Barrier Film for Perovskite Solar Cells: Leading Technology from Japan

Achieving high durability through advanced film-forming technology

November 25th, 2025

Giving Shape to Ideas

Speakers

- **Naoya Kato**
  Representative Director and President,
  Operating Officer and Chief Executive Officer
  EneCoat Technologies Co., Ltd.

- **Yusuke Nakajima**
  Development Department
  Device Technology Development Center
  Technology Development Headquarters
  Konica Minolta Inc.

- **Keiichi Kishi**
  Corporate Vice President, General Manager, Corporate Technology Development Headquarters
  Konica Minolta, Inc.

Giving Shape to Ideas

First, Mr. Kato will discuss the significance of perovskite solar cells, including EneCoat Technologies' business strategy and the need for barrier films. Next, Mr. Nakajima will explain the barrier films provided by our company. Finally, Mr. Kishi will present our vision for the practical implementation of barrier films.

Biography

- **Naoya Kato**
  Representative Director and President,
  Operating Officer and Chief Executive Officer
  EneCoat Technologies Co., Ltd.

  Engaged in a number of investment projects in real estate and business restructuring at a foreign investment bank.
  As a founding member of an independent PE fund, he experienced buyout investment.
  In November 2016, he joined Kyoto University's Incubation Program as the promotion manager.
  In January 2018, he co-founded EneCoat Technologies and assumed the representative director.

- **Tamotsu Horiuchi**
  Director/Operating Officer and Chief Technology Officer
  EneCoat Technologies Co.,Ltd.

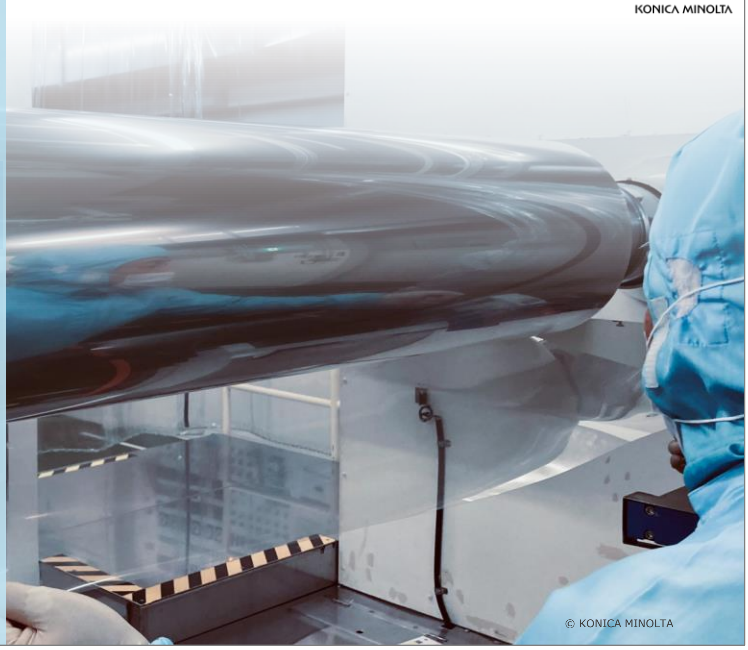
  Engaged in material development at a paper manufacturer and material and device development at an electrical equipment manufacturer. Specializes in organic synthetic chemistry and organic device development. He has published 8 peer-reviewed papers, one of which has been cited more than 1,300 times. He has obtained more than 120 patents in Japan and abroad.
  In March 2022, he assumed the director of EneCoat Technologies.

Significance of perovskite solar cells

Why Konica Minolta can make this possible

Path to practical application of barrier film

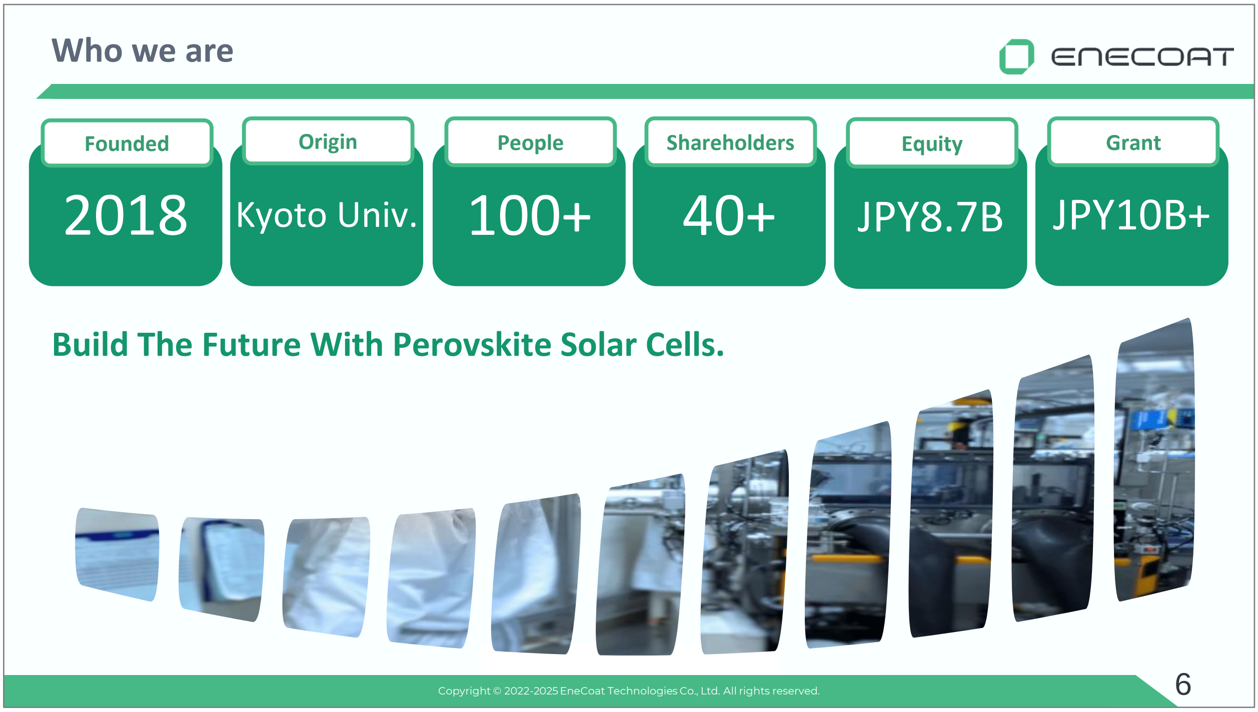
Naoya Kato
Representative Director and President,
Operating Officer and Chief Executive Officer
EneCoat Technologies Co., Ltd.



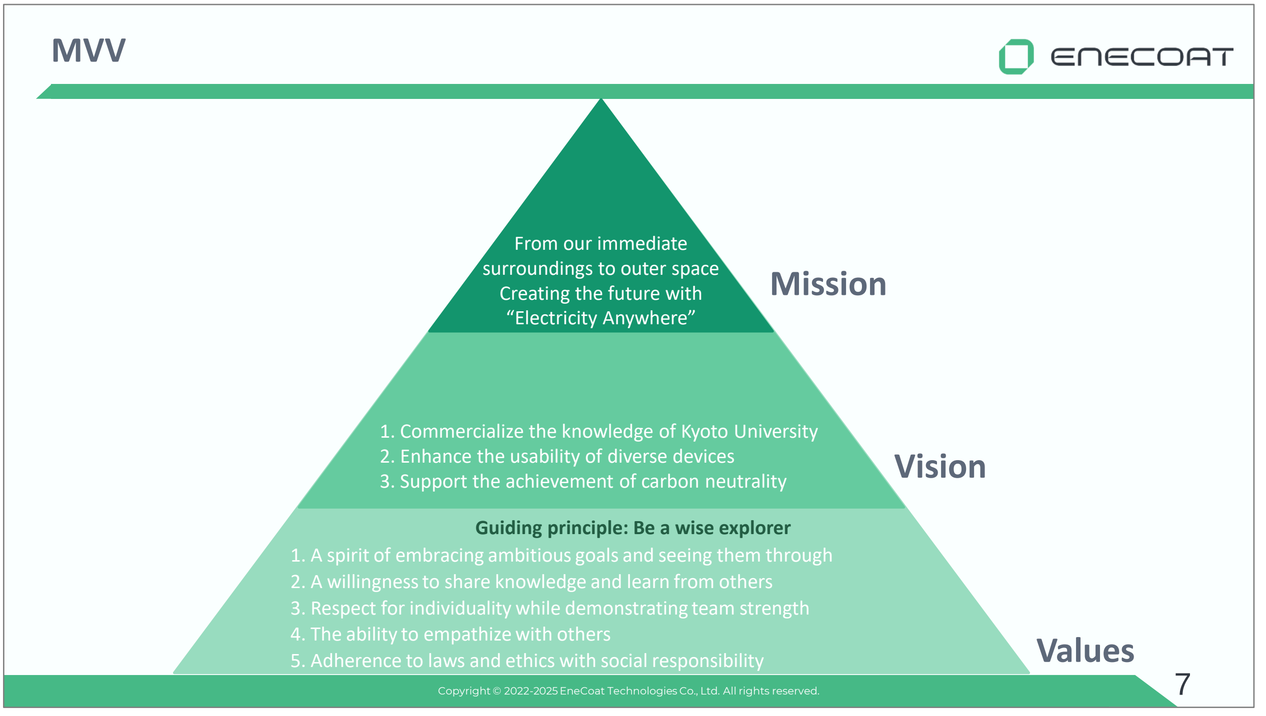
Our Business Strategies and Need for Barrier Film

