Global Climate Tech Trends: Current Status and Future Outlook for Japan

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Introduction

Since the adoption of the Paris Agreement*[1] into the United Nations Framework Convention on Climate Change at the 21st Conference of the Parties (COP21) in 2015, the Parties have established targets for reducing greenhouse gas (GHG) emissions, and global warming and climate change have gained even greater international attention as critical global issues. As a result, initiatives such as carbon offsetting, carbon neutrality and zero carbon, as well as the development of climate tech aimed at addressing climate change, have begun in earnest across countries and regions around the world. Furthermore, efforts to advance climate tech and bring it into practical societal implementation are becoming increasingly active.

In corporate activities as well, ESG (environmental, social and governance) considerations and environmentally conscious management are increasingly emphasized, and efforts to enhance corporate value are becoming more active. In addition, active investment is being directed toward startups that are boldly taking risks to commercialize climate tech, and the global climate tech market is expected to grow rapidly*[2].

In Japan, the 2050 Carbon Neutral Declaration has been issued, and concrete initiatives toward achieving a carbon-neutral society are progressing. For example, the Regional Decarbonization Roadmap*[3] aims to create at least 100 'Leading Decarbonization Areas' by FY2030 and to roll out the models developed in these areas nationwide, with the goal of triggering a 'decarbonization domino effect' that achieves decarbonization even before 2050. In addition, the amended Act on Promotion of Global Warming Countermeasures*[4] is intended to accelerate efforts, investment and innovation toward decarbonization, while also promoting corporate decarbonization management.

In this way, climate tech aimed at reducing, mitigating and assessing the impacts of climate change has been attracting global attention, and the importance of technologies related to climate tech is expected to continue increasing.

Scope of the Climate Tech technology trend analysis

Climate tech is a collective term for technologies aimed at reducing GHG emissions and addressing climate change. In this report, it is classified into eight sectors*[5]—Energy; Mobility and Transport; Climate Change Management and Reporting; Financial Services; GHG Capture, Removal and Storage; Food, Agriculture and Land Use; Industry, Manufacturing and Resource Management; and Built Environment (Figure 1). Using PwC Consulting LLC's proprietary analysis tool, Intelligent Business Analytics (IBA), we investigated and analyzed the technology trends of these climate tech fields, as well as the trends observed across different countries and regions.

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*1 'The Paris Agreement.' United Nations Climate Change
https://unfccc.int/process-and-meetings/the-paris-agreement

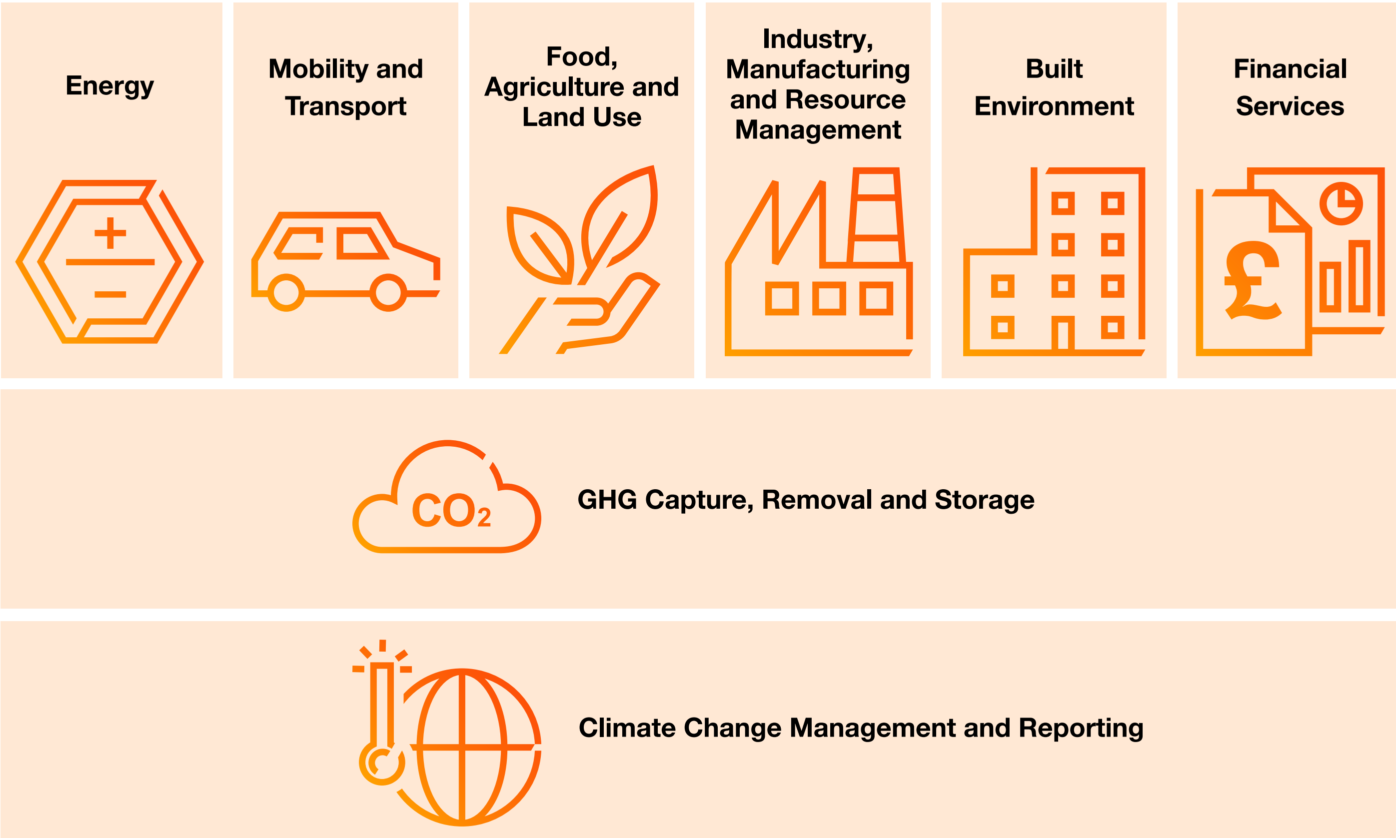
*2 PwC, 'State of Climate Tech 2021: Scaling breakthroughs for net zero'
https://www.pwc.com/gx/en/services/sustainability/assets/pwc-state-of-climate-tech-report-2021.pdf

*3 Cabinet Secretariat 'Regional Decarbonization Roadmap.' 9 June, 2021.
https://www.cas.go.jp/jp/seisaku/datsutanso/pdf/20210609_chiiki_roadmap.pdf

*4 Ministry of the Environment 'The Act on Promotion of Global Warming Countermeasures and the Global Warming Action Plan' https://www.env.go.jp/earth/ondanka/domestic.html

*5 PwC, 'State of Climate Tech 2021: Scaling Breakthrough Innovation in Climate Tech'
https://www.pwc.com/gx/en/services/sustainability/publications/state-of-climate-tech.html

