Flexibility

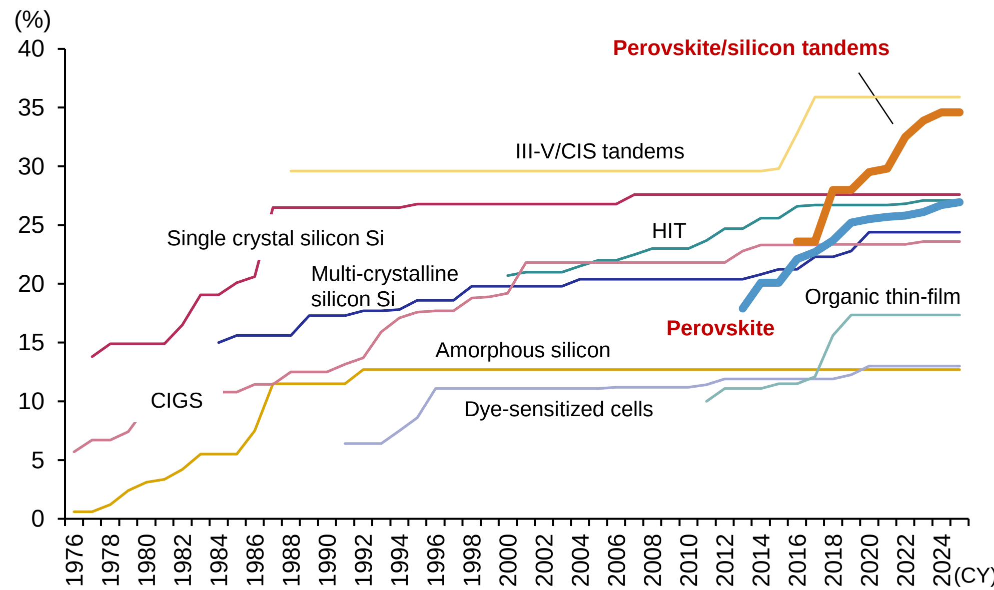


- Although lightweight and flexible solar cells have existed before now, issues such as limited improvement in conversion efficiency through R&D and lower durability compared to crystalline systems have prevented full-scale adoption.

Note: CIGS... An acronym for Cu (copper), In (indium), Ga (gallium), and Se (selenium), referring to solar cells that make use of compounds that mix these four elements.
Thin-film technology... Solar cells formed by creating thin films of compound materials on substrates. Depending on the substrate used, they can have lightweight and flexible properties.

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on published information.

Trends in highest conversion efficiency of solar cells at research level



- Perovskite solar cells (film type) have shown **remarkable improvement in conversion efficiency in recent years, and competition in global development and commercialization competition is accelerating, including for tandem-type solar cells (described later)**
- However, it should be noted that film-type perovskite solar cells still face the challenge of improved durability and are expected to compete with flexible crystalline silicon.

Note: In the reference data, the values that achieved the highest conversion efficiency in each year (CY) were used (regardless of the area at which the conversion efficiency was achieved). For 2025, data is as of March 26. For years without data, the most recent highest conversion efficiency was carried forward. It should be noted that these are research-level conversion efficiencies and do not necessarily represent values achieved at practical levels (≒ values that take into account large area size and years of durability).

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on NREL, *Best Research-Cell Efficiency Chart*

Promotion of Commercialization of Film-type Perovskite Solar Cells, Expected to Increase New Installation Locations, Through Public-private Partnerships

- There are two types of perovskite solar cells (single junction), depending on the substrate: film type and glass type. The film type is expected to be introduced in locations where silicon solar cell installation has been difficult, leveraging its lightweight and flexible characteristics.
  - SEKISUI CHEMICAL leads public-private partnerships to promote the commercialization and supply chain development of the film type.

Approaches to increase power generation in perovskite solar cells

Limited Suitable Sites / Decrease in New Solar Panel Installation Potential

Development of new installation locations that were previously difficult to use

Improvement in power generation per unit area, including replacement of existing installations

Single junction

Film type	Glass type

(From SEKISUI CHEMICAL)

(From Toshiba Energy Systems & Solutions Corporation)

- Uses PET films as substrates to achieve **lightweight and flexible** modules
- Can be installed on low load-bearing roofs and walls where silicon solar cells were difficult to install
- Scaling up and improving durability are challenges

(Both from Panasonic Holdings)

- Uses glass substrates to achieve modules with a certain transparency
- Can be installed as building materials on windows of high-rise buildings and residences
- Easier to ensure durability compared to films

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on published materials from SEKISUI CHEMICAL, Toshiba Energy Systems & Solutions Corporation , and Panasonic Holdings.