Naoya Kato
Representative Director, EneCoat Technologies Co., Ltd.
November 25th, 2025

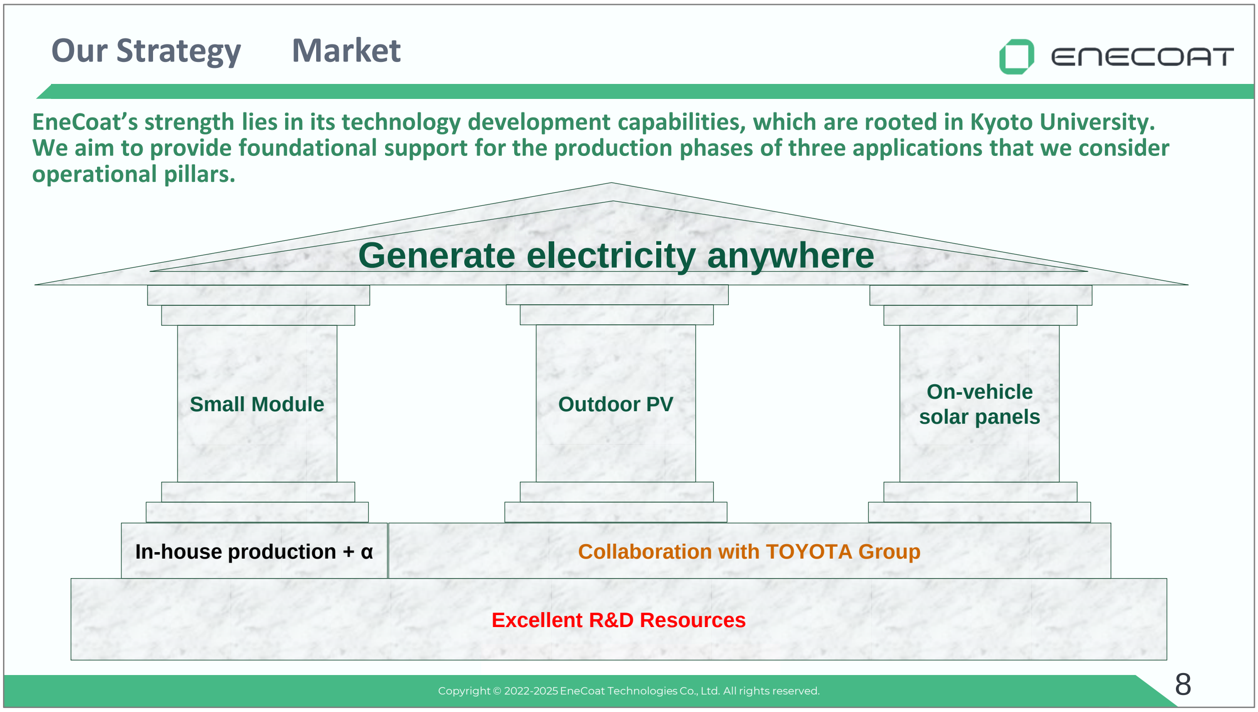
I am Kato, the Representative Director of EneCoat Technologies. Thank you for joining us.



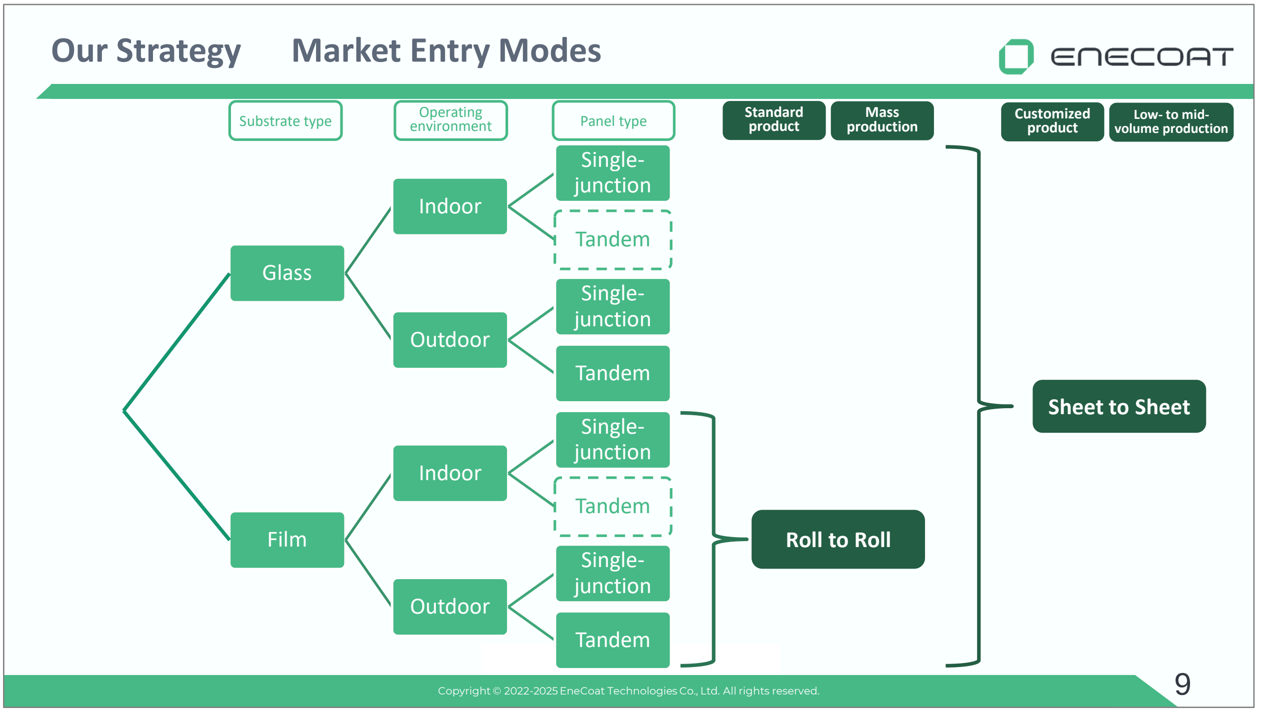
Let me begin with an overview of our company. EneCoat Technologies is a startup founded in 2018, originating from Kyoto University. Our team now exceeds 100 members, and to date, we have secured nearly 20 billion yen in funding through a combination of equity and grants.



Here are our Mission, Vision, and Values. Our company is dedicated to a single objective: achieving the social implementation of perovskite solar cells. As stated in our mission, we aim to help create the future by realizing perovskite solar cells as "Electricity Anywhere," enabling their use across a broad range of environments—from our immediate surroundings to outer space.



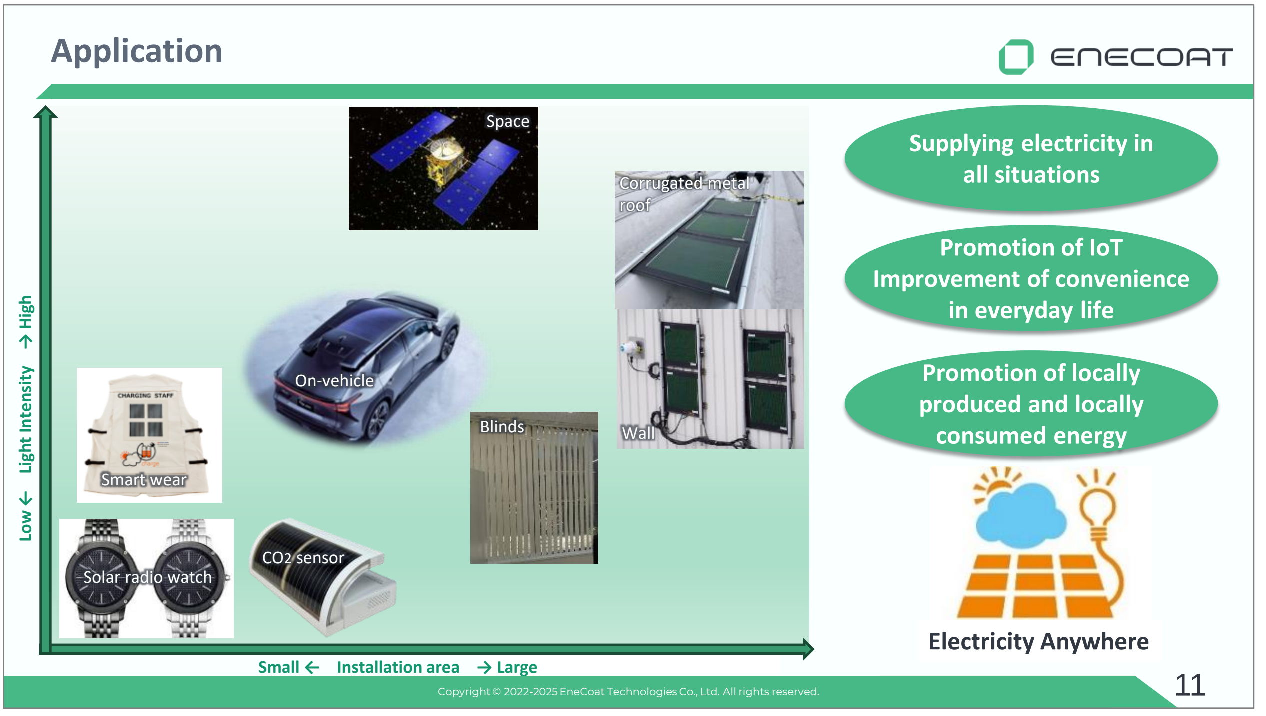
Here is an overview of our strategy and the markets we intend to enter. Since our founding, we have been engaged in research, development, and manufacturing; ultimately, our core strength lies in the university-originated technologies that underpin our development capabilities. We will continue to support the perovskite solar cell industry through technological innovation.
As for our target markets, from left to right, they include: compact modules for both indoor and outdoor use, large-scale outdoor stationary applications—which represent the largest market—and automotive applications. For the latter two segments, automotive and outdoor stationary, we plan to advance our efforts together with the Toyota Group, including ongoing collaboration with Toyota Motor Corporation.