Figure 1: Classification of climate tech technologies



Source: PwC, 'State of Climate Tech 2021: Scaling breakthroughs for net zero'*2

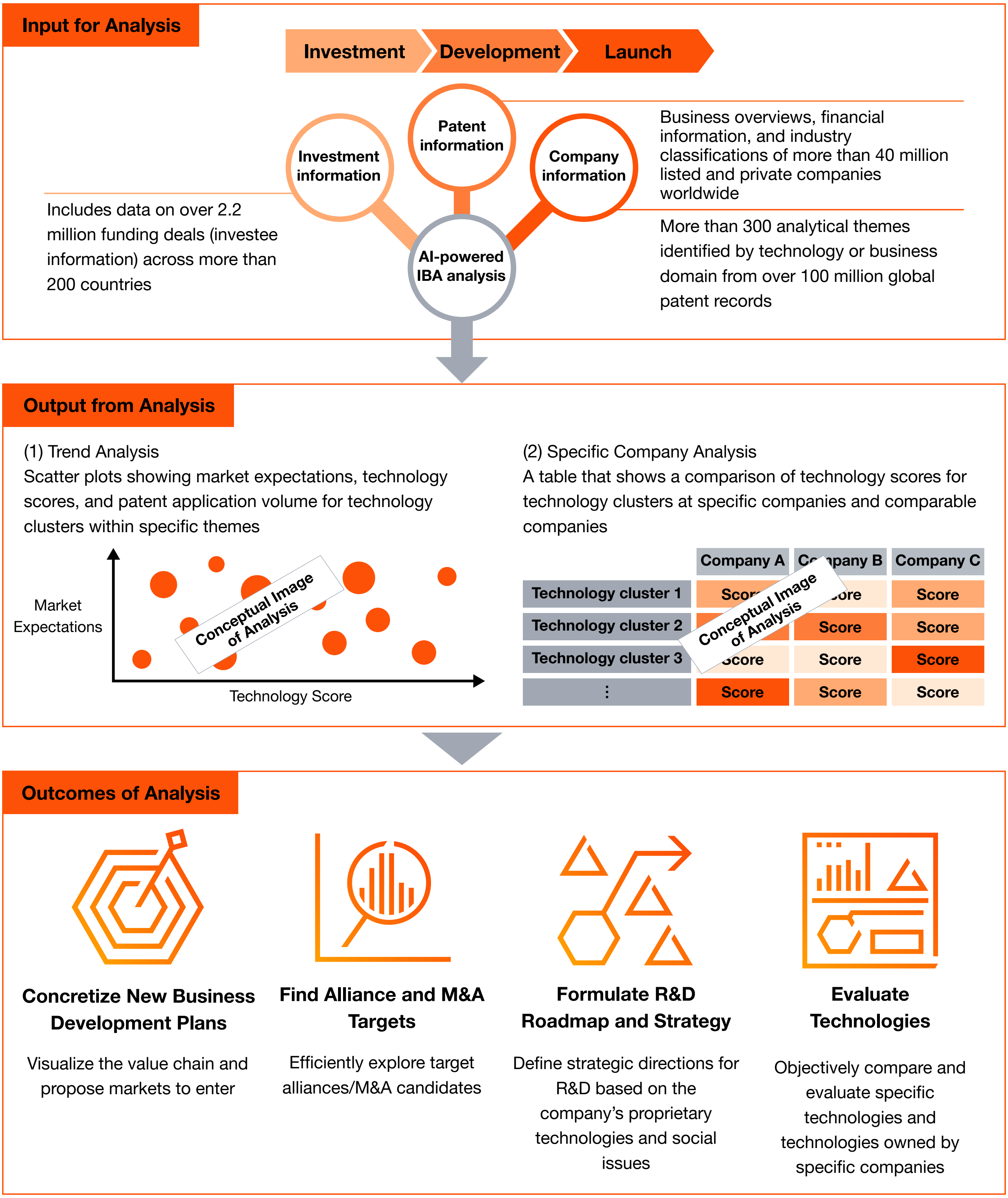
About Intelligent Business Analytics

IBA is a new strategic analysis tool that uses AI to analyze global patent data and corporate financial and investment information for specific technology domains. It enables qualitative analysis of patented technologies and quantitative analysis of corporate investments, and offers a range of capabilities such as providing a market-oriented overview of technology trends and companies' technology portfolios. By identifying macro trends and understanding each company's technology strategy, IBA provides new insights for corporate strategic planning through its consulting services.

IBA utilizes data related to patents, financials and investments. By combining business data with technology data, IBA supports a wide range of use cases, including new business development, R&D strategy formulation, the identification of alliance partners or M&A targets, and technology due diligence. In addition, the ability to visualize an individual company's technology portfolio and to drill down into its financial and patent data serves as a key differentiating feature of IBA. This enables both idea generation through trend identification and hypothesis testing, allowing companies to formulate more concrete and robust new business development and R&D strategies (Figure 2).

In this article, we analyzed patent information related to climate tech, as well as corporate and investment information, using IBA.

Figure 2: Overview of Intelligent Business Analytics



Source: PwC

01

Energy Sector

The Energy sector includes renewable energy such as solar and wind power; advanced zero-carbon and carbon-offset energy technologies such as nuclear power, nuclear fusion and hydrogen; as well as other synthetic fuel technologies (Figure 3). In the stage of producing energy, the sector encompasses the design, manufacturing and development of power generation and production equipment, machinery and components, as well as the technologies used to manage and control these systems. In the stages of delivering and using energy, the sector includes transmission and distribution technologies, control systems, hydrogen storage and transportation technologies, technologies for managing and controlling electricity and other forms of energy, infrastructure such as charging stations and hydrogen stations, and technologies for energy reuse. In this way, the sector encompasses a broad range of energy-related technologies that contribute to reducing GHG emissions and minimizing energy loss.

Figure 3: Overview of technologies in the Energy sector

Make (generation/production)

Energy production
- Use of renewable energy (solar power, wind power, hydropower, geothermal, biomass, etc.)
- Nuclear power generation
- Nuclear fusion power generation
- Hydrogen production
- Alternative fuels (biodiesel, alcohol, etc.)

…etc.

Deliver (storage/transportation)

Design and manufacturing technologies for power generation/production facilities
- Plant
- Turbine
- Substations and transformers
- Components and materials

…etc.

Facility management and control technologies
- Safety monitoring
- Management and control

…etc.

Hydrogen storage and transportation technologies
- Storage vessels and pressure vessels
- Pressure/temperature management and control
- Energy carriers (liquefied hydrogen, ammonia, methanation, etc.)

…etc.

Power transmission/distribution and energy management/control technologies
- Energy storage technologies (batteries, systems, etc.)
- Smart grid
- Smart meter
- Supply-demand forecasting
- High-efficiency transformer
- Energy management system
- Integrated energy system

…etc.

Use (supply/utilization)

Supply and utilization equipment
- Charging station
- Hydrogen station
- Fuel cell

…etc.

Energy reuse technologies
- Waste heat recovery and utilization

…etc.