SEKISUI CHEMICAL's mass production plan for film-type perovskite solar cells

〈Overview of capital investment for 1st production line〉

- Investment purpose: Construction of film-type perovskite solar cell production line
- Total investment: 90 billion yen (building purchase cost, 100 MW manufacturing equipment cost)
- Investment period: January 2025 - March 2027 (scheduled operation: April 2027-)
- Production capacity: 100 MW

〈Details of GX supply chain development support project adoption〉

- Product: Film-type perovskite solar cells
- Subsidy targets: Building acquisition costs, equipment costs, system purchase costs
- Subsidy rate: 1/2
- Eligible subsidy amount: 314.5 billion yen
- Total subsidy amount: 157.25 billion yen
- Subsidy period: November 2024 - end of February 2029
- Production capacity: 1 GW class

〈Schedule for commercialization〉

(FY)

	2024	2025	2026	2027	2028	2029	2030 onwards
1st production line 100 MW		Construction start	Equipment purchase & trial production	Production	Production	Production	Production
2nd production line 100 MW	Review and decision based on demand trends		Construction start	Equipment purchase & trial production	Production	Production	Production
3rd production line 600-800 MW		Review and decision based on 1st production line performance	Review and decision based on 1st production line performance	Construction start	Equipment purchase & trial production	Equipment purchase & trial production	Production

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on published materials from SEKISUI CHEMICAL

Commercialization of Tandem-type Solar Cells Expected to Improve Power Generation per Unit Area is Yet to Come

- Tandem solar cells, which are made by stacking two different solar cells and improve conversion efficiency by absorbing the wavelengths that are each cell's specialty, are one of the important approaches for increasing solar power generation as they enable improvement in power generation per unit area.
- Among these, perovskite/silicon tandem-type solar cells are expected to be utilized in ground-mounted (mega solar) applications with large total power generation, including to replace existing installations, but they are still in the R&D stage and commercialization efforts are underway.

Approaches to increase power generation in perovskite solar cells

Limited Suitable Sites / Decrease in New Solar Panel Installation Potential

↓

Development of new installation locations that were previously impossible

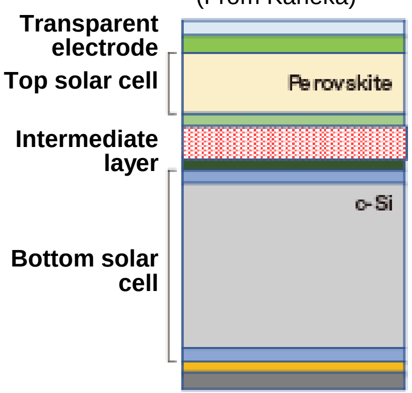
Improvement in power generation per unit area, including replacement of existing installations

↓

Tandem type
(Stacking two different solar cells to achieve high efficiency)

〈Example: Perovskite/heterojunction crystalline silicon solar cells in tandem configuration〉

(From Kaneka)



- Apply a perovskite power generation layer on top of silicon solar cells to improve conversion efficiency by leveraging differences in absorption wavelengths
- Can increase power generation per unit area by replacing existing silicon solar cell installations
- Currently in R&D stage, aiming to improve conversion efficiency

Note: The tandem type connects two different types of solar cells in series, and combinations with solar cells other than silicon solar cells also exist.
Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on Kaneka website

Main types of tandem-type solar cells and companies engaged in research and development

〈Main types of tandem-type solar cells〉

	Features and Challenges	Expected Applications
Perovskite/ Silicon or CIS	■ Pursuing high efficiency ■ Lower durability than silicon	■ Ground-mounted (mega solar) ■ Rooftops
III-V compounds/ Silicon or CIS	■ Pursuing ultra-high efficiency ■ High durability ■ High cost	■ Automotive ■ Special applications (harsh environments like satellites)
Perovskite/ Perovskite	■ Higher efficiency than perovskite alone ■ Lightweight and flexible ■ Low durability	■ Low load-bearing roofs ■ Wall surfaces

〈Companies engaged in tandem R&D〉

	Tandem-type Solar Cells Under Development
Kaneka	■ Perovskite/heterojunction crystalline silicon solar cells
Enecoat Technologies/Toyota Motor Corporation (joint development)	■ Perovskite/crystalline silicon solar cells (4-terminal type)
Toshiba Energy Systems & Solutions Corporation	■ Perovskite/crystalline silicon solar cells ■ Transparent cuprous oxide/silicon solar cells
PXP	■ Perovskite/chalcopyrite solar cells
Panasonic Holdings	■ Perovskite/perovskite solar cells