Next, let me explain our approach to market entry. Perovskite solar cells can be categorized by substrate into glass-based and film-based types. They can also be classified by usage environment—indoor or outdoor—as well as by panel structure, such as single-junction or tandem. We believe that each combination of these factors represents a distinct market opportunity.

Our focus is on film-based products, particularly those suited for mass production using roll-to-roll processing, which is advantageous for standardized products and is especially appropriate for outdoor applications. We also utilize sheet-based production, which manufactures sheets individually and is well suited for customized products or small- to medium-volume production. By employing both production methods, we aim to effectively address the full range of market needs.

Here, I would like to briefly explain what perovskite solar cells are. They offer high power-generation performance and flexibility—particularly in the case of film-based products. They are also thin and lightweight, and importantly, they are highly versatile in terms of potential applications.

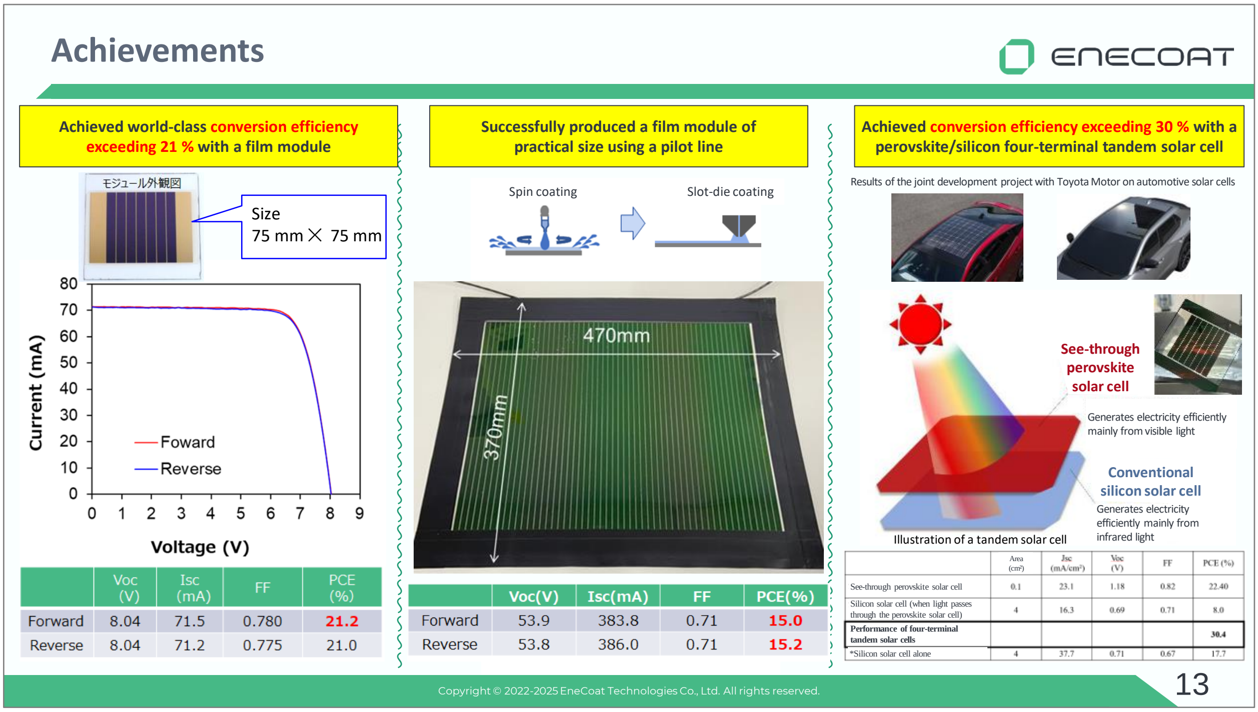


Here are the specific applications as we envision them. On the horizontal axis, we show installation area—or the size of the module itself. The vertical axis represents light intensity, reflecting the usage environment, with higher positions indicating stronger light. We believe the market can be segmented in this manner. As long as light is available, power can be supplied across a wide range of scenarios.
For small modules, perovskite solar cells can contribute to advancing IoT adoption and improving everyday convenience. For outdoor applications in particular, they can help promote local production and consumption of energy. We refer to this concept as "Electricity Anywhere," and we are working to realize it through our activities.

Comparison

	c-Silicon	Perovskite	a-Silicon
Efficiency @ Sun light	✓	✓	△
Efficiency @ Indoor light	×	✓	△
Weight	×	✓	✓
Thinness	△	✓	✓
Flexibility	×	✓	✓
Module cost	✓	△～✓	△
System cost	✓	✓	△
Durability	✓	△	△～✓

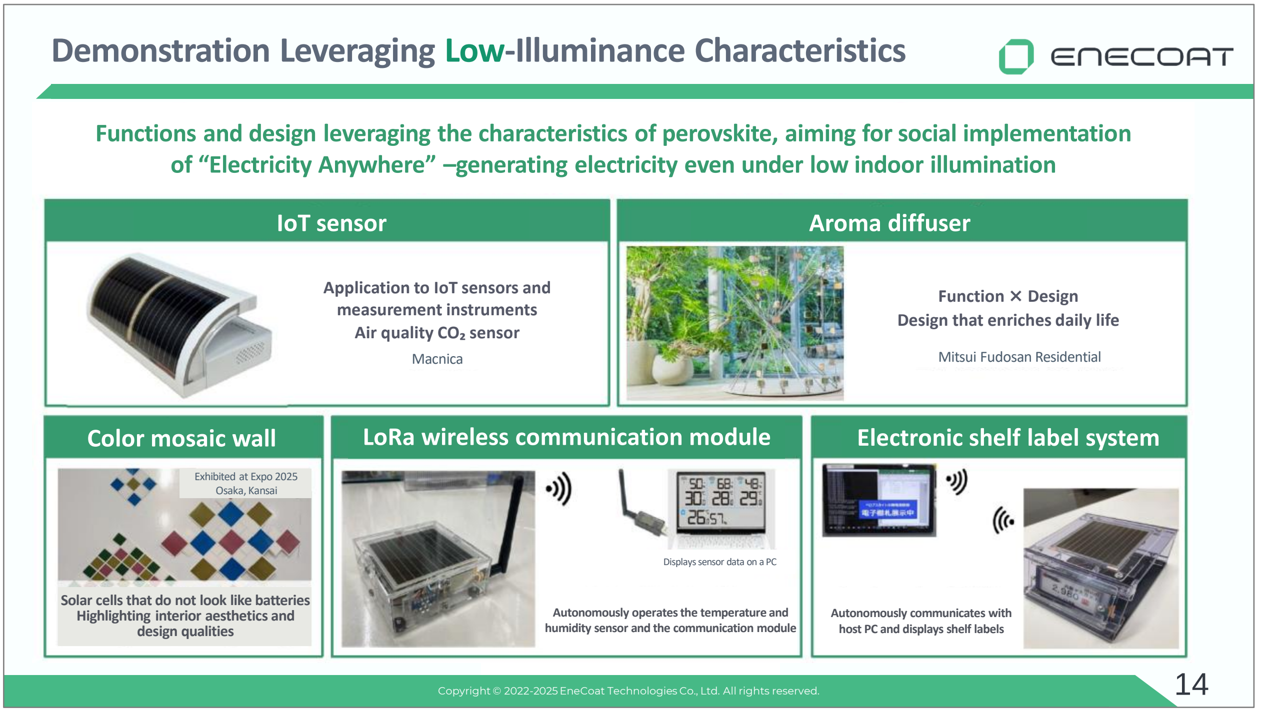
Here, we compare perovskite solar cells with conventional products. On the left is crystalline silicon, and on the right is amorphous silicon, which is used mainly for indoor applications. We compare perovskite with each of these. Our conclusion is that perovskite solar cells can combine the advantages of both crystalline silicon and amorphous silicon. At the bottom of the table, you will see a triangle mark under durability. This is almost the only notable drawback of perovskite solar cells. Once this issue is resolved, we believe there is a strong possibility that perovskite will become a mainstream solar cell technology.