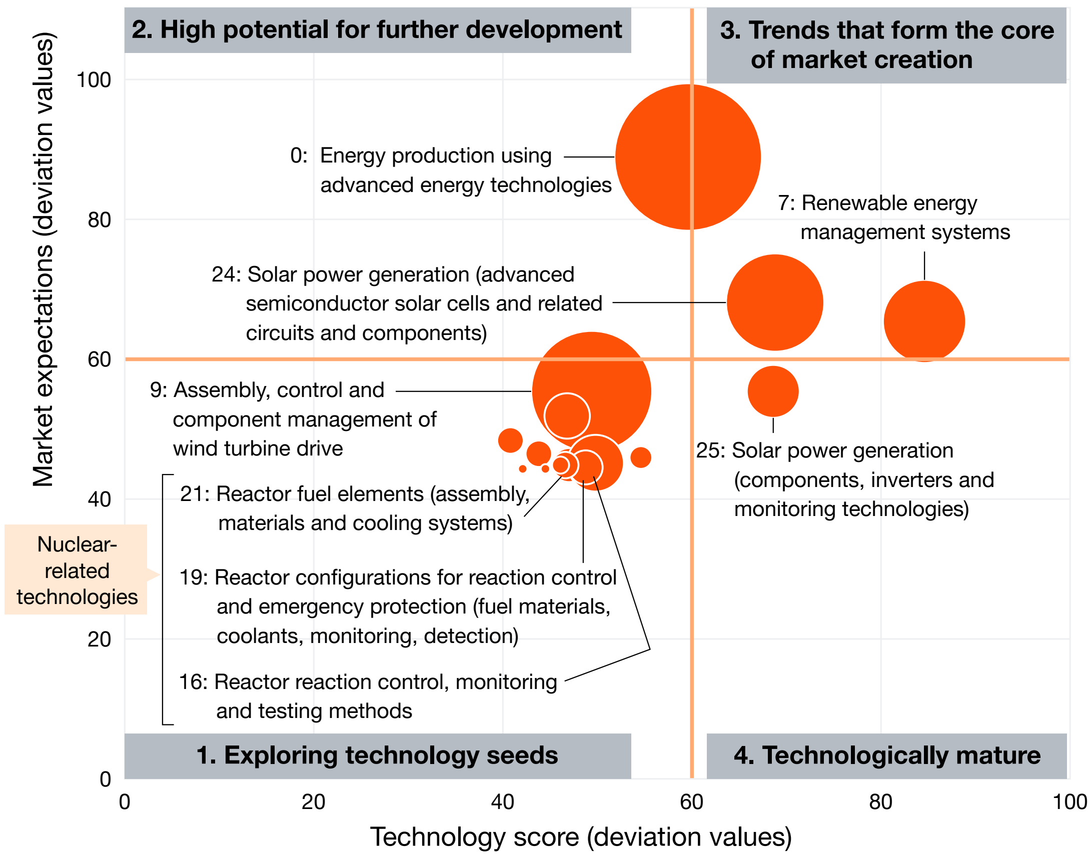
Source: PwC

Technology trend

Figure 4 presents an analysis of current technology trends generated using IBA. The vertical axis represents the market expectations for each technology cluster (measured by minority investment amounts), the horizontal axis indicates the technology score (reflecting technological progress), and the size of each bubble corresponds to the number of patent applications. This chart can be divided into four quadrants based on the technology score and market expectations. Quadrant 1 represents the area for exploring emerging technological seeds. Quadrant 2 comprises technologies with high potential for further development. Quadrant 3 consists of trends that form the core of market creation, where both technological development and investment are already advancing. Quadrant 4 comprises technologies that have undergone long-term development and are reaching maturity.

'Solar power generation (advanced semiconductor solar cells and related circuits and components)' and 'Renewable energy management systems' both show high technology scores and high market expectations, indicating that they are core technology areas in current market formation. The technology cluster of 'Energy production using advanced energy technologies' is in Quadrant 2. Although there is still room for further technological development, it is already attracting substantial investment, suggesting a high likelihood that development will continue to advance. 'Solar power generation (components, inverters and monitoring technologies)' is in Quadrant 4, representing a field where technological development has been ongoing for a long time and is considered to have reached maturity. Quadrant 1 may include technology clusters such as wind power generation and various nuclear-reactor-related technologies—clusters that currently exhibit limited technology scores and market expectations but have the potential to become next-generation trends.

Figure 4: Market expectations, technology scores and patent application counts for technologies in the Energy sector

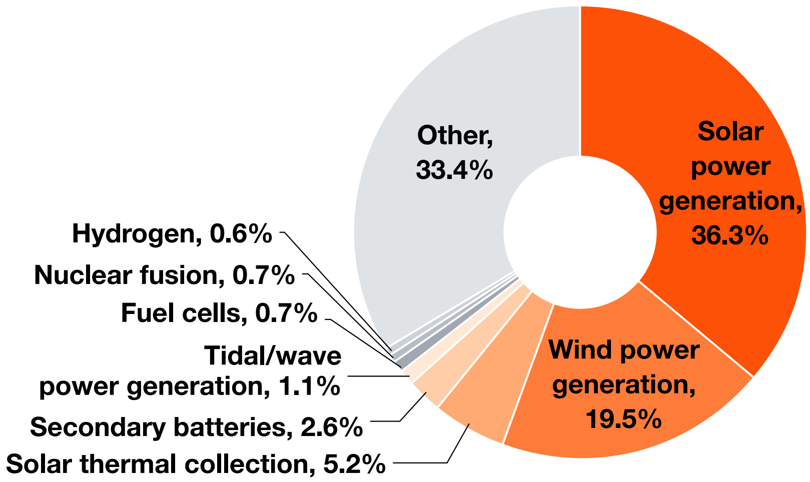


Source: PwC

Technology category and country/region trends

Figure 5 shows the proportion of patents, categorized by energy type, within the high-market-expectation cluster 'Energy production using advanced energy technologies,' based on the International Patent Classification (IPC). It can be observed that patents related to solar and wind power account for a large proportion of the total. Among other renewable energy technologies, patents related to solar thermal collection and tidal or wave power generation also account for relatively high proportions, and this area includes patents related to batteries, nuclear fusion and hydrogen.

Figure 5: Share of patents by energy type within 'Energy production using advanced energy technologies'



Note: Percentages may not total 100% due to rounding to one decimal place.
Source: PwC

Figure 6 presents an analysis of the filing countries and regions for material patents within this cluster—defined as the top 5% of patents with the highest citation counts within the same IPC category*6—categorized by energy type based on the IPC. Here, the analysis focuses on material patents in order to highlight those with high impact. The filing countries and regions exhibit distinct patterns depending on the energy type, which can be attributed to natural factors and policy environments specific to each country or region.

More than 80% of solar thermal collection-related patents are filed in China, which is likely due to the country's abundant sunlight and vast land area, as well as government policies that have actively promoted the use of such technologies. More than 80% of patents related to tidal and wave power generation are also filed in China, where both companies and universities are actively driving technological development.

*6 Sugimitsu, Tatemoto, et al. (2023). 'A Study on the Impact of Material Patents on Corporate Financial Data.' http://fdn-ip.or.jp/files/ipjournal/vol24/IPJ24_26_38.pdf

Approximately 60% of fusion-related patents are filed in the US. In the US, the Department of Energy (DOE) has released the DOE Fusion Energy Strategy 2024*[7]. Through initiatives such as the Fusion Innovation Research Engine Partnership, the US has decided to strengthen investment in the private sector. The government is also promoting fusion as a key policy priority, recognizing it as essential for meeting the enormous power demand expected from the expanding AI market. Approximately 10% of fusion-related patents are filed in Europe, which is actively participating in ITER (the International Thermonuclear Experimental Reactor)*[8]. The European Research Roadmap to the Realisation of Fusion Energy*[9], formulated by EUROfusion—an EU-related research consortium—also emphasizes the necessity of future fusion power plants. Japan, which has positioned the Fusion Energy Innovation Strategy*[10] as a government policy and incorporated it into its industrialization vision, accounts for about 5% of patent filings.

Hydrogen-related patents, meanwhile, are filed predominantly in China, which accounts for more than 60% of the total. China has released the Medium- and Long-Term Plan for the Development of the Hydrogen Energy Industry*[11] and is promoting the construction of hydrogen infrastructure. During the 14th Five-Year Plan period, the country is also implementing industrial innovation demonstration projects in the sectors of transportation, energy storage, power generation and industry.*[12] Patent filings in the US follow at around 20%, supported by the US commitment to invest more than USD 60 million in the research, demonstration and practical utilization of next-generation clean hydrogen technologies.*[13] In Europe—where hydrogen is positioned as a key element in the Green Deal Industrial Plan*[14] and the Fit for 55 decarbonization policy package*[15]—and in Japan, which developed the world's first Basic Hydrogen Strategy*[16], the share of patent filings remains below 10%.