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on published materials

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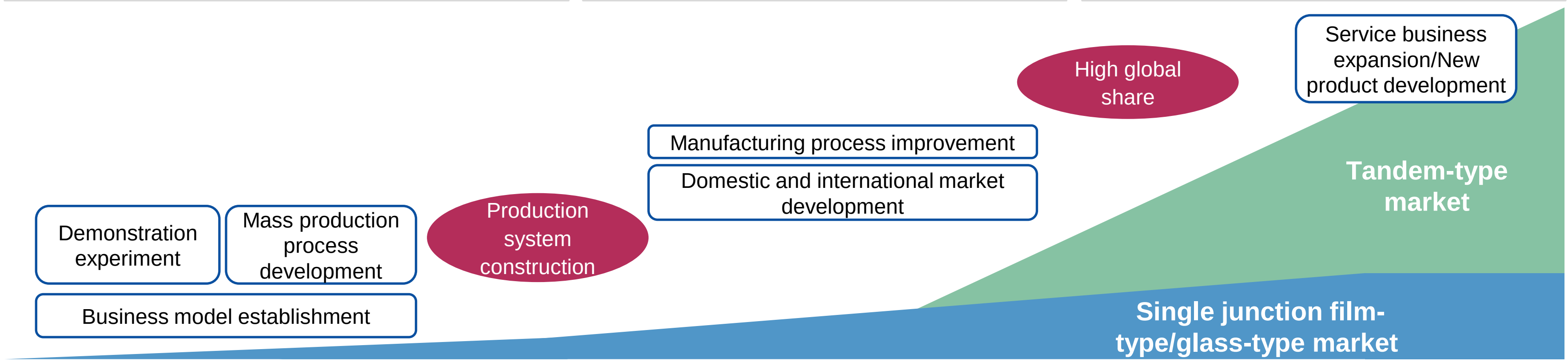
Perovskite Solar Cells Require Technology Development and Industry Development From a Long-term Perspective Through Public-private Partnerships

- Film and glass types, which target new installation locations, and tandem types, which aim to improve power generation per unit area, are all important from the perspective of increasing energy supply.
- For tandem types, a considerable scale is expected in the solar panel equipment market, and, as with film types, it is necessary to conduct technology development and industry development from a long-term perspective through public-private partnerships.

Approaches for perovskite solar cells

		2024-2030	2031-2035	2036-2040
Environmental recognition	Film type Glass type	**Introduction phase** ■ Accumulation of track record through demonstrations ■ Establishment of mass production process and cost reduction ■ Policy support for business launch	**Growth phase** ■ Production operation improvement ■ Global expansion	**Maturity phase** ■ Oligopoly market formation ■ Business model transformation ■ Replacement by new technology
	Tandem type	**Technology development phase** ■ Basic research using silicon solar cells as a benchmark ■ Policy support for R&D	**Introduction phase** ■ Establishment of mass production process and cost reduction ■ Policy support for business launch	**Growth phase** ■ If advantages over silicon solar cells are realized, utilization in ground-mounted (mega solar) installations
Direction of manufacturer's approach		■ Launch new markets for film/glass types through collaboration with customers, aiming to build mass production systems	■ Improve cost competitiveness through mass production process improvements, expand production scale according to domestic and international demand, secure high global share	■ Advance investment recovery by securing certain scale production and stable demand, while expanding service business after sales and installation for further share improvement

Market size image and manufacturer initiatives



Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

Estimation of Japan's Solar Power Generation Equipment Capacity in 2040 (Assumptions)

- Solar power generation equipment capacity as of 2040 is estimated for three scenarios: (1) without utilizing perovskite, (2) utilizing single-junction perovskite (film type and glass type), and (3) early commercialization of tandem type with a certain amount of introduction.

Assumptions for estimation

	Item	Value	Approach
Stock	Capacity of existing installations	73.8 GW	Capacity of solar power generation equipment in operation as of end of FY2023.
Flow	Annual new installation volume	3.1 GW/year	Annual installation volume in FY2023 (residential 1.0 GW + commercial 2.1 GW). Assumes continuation with policy support.
	Replacement capacity	—	Assumes that FIT system installations from July 2012 to FY2020 will be replaced 20 years after installation. For convenience, installations before June 2012 are assumed to be replaced in 2032.
Others	Conversion efficiency	—	➢ Silicon: Module conversion efficiency assumed to be 16.0% in 2012 and 20.0% in 2020. Assumes subsequent gradual improvement with theoretical upper limit of 29.0%. ➢ Tandem type: Based on Oxford PV's published commercial efficiency of 28.6%, assumes commercialization in 2030 with subsequent gradual improvement.