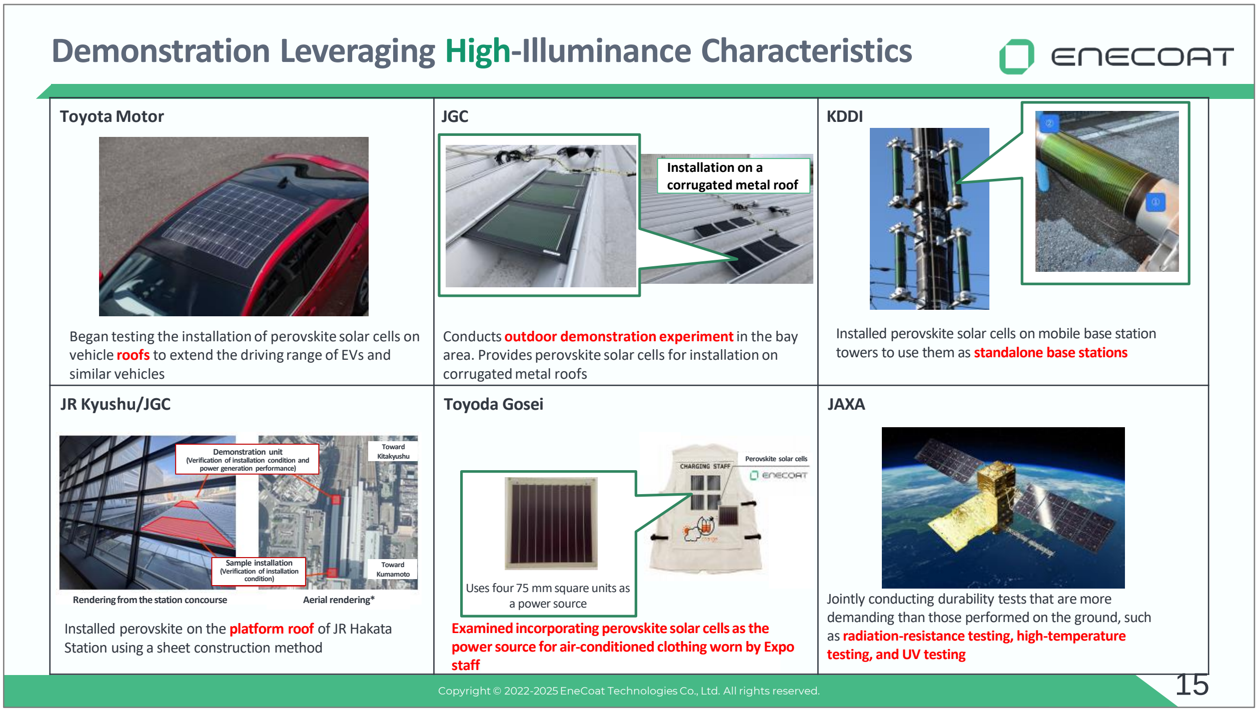
Here are the achievements we have made at EneCoat to date. As shown on the left, we have long been engaged in the development of film-type modules. We achieved a conversion efficiency exceeding 21 %—a very high figure—quite some time ago. We have also been steadily advancing our efforts toward larger-area modules. At present, we have reached a size of 37 cm × 47 cm, which corresponds to the Generation-2 LCD panel standard, and we have successfully achieved a power-generation efficiency exceeding 15% at this size.

We have brought the actual samples with us today. This is an example of our film-type module, with a copper electrode on the back side, making it non-transparent. On the other hand, this is our see-through type, which is used for tandem structures, and it looks like this.

On the right side of the slide, you see our tandem development. By stacking perovskite on crystalline silicon, higher conversion efficiency can be obtained, and we have already achieved a combined conversion efficiency exceeding 30 %.



This page presents examples of demonstration projects we have carried out to date. These are focused specifically on low-illumination applications. They include IoT sensors, and the item shown in the lower left was exhibited at Expo 2025 Osaka, Kansai.



This page shows examples of our demonstration tests conducted outdoors under high-illumination conditions. We have been working on applications for automotive use, as well as several fixed installations in which film-type perovskite solar cells are exposed to outdoor environments. In addition, as shown in the lower right, we are also engaged in the development of solar cells for space applications.

Topics

Press release on the NEDO website dated September 10, 2025

NEDO has adopted three new projects under the Green Innovation Fund Projects: "Development of Next-Generation Solar Cells/Next-Generation Solar Cell Demonstration Project." The projects aim to cultivate the market for perovskite solar cells through the development of mass-production technology and field demonstrations.

次世代型太陽電池の開発

別紙２

次世代型太陽電池実証事業

事業の目的・概要

- フィルム型・建材一体ガラス型のペロブスカイト太陽電池の実用化へ向けて一定条件下での発電コスト14円／kWh以下を達成するため、品質を安定させつつ大量生産可能な量産技術の確立に向け、一連の生産プロセスとして高いスループットや高い歩留まりを実現する技術開発を行う。
- 量産技術の確立と並行して、ペロブスカイト太陽電池の特徴を活かした設置方法や施工方法などを含めた性能検証のため、国内外の市場を想定した建築物などの実用箇所への施工、運用試験といったフィールド実証を行い、必要に応じて検証結果を踏まえた改良を行うことで、ペロブスカイト太陽電池の実用化を促進させる。

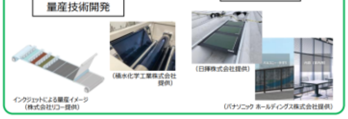
今回新規採択したテーマの規模等

- 事業期間　：2025年度～2029年度（5年間）
- 事業規模　：約335億円
- 支援規模*：約246億円
  *インセンティブ額を含む。
  採択予定額であり、契約などの手続により変更の可能性あり。
- 補助率：助成2/3、1/2

事業イメージ

量産技術開発

フィールド実証



実施体制

テーマ名（●は今回の新規採択テーマ）	事業者名　※太字は幹事企業
○軽量フレキシブルペロブスカイト太陽電池の量産実証	・**積水化学工業株式会社**、東京電力ホールディングス株式会社
●インクジェット印刷ペロブスカイト太陽電池生産技術開発および社会実装に向けた設置施工技術・電装技術開発	・**株式会社リコー**
●ガラス型ペロブスカイト太陽電池の量産技術開発とフィールド実証	・**パナソニック ホールディングス株式会社**
●設置自由度の高いペロブスカイト太陽電池の社会実装に向けた量産技術開発と実証	・**株式会社エネコートテクノロジーズ**

Nikkei dated September 10, 2025

京大発エネコート、曲がる太陽電池で産学連合　豊田合成や青学も

スタートアップ　✓フォロー済み

2025年9月10日 12:26

保存

京都大学発スタートアップエネコートテクノロジーズ（京都府久御山町）は10日、薄くて曲がる「ペロブスカイト型太陽電池」の開発に向けて産学連合をつくると発表した。トヨタ自動車や日揮、豊田合成など9社のほか、京大や青山学院大学が参加する。建物の屋根や壁に設置しやすい太陽電池の開発を急ぐ。

エネコートの事業がこのほど国の「グリーンイノベーション（GI）基金」に採択された。同基金からの補助と自己資金を合わせて100億円規模を投じるとみられる。素材や実証の技術を持つ大企業と組んで開発する。

エネコートを幹事としてコンソーシアムをつくる。トヨタ自動車、日揮、KDDI、豊田合成、YKKAP、京大、青山学院大などの企業や大学が加わる。2030年までの研究開発と実証で協力する。

ペロブスカイト型は次世代の太陽電池として今後の普及が期待されている。エネコートは23年からトヨタと車載用を共同開発してきた。今回の資金で建物の屋根や壁に設置する用途に参入する。

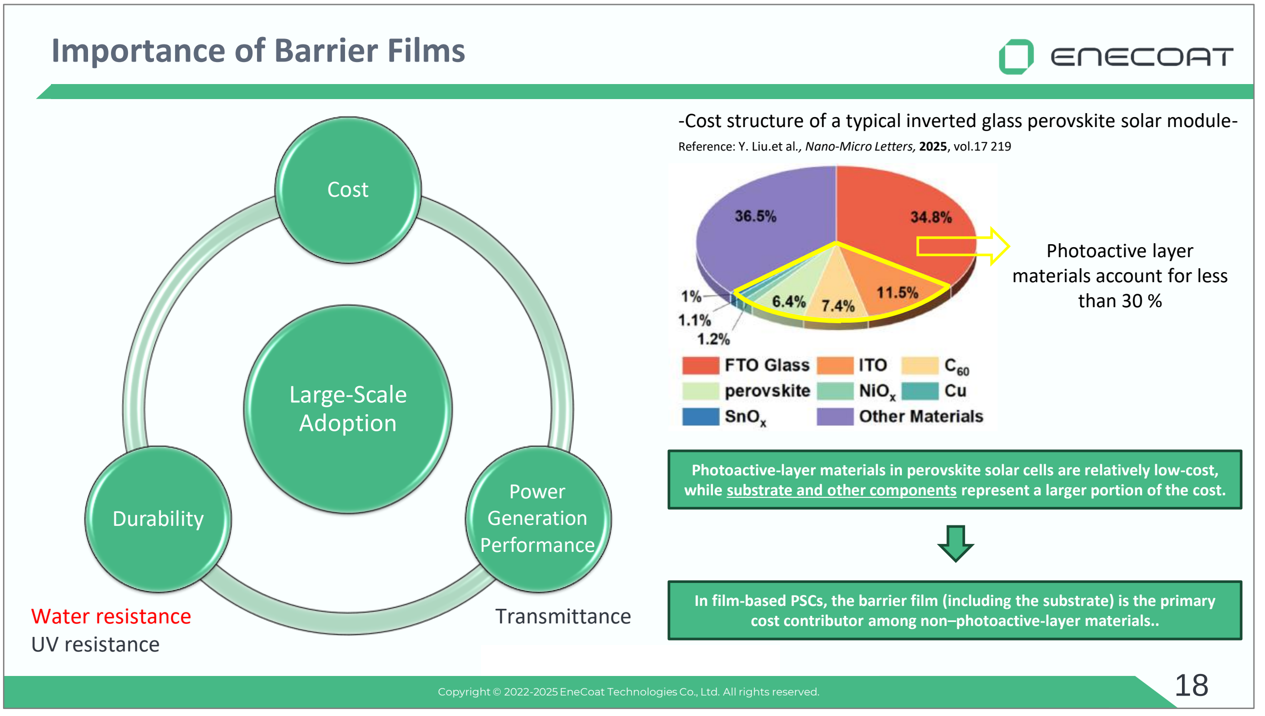
This page highlights our most recent topic. In September of this year, we were selected for Phase 3 of the Green Innovation Fund program, which supports demonstration projects for next-generation solar cells. As noted in the article on the right, this initiative is being pursued through a consortium, in which we are collaborating with various partners, including Toyota Motor Corporation.