*7 US Department of Energy 'Fusion Energy Strategy 2024'
https://www.energy.gov/sites/default/files/2024-06/fusion-energy-strategy-2024.pdf

*8 ITER ITER Organization
https://www.iter.org/

*9 EUROfusion 'THE ROAD TO FUSION ENERGY'
https://euro-fusion.org/eurofusion/roadmap/

*10 Cabinet Office, Government of Japan. 'Fusion Energy Innovation Strategy.' August 2024.
https://www8.cao.go.jp/cstp/fusion/7kai/siryo2.pdf

*11 National Development and Reform Commission and National Energy Administration of China. 'Medium-and Long-Term Plan for the Development of the Hydrogen Energy Industry (2021-2035).' March 2022.
https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202203/t20220323_1320038_ext.html

*12 New Energy and Industrial Technology Development Organization (NEDO), Beijing Office. 'Trends in Hydrogen-Related Developments in China.' April 2023.
https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/pdf/031_06_00.pdf

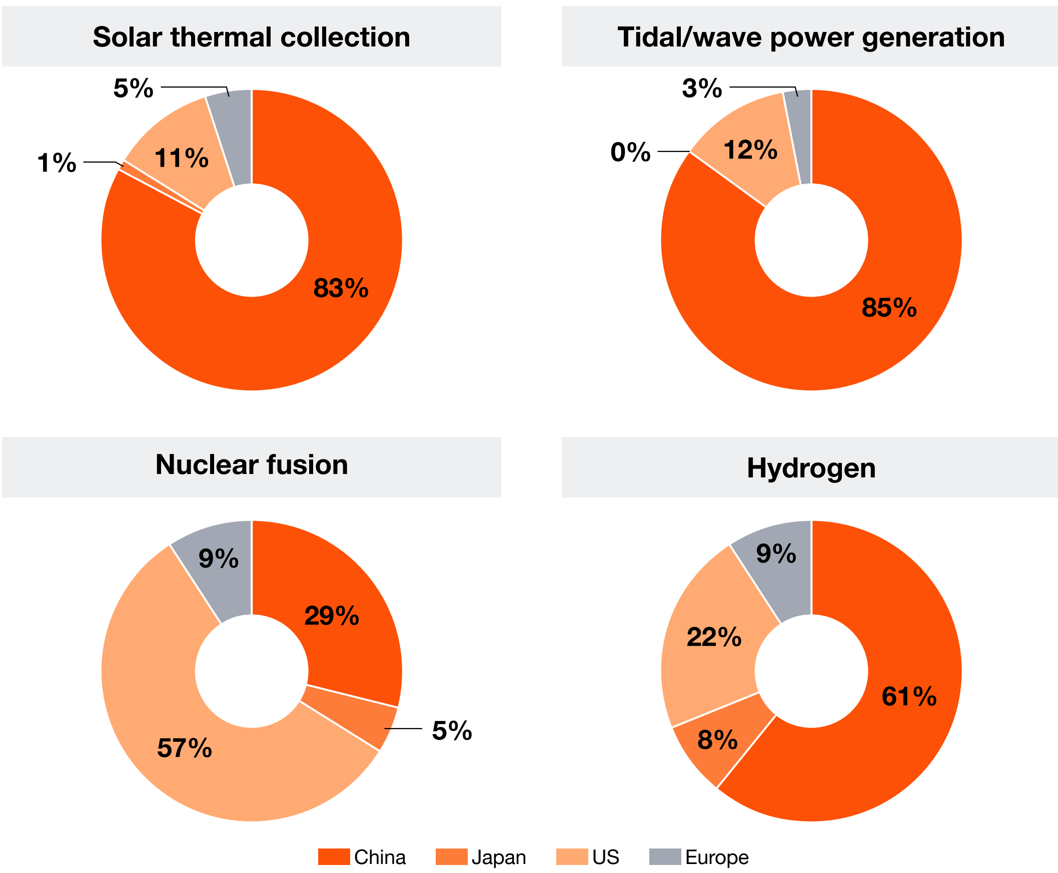
*13 US Department of Energy 'Selections for Hydrogen and Fuel Cell Technologies Office Funding Opportunity Announcement to Advance the National Hydrogen Strategy'
https://www.energy.gov/eere/fuelcells/selections-hydrogen-and-fuel-cell-technologies-office-funding-opportunity-0

*14 European Commission 'The Green Deal Industrial Plan Putting Europe's net-zero industry in the lead'
https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan_en

*15 European Commission 'Fit for 55: Delivering on the proposals'
https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal/fit-55-delivering-proposals_en

*16 Ministerial Council on Renewable Energy, Hydrogen and Related Issues. 'Basic Hydrogen Strategy.' 6 June, 2023.
https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/20230606_2.pdf

Figure 6: Filing countries and regions for material patents by energy type within 'Energy production using advanced energy technologies'



Source: PwC

Mobility and Transport Sector

The Mobility and Transport sector includes vehicles and aircraft, the devices and equipment that constitute them, energy and infrastructure technologies that serve as power sources for mobility, and operational and transportation efficiency technologies that contribute to reducing GHG emissions. It also includes technologies that serve as alternatives to physical mobility, such as VR and teleworking (Figure 7).

Figure 7: Overview of technologies related to the Mobility and Transport sector

Vehicle/aircraft design and manufacturing

- Electric vehicles
- Fuel cell vehicles
- Hybrid vehicles
- Low-GHG vessels
- Low-GHG aircraft
- Micromobility

…etc.

Operational and transport efficiency

- Battery diagnostics and management
- Energy efficiency (idling prevention, power control, charging management, etc.)
- Autonomous driving/automated driving
- Driving management
- Safety management
- Transport route optimization

…etc.

Alternatives to physical mobility

- VR
- Telework

…etc.

*In this analysis, patents referring to 'mobility or alternatives to physical movement' were included

Energy infrastructure

- Battery technologies
- Charging stations and charging systems
- Power distribution control for charging infrastructure

…etc.

Digital mobility services

- Ride sharing
- Multimodal transport platforms
- Mobility as a service (MaaS)