(Scenario (1): No perovskite utilization scenario)

Annual new installation volume	Based on 3.1 GW/year installation, all silicon solar cells are installed. For conversion efficiency improvement, the silicon module conversion efficiency as of 2024 is used as a baseline, and the difference between this and the conversion efficiency of the installation year is reflected in the equipment capacity.
Replacement capacity	Based on the above replacement capacity, everything is replaced with silicon solar cells. For conversion efficiency improvement, the difference between the conversion efficiency of the installation year and the initial installation date is reflected in the equipment capacity.

(Scenario (2): Film type/glass type utilization scenario)

Annual new installation volume	Same as Scenario (1).
Replacement capacity	Same as Scenario (1).
Film-type perovskite new installation volume	Based on the Agency for Natural Resources and Energy's "Next-generation Solar Cell Strategy," assumes 20 GW installation by 2040.

(Scenario (3): Tandem type utilization scenario)

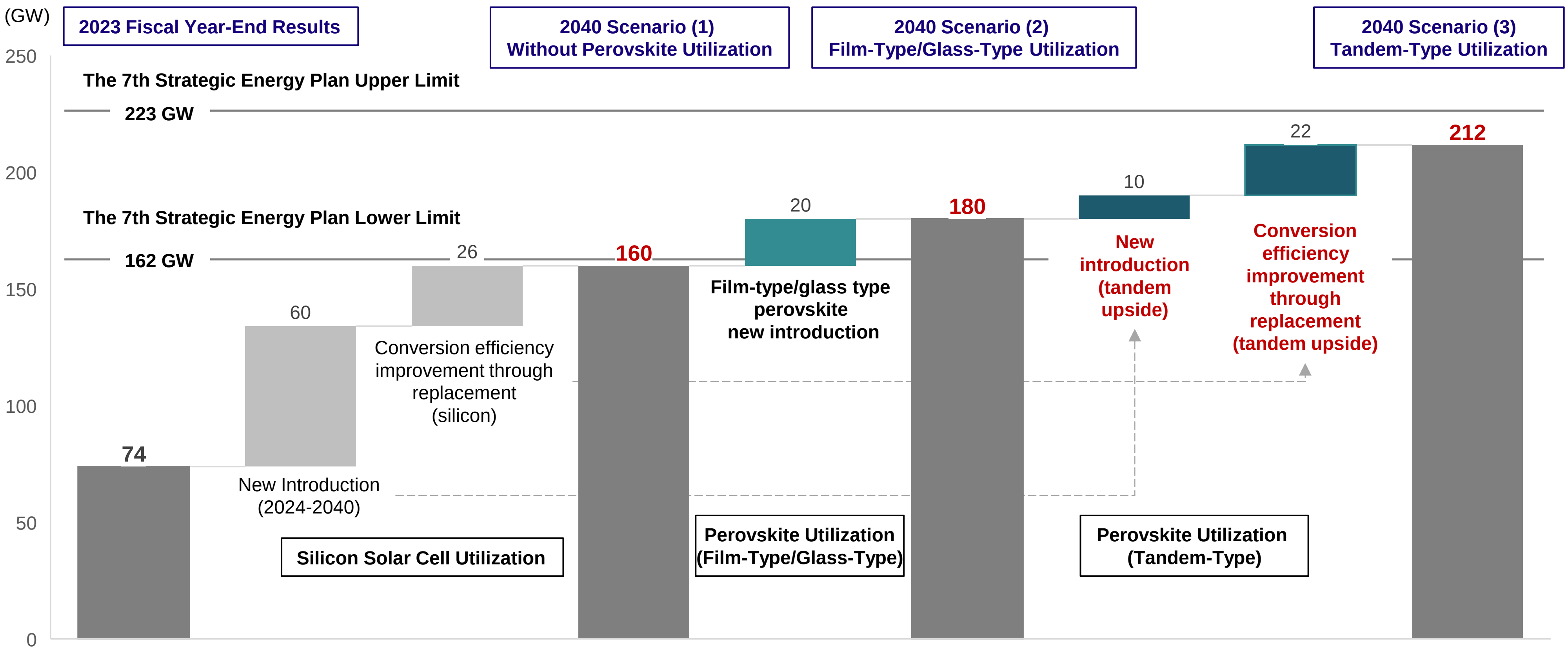
Annual new installation volume	Based on 3.1 GW/year installation, silicon solar cells are installed until FY2029, and all tandem types are installed from FY2030 onwards. For conversion efficiency improvement, the silicon module conversion efficiency as of 2024 is used as a baseline, and the difference between this and the conversion efficiency of the installation year is reflected in the equipment capacity.
Replacement capacity	Based on the above replacement capacity, everything is replaced with tandem types. For conversion efficiency improvement, the difference between the conversion efficiency of the installation year and the initial installation date is reflected in the equipment capacity.
Film-type perovskite new installation volume	Same as Scenario (2).