New factory

ENECOAT

17

This page presents our upcoming milestones. We are steadily preparing our mass-production facility, which is scheduled for completion next year. Following equipment installation, we are working toward commencing mass production in the first half of 2027, and preparations are currently well underway to achieve this timeline.



From here, I would like to move on to today's main topic — the barrier film.
The diagram on the left illustrates what is required for perovskite solar cells to achieve large-scale adoption. Naturally, costs must be low. They must also offer sufficient durability. And of course, high power-generation performance is essential. Only when all three are fulfilled can large-scale adoption be realized.
What I would like to highlight is that the barrier film is an extremely important component in achieving all three of these requirements.
From a durability standpoint, perovskite is inherently vulnerable to moisture, making water resistance critically important. In addition, under outdoor conditions, UV exposure has a significant impact, so the film must incorporate functionality to protect against UV as well.
From a power-generation performance standpoint, transmittance is key. Without high transmittance, conversion efficiency cannot be high; therefore, the film must provide high optical transparency.
Regarding cost, improving performance and durability lowers the levelized cost of electricity, but the cost of the film itself also becomes a major factor. This relationship is illustrated in the chart on the right.
Perovskite solar cells are often described as being very inexpensive to manufacture, and this is partially true. The pie chart shows the cost structure of a glass-type perovskite module, estimated by a Chinese research group. The yellow-highlighted area indicates the share accounted for by the photoactive layer, which is less than 30 %. In other words, the portion corresponding to silicon in crystalline-silicon modules represents only around 30 % in the case of perovskite. This reflects the inherently low material cost.
However, for film-type perovskite solar cells, most of the remainder is attributable to the film. Because barrier films are used in this portion, at least two-thirds of the total cost of a film-type perovskite solar cell comes from the films. Therefore, reducing the cost of the barrier film becomes extremely important.

Our Expectations to Konica Minolta's Barrier Film

ENECOAT

- Achievements (technologies and expertise) in high-barrier films developed through OLED and related applications
- Exceptional water resistance (low water vapor transmission rate, WVTR)
- Device compatibility (thin film and curvature conformance)

↓

We look forward to products that offer both high functionality and low cost

This page summarizes our expectations for Konica Minolta's barrier film.
There are various manufacturers in this field, but Konica Minolta already has commercial products in areas such as OLEDs, and possesses outstanding technologies. We believe the company has achieved truly exceptional results.
The products actually provided exhibit remarkably high water-resistance. We have conducted our own verification as well, and the results have been extremely positive.
As for device compatibility, unlike some other companies, Konica Minolta manufactures the film in thin-film form, which offers excellent conformability to curved surfaces and makes handling very easy.
In terms of performance, we believe the current level is already more than sufficient. The remaining point is cost. As mentioned earlier, for perovskite solar cells, reducing the cost of the film portion is critically important. We therefore look forward to the development of products that achieve both high performance and cost competitiveness, and to Konica Minolta supplying such solutions to the perovskite solar-cell industry.

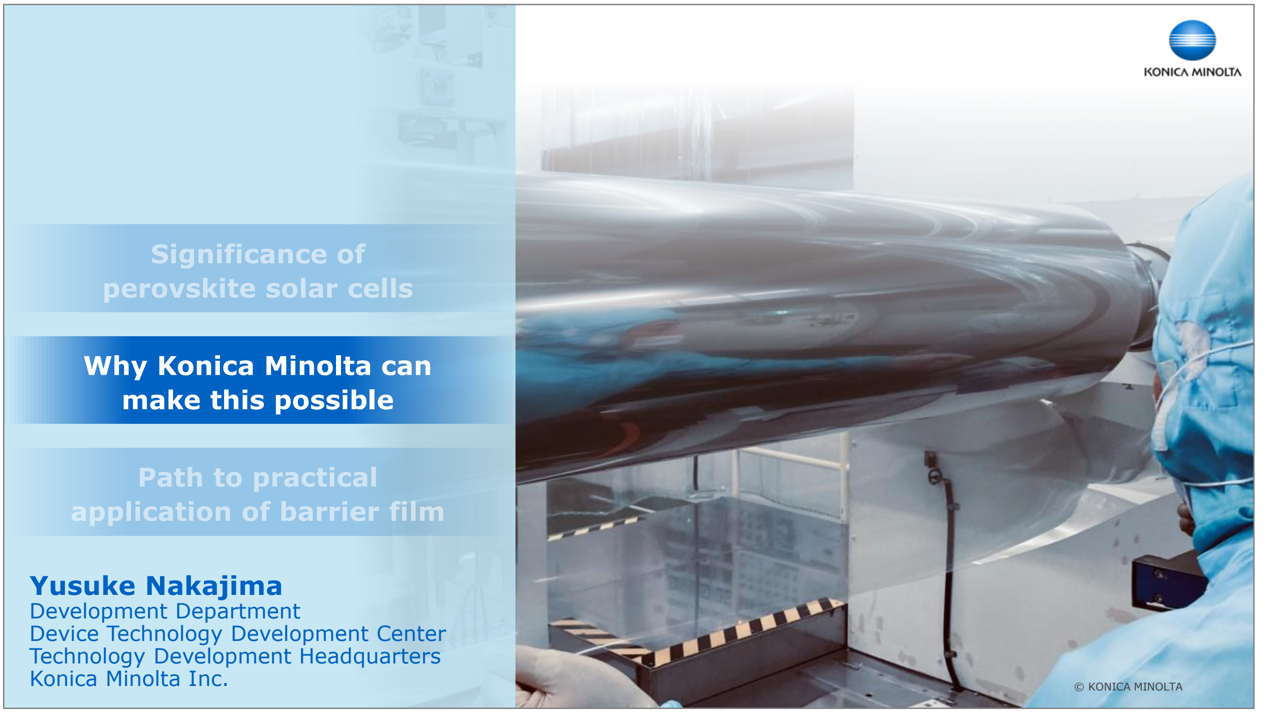
ペロブスカイト太陽電池で未来を創ります。

Build The Future With Perovskite Solar Cells.

株式会社エネコートテクノロジーズ

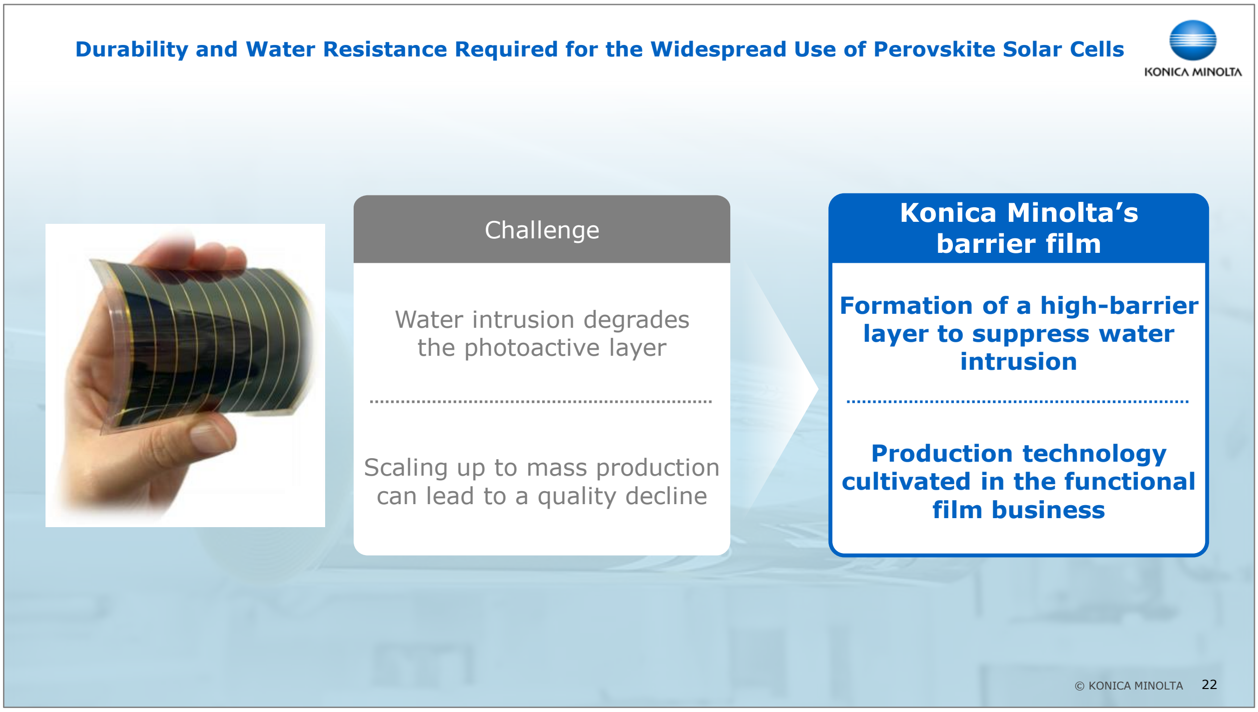
EneCoat Technologies Co., Ltd.