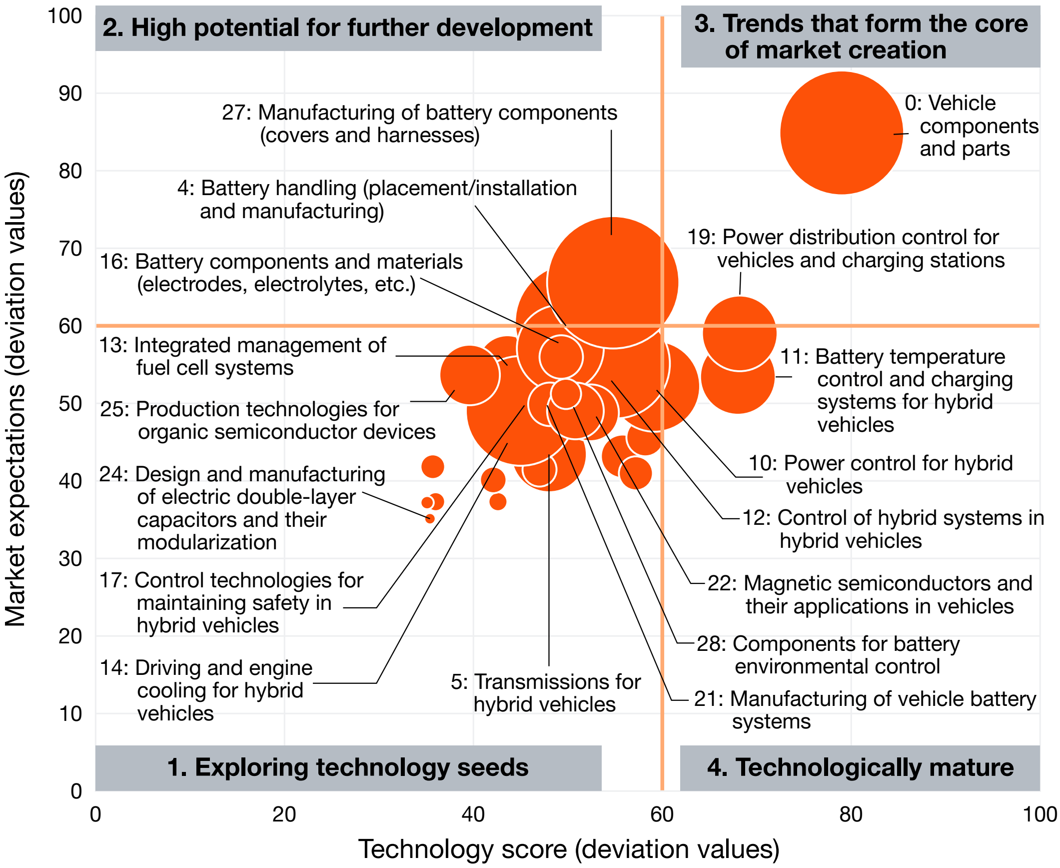
…etc.

Source: PwC

Technology trend

Figure 8 shows the current technology trends in the Mobility and Transport sector based on IBA analysis. 'Vehicle components and parts' exhibits both a high technology score and a high market expectation value, indicating that it is at the center of market formation. The technology clusters 'Manufacturing of battery components (covers and harnesses)' and 'Battery handling (placement/installation and manufacturing)' are in Quadrant 2. Although there remains room for further technological development, these clusters are already attracting significant investment, suggesting a high likelihood of continued technological advancement going forward. Technology clusters related to hybrid vehicles, battery technologies and semiconductor technologies are in Quadrant 1, encompassing clusters that have the potential to become next-generation trends.

Figure 8: Market expectations, technology scores and patent application counts for technologies in the Mobility and Transport sector



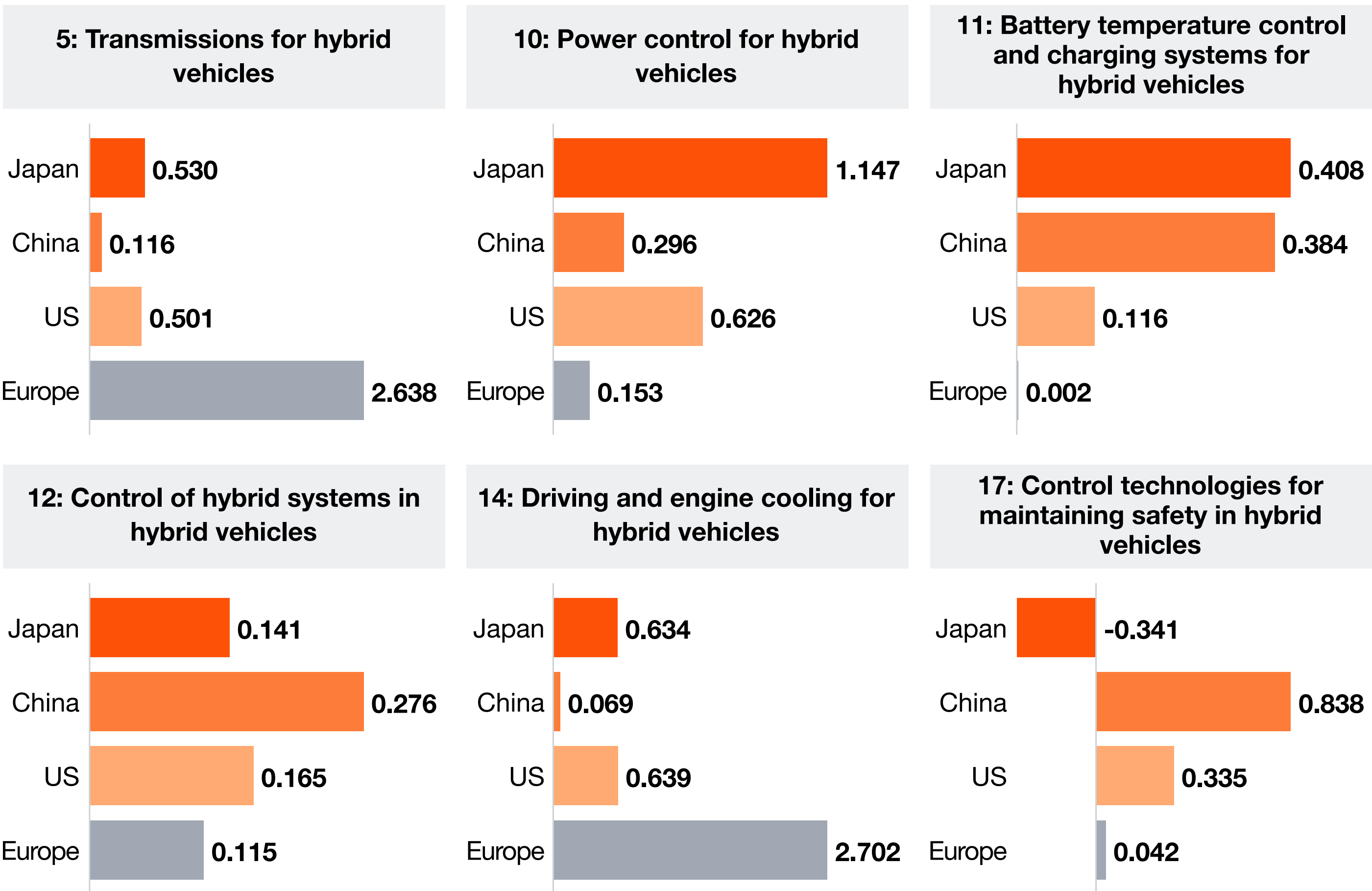
Source: PwC

Technology trends by country and region

We compare the technology trends of hybrid vehicle technologies, vehicle battery technologies and vehicle semiconductor technologies, which largely fall into Quadrants 1 and 2, across different countries and regions.

Figure 9 compares the average technology scores of hybrid vehicle-related technologies across different countries and regions. Japan demonstrates strong technological capabilities in power control, battery temperature control and charging systems, while Europe shows strengths in transmission technologies and engine cooling. China exhibits the second-highest technological capabilities after Japan in battery temperature control and charging systems, and it also shows strong capabilities in control technologies related to maintaining hybrid system control and safety. It should be noted that a negative technology score does not necessarily indicate low technological competitiveness; rather, it suggests that the technologies are being developed in a direction different from prevailing trends. Among the major Chinese patents that are driving trends in control technologies related to maintaining safety and other key functions, many involve technologies that enable safe movement by preserving minimum functionality while maintaining safety in the event of a failure. In contrast, many of Japan's major patents involve technologies that prevent accidents or the escalation of system damage by stopping or controlling the functions of specific components when failures or abnormalities occur. These directional differences are considered to be reflected in the scores.