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

Estimation of Japan's Solar Power Generation Equipment Capacity in 2040 - Early Commercialization of Tandem-Type Solar Cells is Key

- If new installations continue at the current pace, even using only silicon solar cells, cumulative installed capacity will reach 160 GW by 2040 through an additional 86 GW installation from 2024 to 2040.
- If perovskite solar cells are used, the cumulative installed capacity could expand to as much as 212 GW through an additional maximum 52 GW installation.
  - In addition to achieving the next-generation solar cell strategy's 20 GW installation target, early commercialization of tandem-type solar cells is key.

Domestic Solar Power Generation Capacity Calculation (Cumulative Installation from 2024-2040)



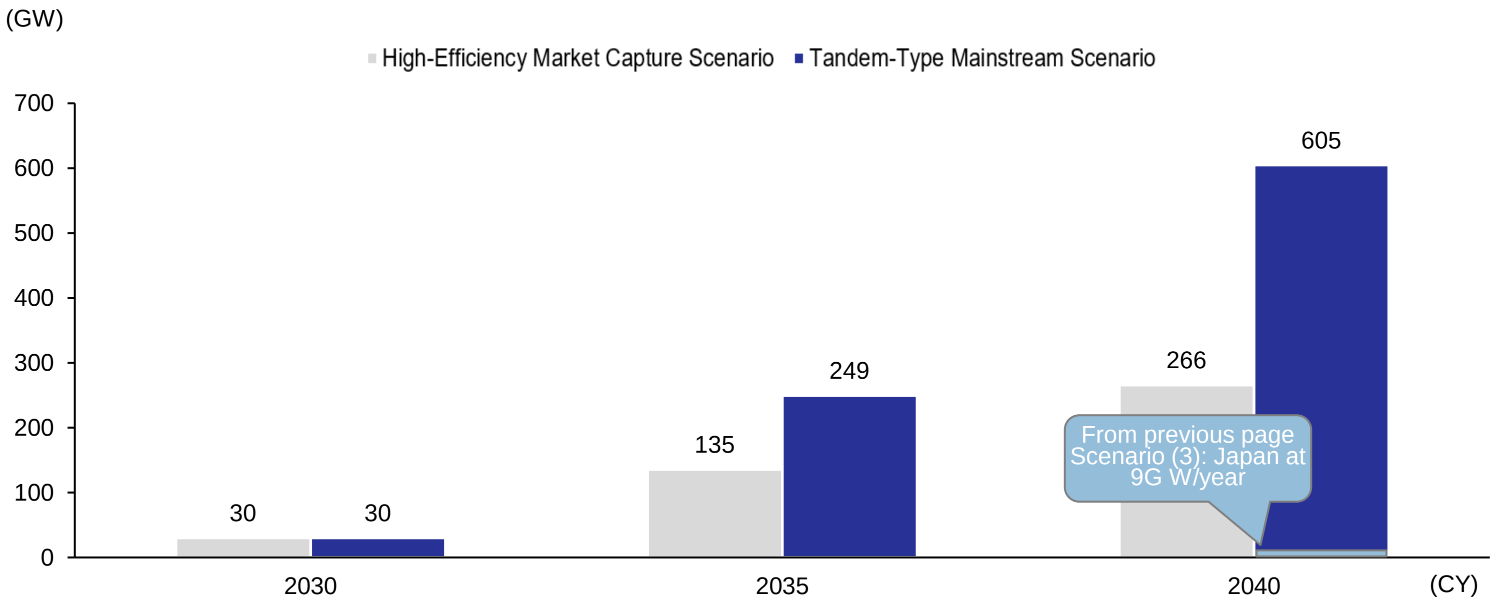
Note: The required equipment capacity for 2040 is calculated based on the power generation amount from solar power in The 7th Strategic Energy Plan and equipment utilization rate (17.8%). The equipment utilization rate is a weighted average of residential and commercial solar power utilization rates based on their respective cumulative installed capacity ratios as of the end of FY2023, sourced from the Ministry of Economy, Trade and Industry's Power Generation Cost Verification Working Group.

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on Ministry of Economy, Trade and Industry materials and published materials.