That concludes my explanation. Thank you very much for your attention.



Thank you very much, Mr. Kato, for your explanation. Once again, my name is Nakajima from the Technology Development Headquarters, and I am in charge of the barrier film development project.

Now, under the theme "Why Konica Minolta can make this possible," I will provide a detailed explanation of our barrier film.



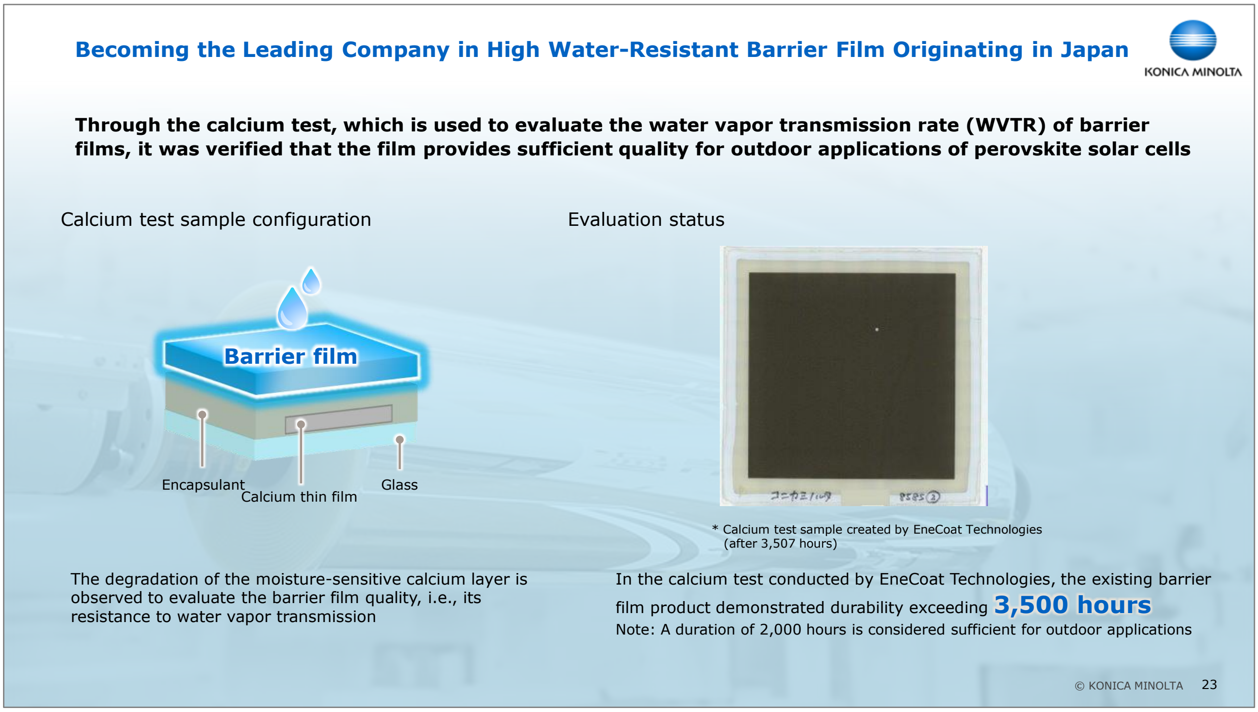
As Mr. Kato mentioned earlier, it is well understood that there are certain challenges that must be addressed in order to accelerate the widespread adoption of perovskite solar cells.

The most significant challenge is water resistance. The materials used in perovskite solar cells have limited resistance to moisture, and when water penetrates the device, the photoactive layer deteriorates, resulting in a substantial decline in conversion efficiency—which is the key performance indicator for solar cells. Once conversion efficiency drops, the product's value decreases accordingly. While conventional silicon solar cells currently in widespread use have a product lifetime of around 20 years, perovskite solar cells are said to last only about 5 years, or up to 10 years at best. This has become a major barrier to broader adoption.

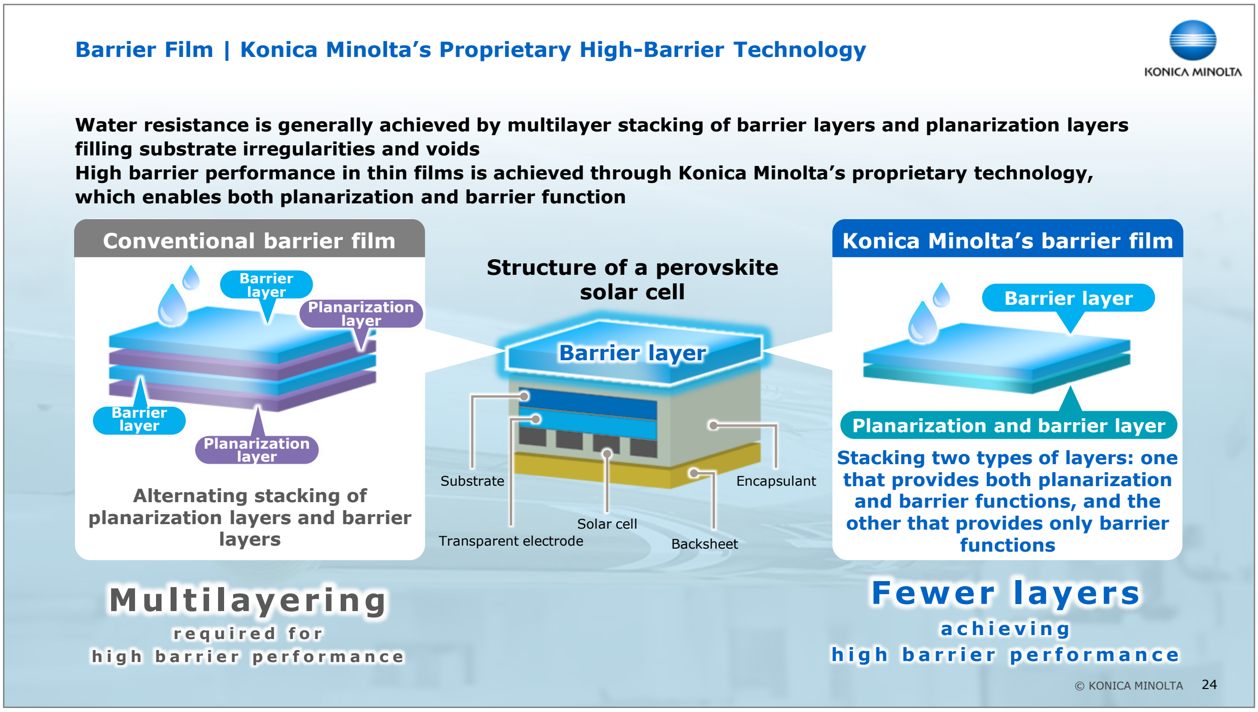
In addition, although perovskite solar cells have demonstrated high conversion efficiency in laboratory and academic studies at small sizes, the technology for scaling up to mass production has not yet been established. Quality degradation when producing larger modules for mass production is also cited as a challenge.

To address these issues, Konica Minolta aims to provide solutions by leveraging our barrier film technology, originally developed for film-based OLED products, as well as the production technologies we have cultivated over many years in film manufacturing.

Our barrier films, which have already been proven in outdoor applications, are capable of forming high-barrier layers that suppress moisture intrusion. We are confident that this will help improve the water resistance, which is a major challenge for perovskite solar cells.



This slide explains the results of the barrier film evaluation conducted by EneCoat Technologies.
In this evaluation, the properties of the barrier film were assessed using a method called the calcium test. In the calcium test, a sample is prepared by sandwiching a calcium thin film—which is highly sensitive to moisture—between a glass substrate and the barrier film using an encapsulant. The degree of degradation of the calcium layer is then observed to verify how effectively the barrier film prevents moisture penetration.
Our existing barrier film product was tested by EneCoat Technologies, and we confirmed durability exceeding 3,500 hours, well above the 2,000 hours required to ensure quality for outdoor applications of perovskite solar cells. While this is an evaluation of the barrier film component, customer assessments have also verified that our product can sufficiently ensure quality for outdoor use.
Currently, technical validation using perovskite solar cell samples is also underway.