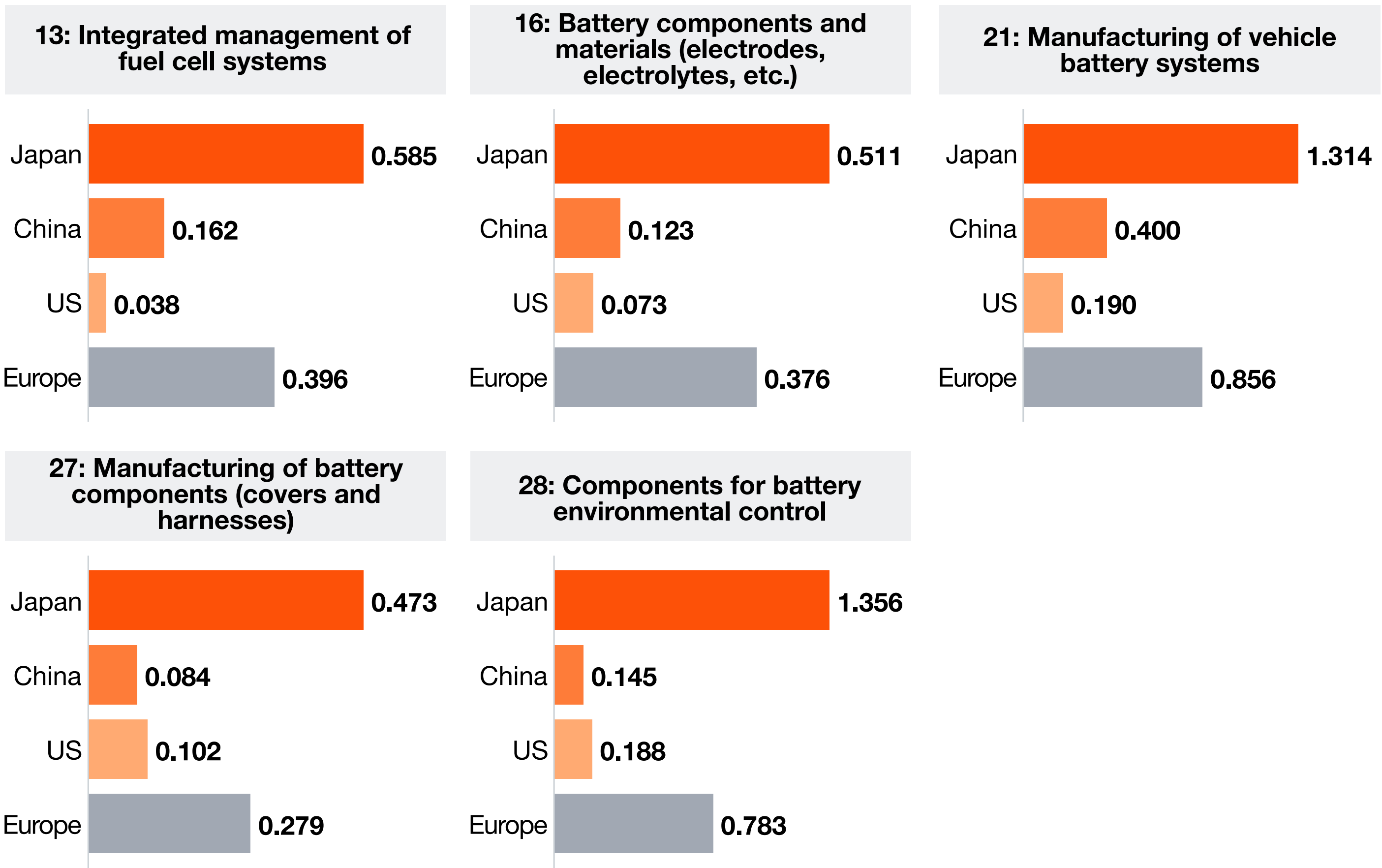
Figure 9: Technology scores for hybrid vehicle-related technologies by country and region



Source: PwC

Figure 10 shows the average technology scores for vehicle battery-related technologies by country and region. Vehicle batteries include fuel cells, liquid lithium-ion batteries and all-solid-state batteries. Across all of these technology clusters, Japan, followed by Europe, demonstrates strong technological capabilities.

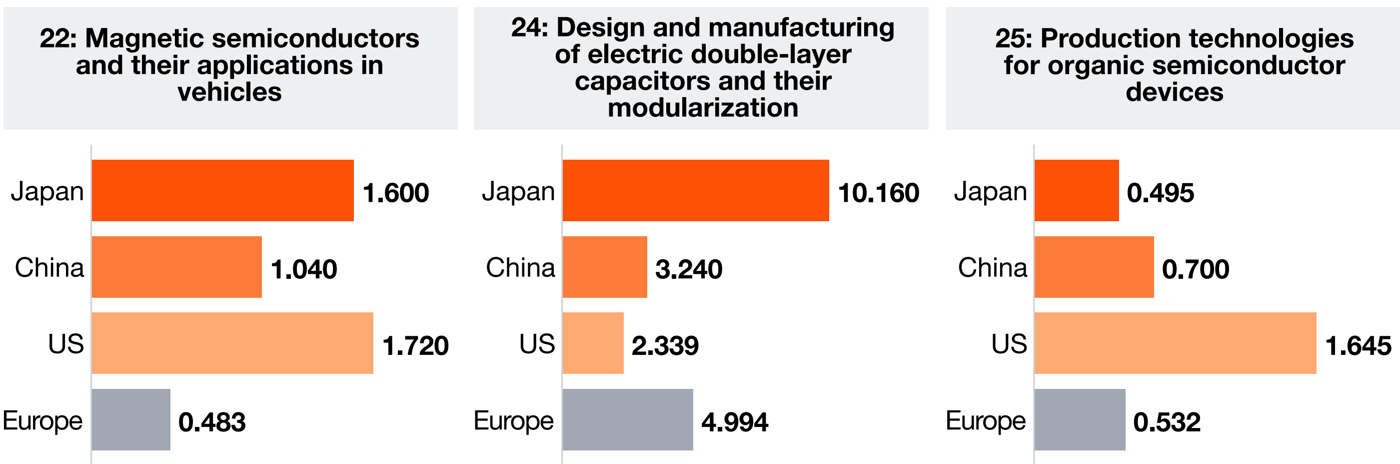
Figure 10: Technology scores for vehicle battery-related technologies by country and region