Global Tandem Solar Cell Market Size Forecast – Maximum Market of Over 600 GW by 2040

- Following the same approach as Scenario (3) on the previous page, we estimate the global tandem-type market size in the "Tandem-Type Mainstream Scenario," where tandem-type solar cells account for the majority of the solar cell market. The market size is expected to reach over 600 GW annually by 2040.
  - Of this, Japan's installation volume in 2040 based on Scenario (3) from the previous page is 9 GW/year.
  - Assuming a solar panel price of 21 yen/W (using the cost of single crystal silicon as a reference), the market size in 2040 would be approximately 12 trillion yen in value terms.
  - A "High-Efficiency Market Capture Scenario" is also conceivable, where Tandem-Type solar cells are only installed in locations with high-efficiency needs such as limited installation area due to insufficient reduction in power generation costs. In this case, the market size is estimated to exceed 250 GW by 2040.

Global Tandem-type Solar Cell Market Size Forecast (Annual Basis, Equipment Capacity)



Tandem-Type Mainstream Scenario
- Scenario where tandem-type solar cells account for the majority of the solar cell market, including ground-mounted (mega solar) installations
- Estimated based on the trend of rapid share increase of single-layer silicon solar cells since 2013 (approximately 90% tandem-type ratio by 2040)

[Reference] High-Efficiency Market Capture Scenario
- Scenario where solar cells are only installed in locations with high-efficiency needs such as limited installation area
- Estimated based on the trend of share increase of high-efficiency silicon-based solar cells since 2022 (approximately 40% tandem-type ratio by 2040)

Note: Market size (GW) is estimated by "Solar installation volume × Tandem-type ratio." In the case of solar installation volume, new installations assume the annual installation volume from cumulative installation in IEA WEO 2024's Stated Policies Scenario; replacement assumes replacement occurs 25 years after initial installation based on new installation volume. It is assumed that tandem-type solar cells will be commercialized from the latter half of the 2020s and have a 5% share of all solar cells by 2030. The tandem-type ratio by 2040 is set at 90% for the Tandem-Type Mainstream Scenario and 40% for the High-Efficiency Market Capture Scenario.

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on *IEA, World Energy Outlook 2024*

Challenges and Solutions for Commercializing Tandem-Type (Perovskite/Silicon) Solar Cells

- The challenges for commercializing tandem-type (perovskite/silicon) solar cells can be broadly categorized into three main points: (1) economic rationality, (2) supply chain dependence on specific countries, and (3) global competition.
- Collaboration with like-minded countries (nations seeking to increase solar power generation and attract manufacturing investment) could be one solution to address these challenges.