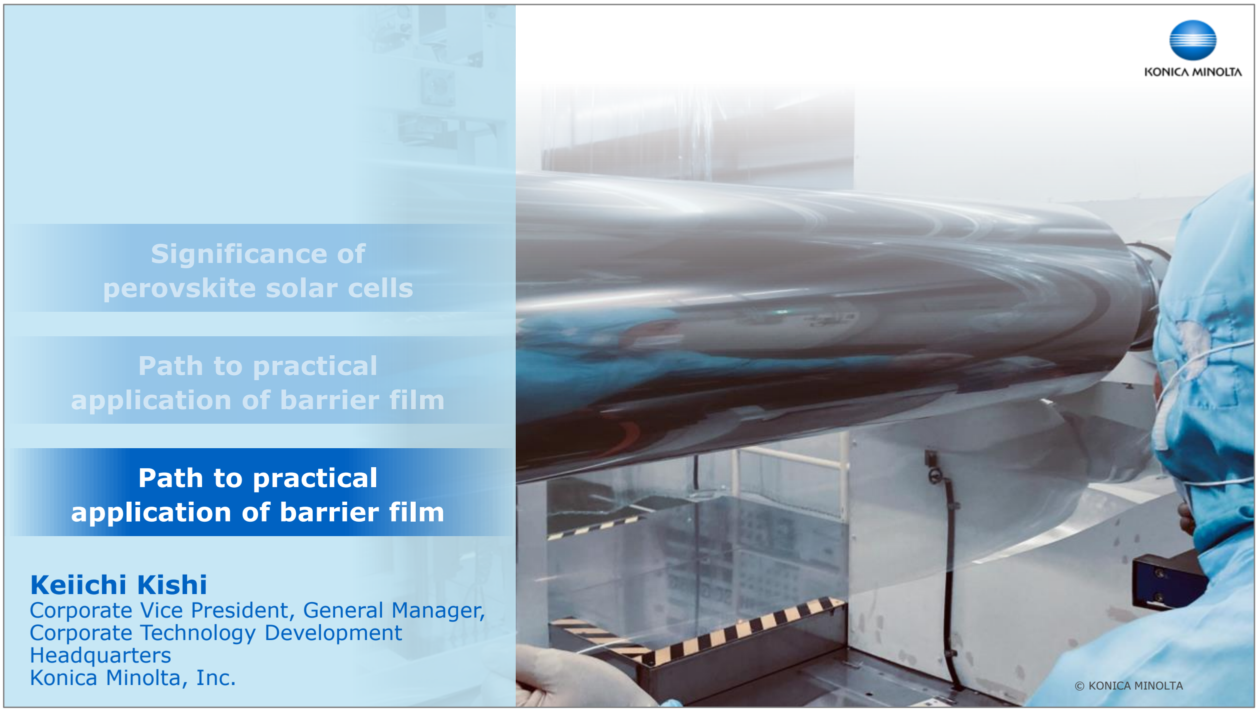
This slide explains the specific technologies used to achieve high-barrier layers.
In general, to form the barrier layers required for high-barrier films, planarization layers and barrier layers are alternately stacked on a base substrate, such as PET film. The planarization layer not only smooths out the surface irregularities of the substrate, but also suppresses moisture intrusion through the countless tiny holes that can occur during the manufacturing process of the barrier layer—although it does not itself provide a barrier function.
As a result, increasing the total film thickness leads to higher manufacturing costs. In contrast, Konica Minolta has leveraged its expertise in materials and film processing to realize high-barrier performance by using just two types of layers: one that combines both planarization and barrier functions, and a dedicated barrier layer.
This approach enables thinner films, delivering cost advantages while still ensuring a high level of water resistance.

Next, I would like to introduce our production technology. Starting with photographic film, Konica Minolta has cultivated its film manufacturing expertise over more than half a century. About ten years ago, we began mass production of barrier films for OLED applications, and we have a proven track record of stably producing water-resistant barrier films at scale.

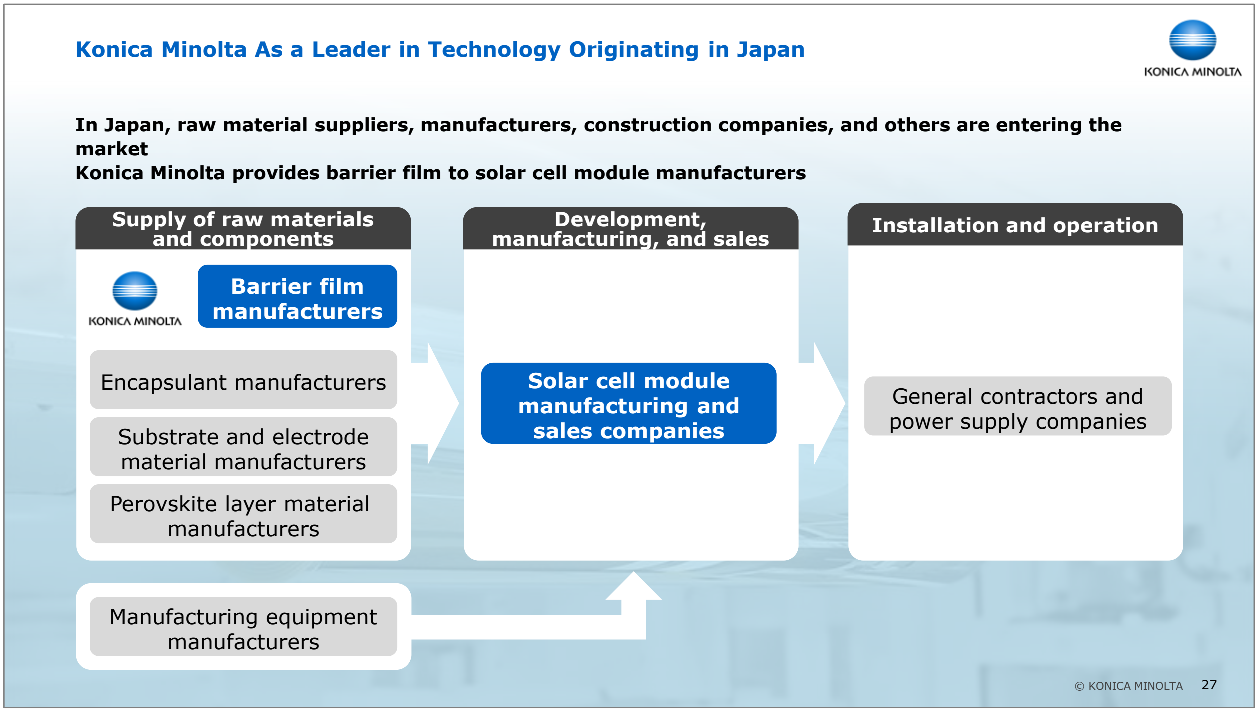
Since the basic manufacturing process for barrier films used in perovskite solar cells is the same as that for OLED applications, we are able to establish a mass production system utilizing our existing facilities. In the short term, this allows us to provide high-quality barrier films tailored to market conditions and customer needs without the need for additional investment.

By leveraging these two technological strengths I have introduced, we will continue to drive the market expansion of our barrier films.

From here, Mr. Kishi will explain our vision for the practical implementation of barrier films.

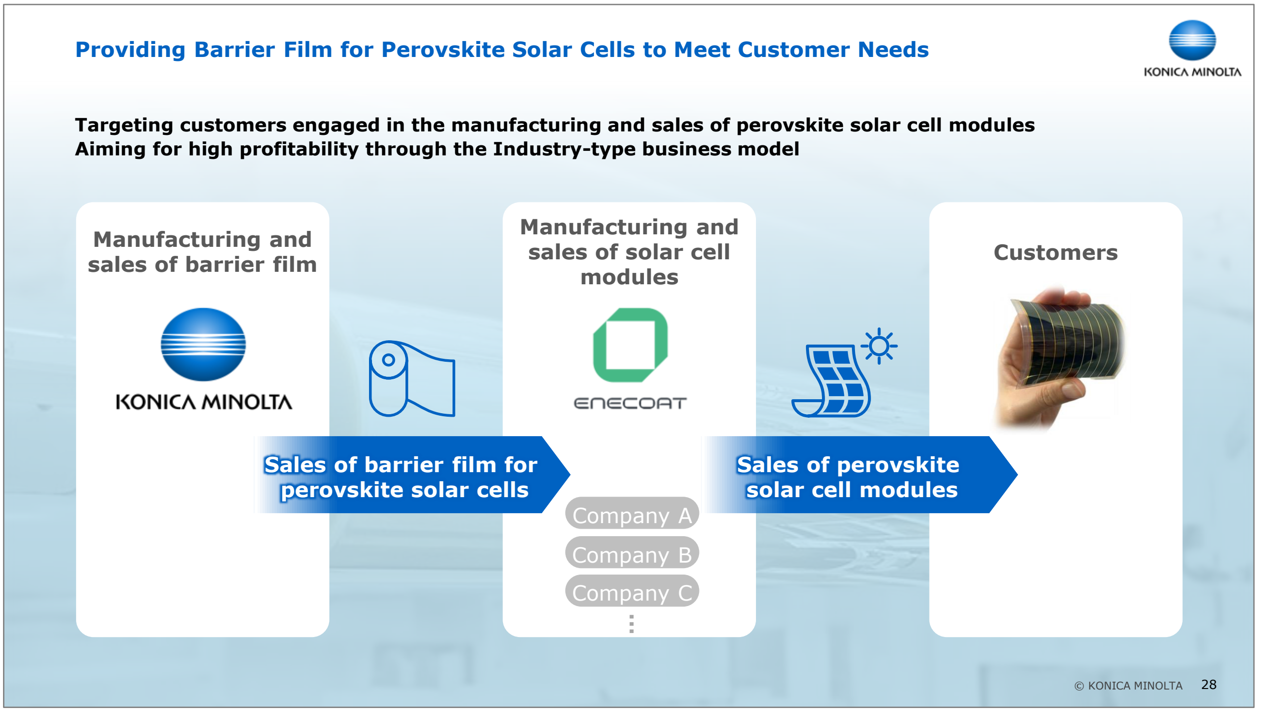


Once again, my name is Kishi, General Manager of the Technology Development Headquarters. Thank you for your attention.
From here, under the theme "The path to practical application of barrier film," I would like to provide a more detailed explanation of the vision that Konica Minolta has for this technology.