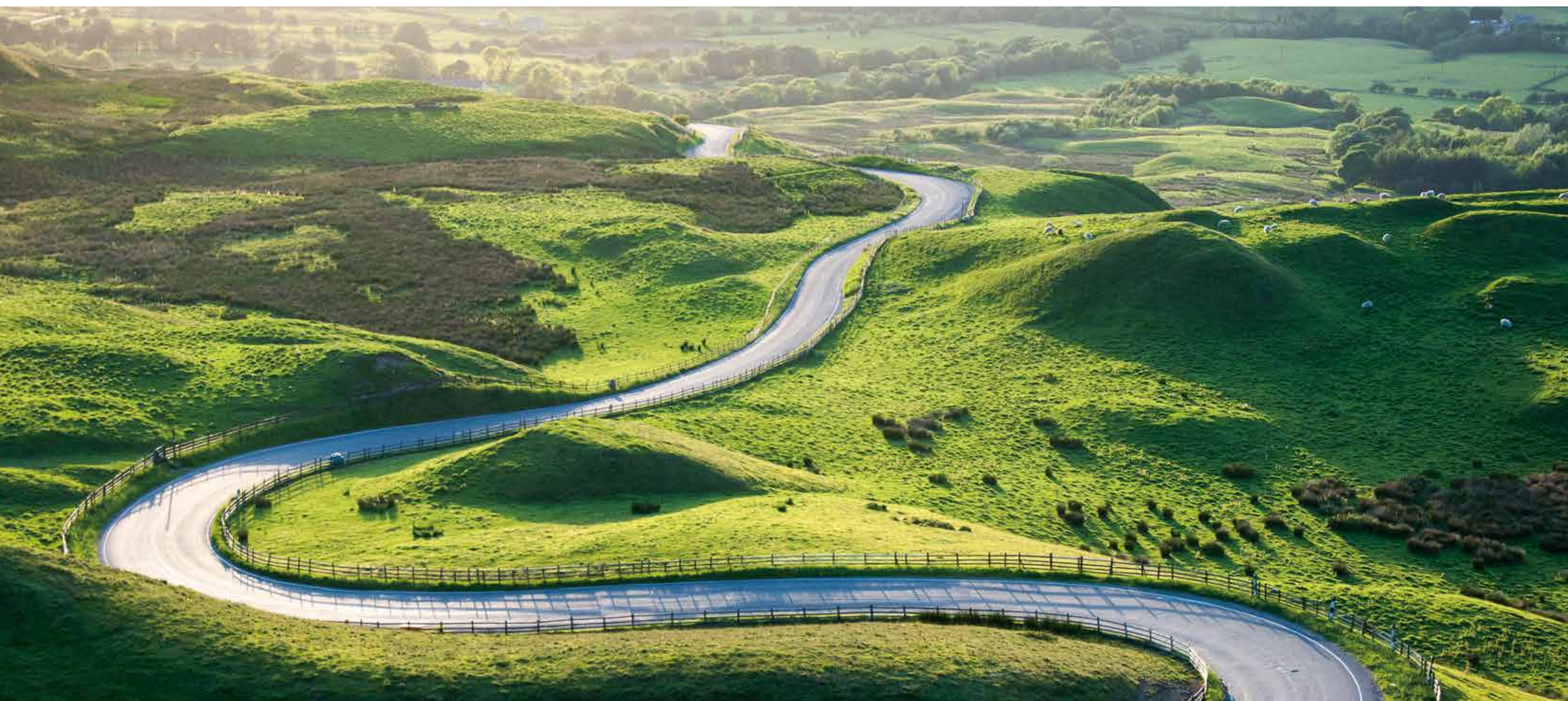
Source: PwC

Figure 11 shows the average technology scores for vehicle semiconductor technologies by country and region. Vehicle semiconductors include magnetic semiconductors, electric double-layer capacitors and organic semiconductors. The results show that the US has the highest technological capabilities in magnetic semiconductors, followed by Japan. Magnetic semiconductors are used in applications such as detecting the opening and closing of vehicle doors and windows, adjusting vehicle height and suspension, detecting motor rotational speed, and supporting functions such as speed sensing and ABS (anti-lock braking systems). Japan demonstrates the highest technological capabilities in electric double-layer capacitors, which are used in vehicle start-stop systems and regenerative braking systems for electric vehicles. The US has the highest scores for organic semiconductor devices. The US demonstrates strong technological capabilities in organic semiconductor devices, which are used in applications such as in-vehicle environment monitoring, touch interfaces for displays and instrument panels and are valued for their lightweight and flexible properties.

Figure 11: Technology scores for vehicle semiconductor technologies by country and region



Source: PwC



03

Climate Change Management and Reporting Sector

As shown in Figure 12, the Climate Change Management and Reporting sector includes technologies for monitoring, managing and reporting climate-related data at the corporate level, as well as technologies for monitoring and analyzing climate and environmental data at the global level. Image analysis and machine learning are also included in the analysis and evaluation of data. This analysis also includes technologies related to corporate-level climate change management, such as management technologies for production and manufacturing processes aimed at reducing GHG emissions, as well as technologies that improve energy efficiency.

Figure 12: Overview of technologies related to the Climate Change Management and Reporting sector

Corporate/organizational level		Global level
Management technologies for GHG reduction • Production management • Low-environmental-impact manufacturing processes • Energy efficiency • Data collection, processing and analysis (including IoT and machine learning) …etc.	**Technologies for monitoring, managing and reporting climate-related data** • Carbon emissions management systems/ carbon accounting tools • Environmental impact assessment tools • ESG risk management tools • Supply chain management systems • Waste tracking systems …etc.	**Technologies for monitoring and analyzing climate and environmental data** • Remote sensing (including communication and location-based technologies) • Data collection and analysis platforms • Data processing, analysis and evaluation (including image analysis and machine learning) • Climate simulation …etc.

Source: PwC

Technology trend

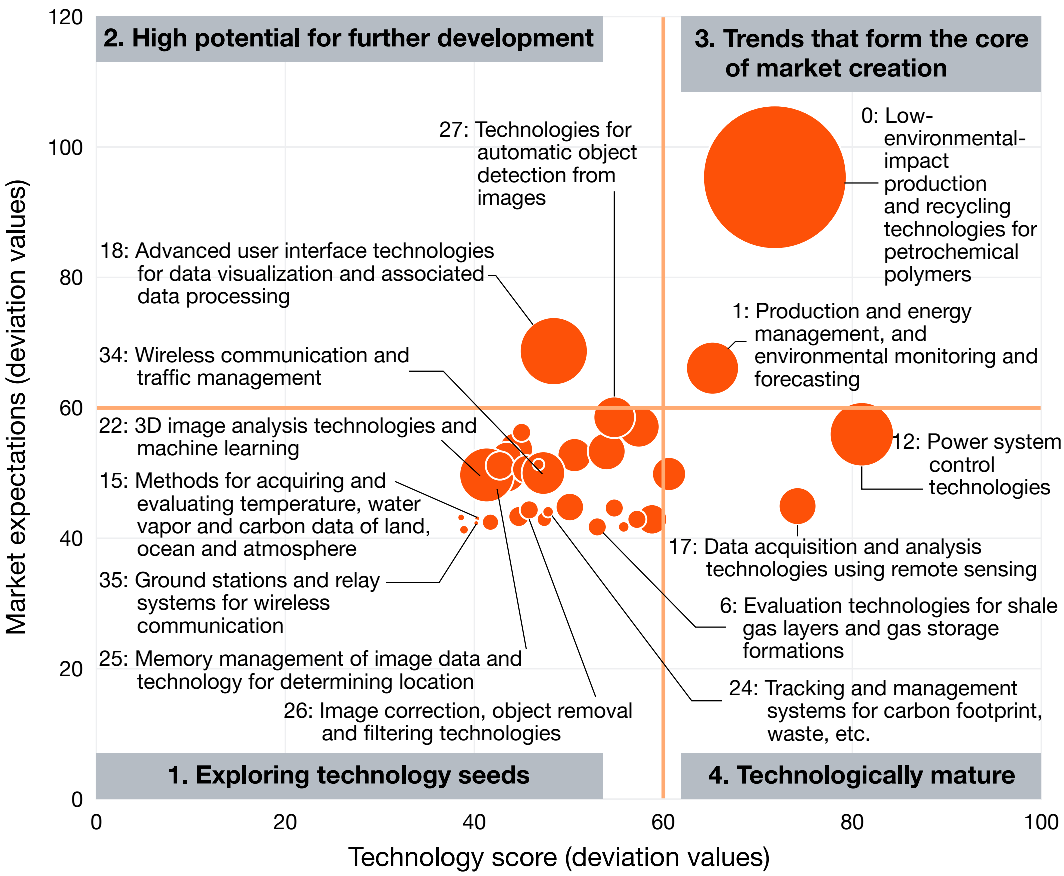
Figure 13 shows the technology trends in the Climate Change Management and Reporting sector analyzed using IBA.