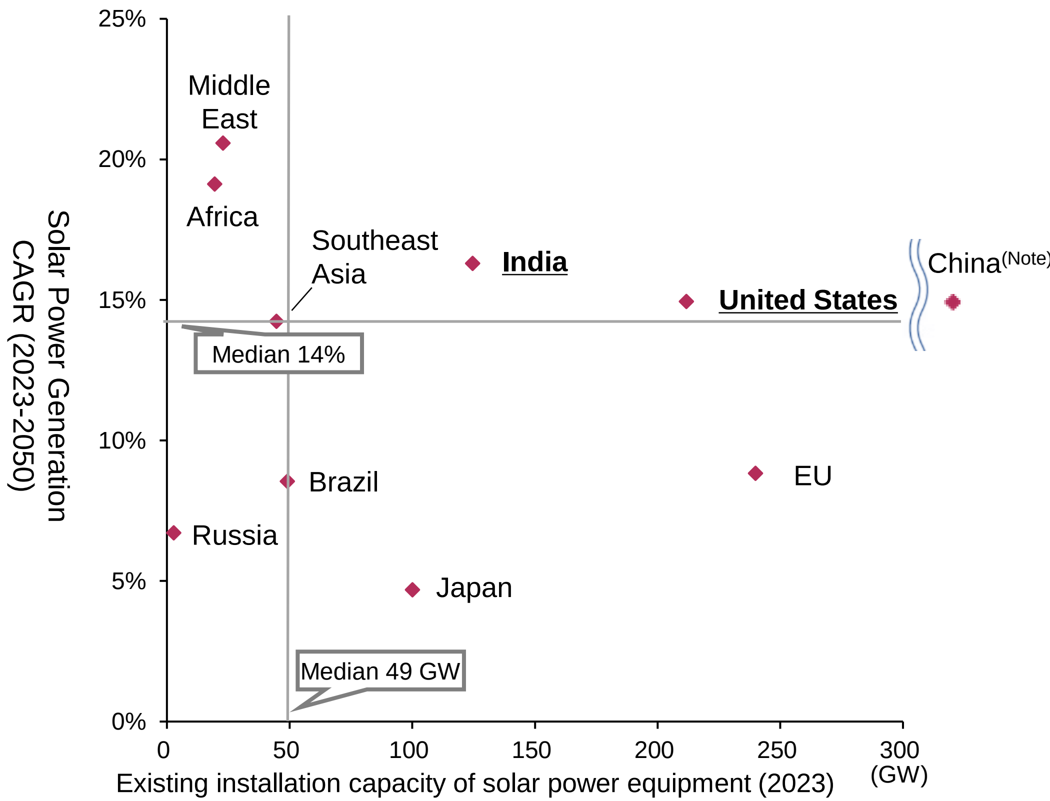
Challenges for Commercializing Perovskite/Silicon Tandem-type Solar Cells		Direction of Solution
1 Energy Supply Perspective "Economic Rationality"	■ Need to reduce power generation costs (Levelized Cost of Electricity, LCOE) through improved conversion efficiency, longer service life, and reduced manufacturing costs ■ **No matter how high the conversion efficiency of tandem-type solar cells, if power generation costs do not decrease to a certain level, they will lead to an increased burden on citizens**	**(Accelerating R&D and Government Support)** ■ Examine optimal approaches for top cells (perovskite) and bottom cells (silicon solar cells) that achieve both high conversion efficiency and durability, as well as their bonding methods ■ The government supports development toward social deployment and mass production of tandem-type solar cells
2 Stable Supply Perspective "Supply Chain Dependence on Specific Countries"	■ Silicon, which serves as the raw material for silicon solar cells used in bottom cells, **is highly dependent on China, necessitating diversification of procurement sources from a stable supply perspective** ■ In the past, Japanese companies have withdrawn from the market regarding silicon for solar cells, making it unrealistic to rebuild the entire supply chain domestically	**(Supply Chain Reconstruction through Collaboration with Like-minded Countries)** ■ There are still many challenges to face until tandem-type solar cells reach a level that can withstand practical use in ground-mounted installations, such as extending the service life of perovskite layers; more time is required. ■ In the meantime, **collaborate with like-minded countries (nations seeking to increase solar power generation and attract manufacturing investment, etc.) to diversify silicon solar cell procurement sources and rebuild supply chains**
3 Industrial Development Perspective "Need to Come Out on Top in Global Development Competition"	■ From the perspective of industrial development to maximize the utilization of perovskite solar cells (technology from Japan) and capture domestic and international markets, **it is necessary to come out on top in competition against global players, primarily China**	**(Cost Reduction through Large-scale Production in Collaboration with Like-minded Countries)** ■ From the perspective of pursuing competitive advantages based on power generation costs, reducing solar module unit prices through manufacturing cost reduction is essential ■ In silicon solar module manufacturing, the weight of labor and electricity costs has recently decreased due to factory automation and manufacturing process improvements. **If there are no significant differences in manufacturing technology, large-scale production in like-minded countries (same as above) could potentially compete with businesses from other countries**

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

When Considering Like-minded Countries, it is Necessary to Examine the Attractiveness of their Solar Power Generation Markets and the Feasibility of Tandem-type Manufacturing

- When considering partnerships with like-minded countries, the partner country's domestic market must first have high attractiveness as a solar power generation market.
  - — Considering only the size of potential replacement capacity (existing installation capacity of solar power equipment) and future growth potential, the United States and India could be candidates.
- Other factors to consider include the partner country's/home country's intentions and the feasibility of tandem-type manufacturing

Solar Power Generation Market Attractiveness Analysis



Note: China (existing installation capacity: 584 GW, CAGR: 15%) is outside the framework. The solar power generation CAGR adopts the Stated Policy Scenario.
Source: Compiled by Industry Research Department, Mizuho Bank, Ltd. based on IEA, *World Energy Outlook 2024*

Other Factors to Consider

1 **Partner Country's Intentions**	■ From the perspectives of energy policy and economic security, do they have interest in or awareness of issues regarding solar power generation equipment supply chain diversification? ■ From the perspective of industrial policy, do they have any intention of producing solar power generation equipment domestically?
2 **Home Country (Japan's) Intentions**	■ Is it possible to build close relationships at government and private sector levels with partner countries that would become partners in collaborative tandem-type solar cell production?
3 **Tandem-Type Manufacturing Feasibility**	■ Solar panels are an equipment industry; can they be manufactured at competitive prices for panel unit costs (yen/W), a major component of power generation costs? ➢ (Material costs) Availability regarding procurement and manufacturing of silicon and other materials that form the base of tandem-type solar cells ➢ (Labor costs) Level of labor costs compared to other countries, etc. ➢ (Expenses) Level of electricity rates compared to other countries, etc.