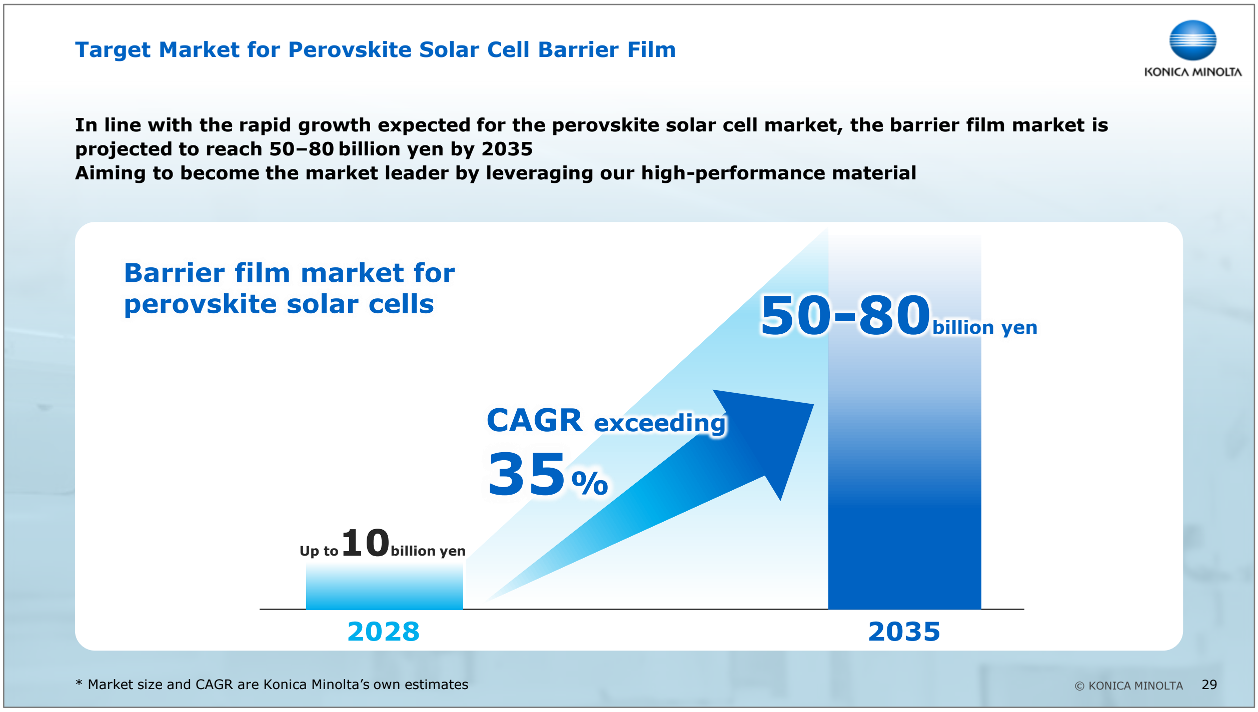
First, I would like to discuss Konica Minolta's position within the broader perovskite solar cell industry. As Mr. Kato mentioned earlier, perovskite solar cells are a technology originating in Japan, and as has been widely reported, many Japanese companies—including raw material suppliers, module manufacturers, and construction firms—are entering this field.

Within this landscape, Konica Minolta is positioning itself as a supplier of barrier films, which are essential for ensuring the water resistance that is key to the widespread adoption of perovskite solar cells. We will provide barrier films to manufacturers of solar cell modules, including EneCoat Technologies.



To reiterate, Konica Minolta's business model is to develop and produce barrier films in-house and supply them to manufacturers engaged in the production and sales of perovskite solar cell modules. This approach is closely aligned with our Industry-type business model, focusing on supplying key materials.

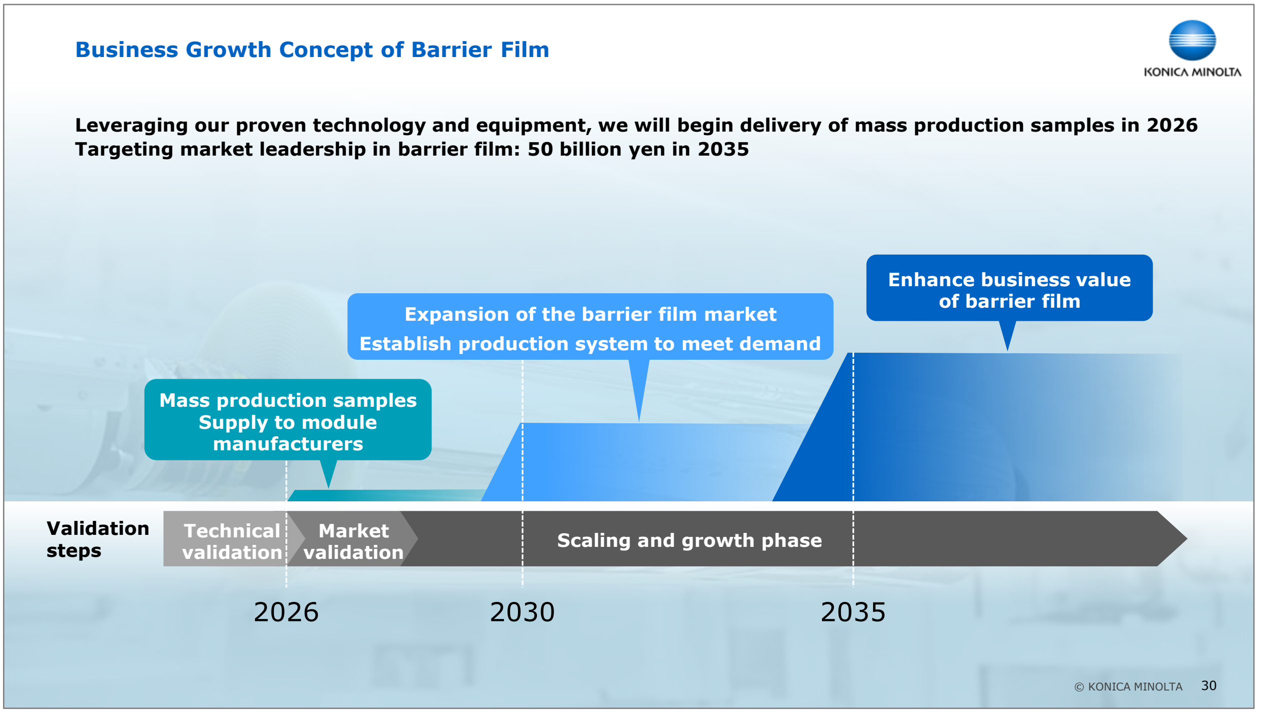
By providing customers with the functional value of water resistance, we aim to achieve high profitability. As the market for perovskite solar cells expands, we expect the demand for barrier films to grow as well. Our goal is to expand sales and profits by supplying barrier films to a wide range of Japanese perovskite solar cell manufacturers, including EneCoat Technologies.



Next, I would like to discuss the target market for barrier films for perovskite solar cells.

With the rapid expansion of the perovskite solar cell market, we anticipate that the market for barrier films alone will also grow significantly. Looking at the long term, we are aiming for the fiscal year 2035, when the market size is expected to reach between 50 and 80 billion yen. Our goal is to promote the value of Konica Minolta's barrier films and become the market leader.

By conducting thorough technical and market validation, and making appropriate capital investments in line with demand, we believe we can steadily expand our business and capture a substantial share of the projected 50 to 80 billion yen market.



This is the final slide.

To reiterate, we are leveraging the production technologies and facilities we have developed through our long-standing film business, and are working toward shipping mass production samples of barrier films in fiscal year 2026.

As we proceed with sample shipments and technical validation, we aim to expand our customer base.

By 2035, our goal is to secure the top share in the barrier film market, which is expected to reach between 50 and 80 billion yen, and to establish this business as a highly profitable one. We see this as a foundation for long-term growth and are committed to nurturing it as a key driver of our future expansion.

That concludes my presentation. Thank you very much for your attention.

Cautionary Statement:
The forecasts mentioned in this material are the results of estimations based on currently available information, and accordingly, contain risks and uncertainties. The actual results of business performance may sometimes differ from those forecasts due to various factors.

Remarks:
Yen amounts are rounded to the nearest 100 million.