Source: Compiled by Industry Research Department, Mizuho Bank, Ltd.

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Commercializing Tandem-type Solar Cells Through Early Commercialization With Technology Utilization and Collaboration With Like-minded Country Partners

- For tandem-type (perovskite/silicon) solar cells, the critical point is the need to integrate materials, structures, and manufacturing processes (fine-tuning) to meet the quality requirements desired by the demand side.
- Therefore, demand for domestic rooftop and ground-mounted (mega-solar) installations can be secured by first establishing technology at an early stage in collaboration with materials and manufacturing equipment manufacturers and achieving commercialization ahead of competitors from other countries.
- For overseas expansion, larger-scale mass production investment and channels are required, so expansion should be carried out utilizing collaboration with like-minded country partners while there is still an advantage in early commercialization.
- In the market maturity phase, the goal is to create a virtuous cycle of investing in the next generation of technology using profits obtained thus far.

[Technology Development Phase - Introduction Phase] Technology Establishment and Domestic Market Creation

Research and Development Phase

Technology Establishment

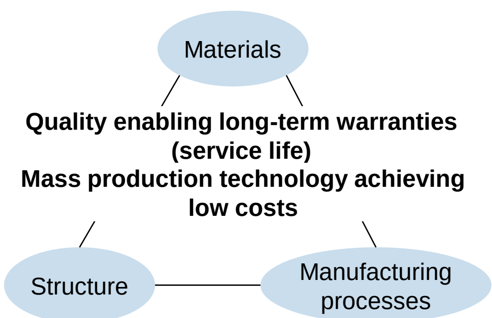
- Solar cell manufacturers, materials, and manufacturing equipment manufacturers work together to establish mass production technology that achieves quality enabling long-term warranties and low costs
- Early commercialization ahead of competitors from other countries

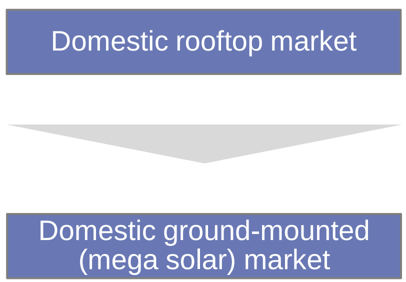
Introduction Phase

Domestic Market Creation

- Market introduction starting with residential use (rooftops) where high-efficiency needs exist
- Build track record and expand to ground-mounted (mega solar) applications with large demand

Technology Required for Perovskite/Silicon Tandems





[Growth Phase - Maturity Phase] Overseas Market Expansion and Investment in Next-Generation Technology

Growth Phase

Overseas (Like-minded Countries) Market Expansion

- Expand into like-minded country markets with large demand through collaboration with local partner companies

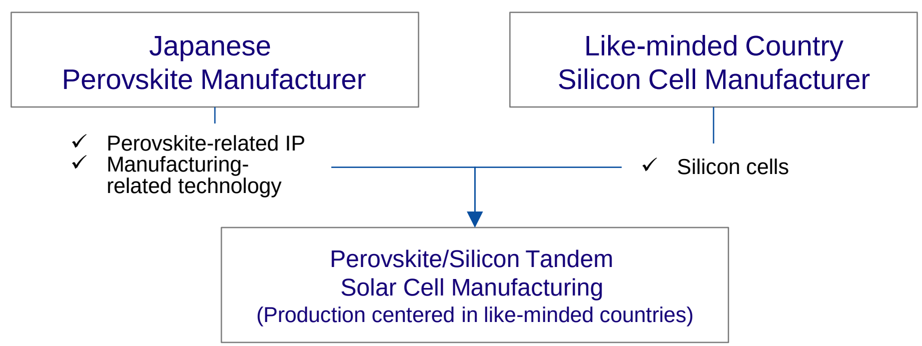
Maturity Phase

Investment in Next-Generation Technology

- Use profits obtained thus far to invest in the next generation of solar cell technology

Example of Collaboration Framework with Like-minded Countries for Overseas Market Expansion

Structure to be considered according to risk level



Source: Both charts were compiled by Industry Research Department, Mizuho Bank, Ltd.

Industry Research Department	Telecom, Media and Technology Team	Tomoki Fujimoto	tomoki.fujimoto@mizuho-bk.co.jp
	Next-Generation Business Support Office Strategic Project Team	Shugo Arai	shugo.arai@mizuho-bk.co.jp

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