From this chart, it can be seen that ‘Low-environmental-impact production and recycling technologies for petrochemical polymers’ and ‘Production and energy management, and environmental monitoring and forecasting’ have both high technology scores and high market expectation values, indicating that they are central technology areas in market formation. Both clusters relate to corporate-level management technologies for reducing GHG emissions. ‘Production and energy management, and environmental monitoring and forecasting’ also includes IoT-based data collection, machine learning and big data analytics.

‘Data acquisition and analysis technologies using remote sensing’ is located in Quadrant 4. This includes technologies that use remote sensing to collect and analyze environmental data such as land use, vegetation and sea surface temperature, as well as technologies that utilize satellite data for climate forecasting, reconstructing land surface temperatures, analyzing urban heat island effects, and performing simulations and assessments for natural disaster prediction. On the other hand, technologies for acquiring Earth and climate data through methods such as remote sensing, as well as related technologies including data processing, image processing, geolocation technologies and communication technologies, are largely found in Quadrant 1. These also include data processing and forecasting technologies that leverage machine learning and AI. Although remote sensing and simulation technologies have reached a certain level of maturity, ongoing technological development suggests continued efforts to achieve higher-precision measurement, evaluation and simulation.

'Tracking and management systems for carbon footprint, waste, etc.' is also in Quadrant 1. This includes technologies such as systems for measuring and tracking corporate carbon emissions, tools for evaluating and managing sustainability indicators, product traceability support systems, and product authentication using blockchain technologies. Patents related to the use of machine learning and AI are also observed in this cluster. Although these technologies are attracting growing attention from the perspective of regulatory compliance and information disclosure, they are still at a developmental stage, and the use of machine learning and AI has the potential to enable more accurate and faster data processing.

Figure 13: Market expectations, technology scores and patent application counts for technologies in the Climate Change Management and Reporting sector



Source: PwC

Financial Services Sector

Figure 14 provides an overview of technologies in the Financial Services sector. This sector includes financial services and related technologies that promote climate change mitigation and adaptation, such as technologies associated with financial activities and financial products including green finance, sustainable supply chain finance and sustainable funds. It also includes services and technologies related to the evaluation and support of financial activities, such as sustainability indices, carbon footprint indicators, supply chain visualization technologies and electricity trading platforms, as well as preparedness for climate-related risks, including risk forecasting and the development of insurance products. In this analysis, technologies related to the digitalization of financial activities are also included as technologies that help reduce the impact of financial services on climate change.

Figure 14: Overview of technologies related to Financial Services sector

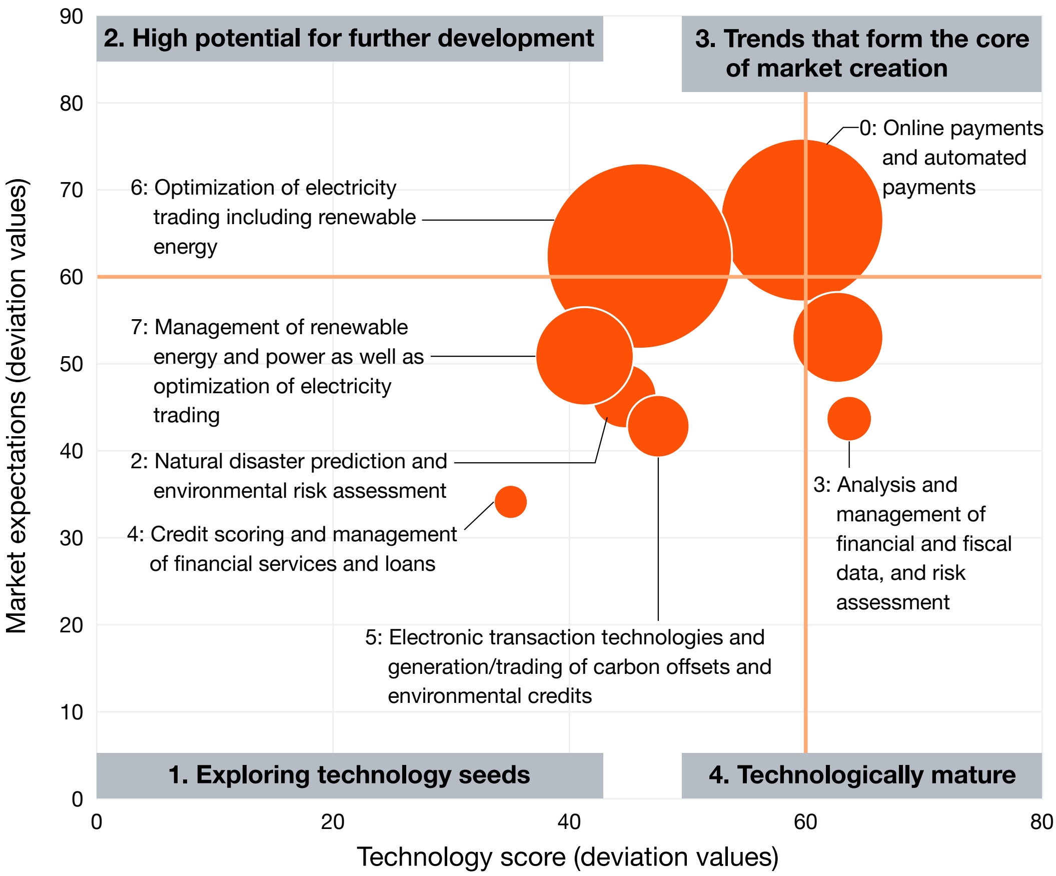
Financial services and related technologies that promote climate change mitigation and adaptation		Technologies that reduce the climate impact of financial services
Technologies related to financial activities and financial products • Green finance (green bonds, sustainability bonds, sustainability-linked bonds, green loans, sustainability-linked loans, etc.) • Sustainable supply chain finance • Sustainable funds …etc.	**Services and technologies for evaluating and supporting financial activities** • Sustainability indices • Carbon footprint indicators • Supply chain visibility (including digital product passports) • Electricity trading platforms …etc. **Preparedness for climate-related risks** • InsurTech (risk forecasting for natural disasters and development of insurance products) …etc.	**Digitalization of financial activities** • Online banking • Internet-only banks • Digital payments …etc.

Source: PwC

Technology trend

Figure 15 shows the current technology trends in the Financial Services sector related to climate tech. 'Online payments and automated payments' is in Quadrant 2, but it is located close to Quadrant 3 which represents the core of market formation. This includes blockchain technologies for transactions. Similarly, 'Optimization of electricity trading including renewable energy' is in Quadrant 2, and it is attracting significant investment, indicating a high likelihood that further technological development will continue. Blockchain technologies are also included in this cluster and are used for multi-energy trading. Quadrant 1 includes a wide range of financial services and related technologies that promote climate change mitigation and adaptation, such as 'Credit scoring and management of financial services and loans,' 'Electronic transaction technologies and generation/trading of carbon offsets and environmental credits' and 'Natural disaster prediction and environmental risk assessment,' which is also closely related to insurance services. Although the level of attention and importance placed on these services seems to have been increasing in recent years, the technology scores and market expectations of the related technologies indicate that they are still in the seed stage. In all of these technology clusters, technologies using blockchain to enhance the transparency and security of transactions are included.

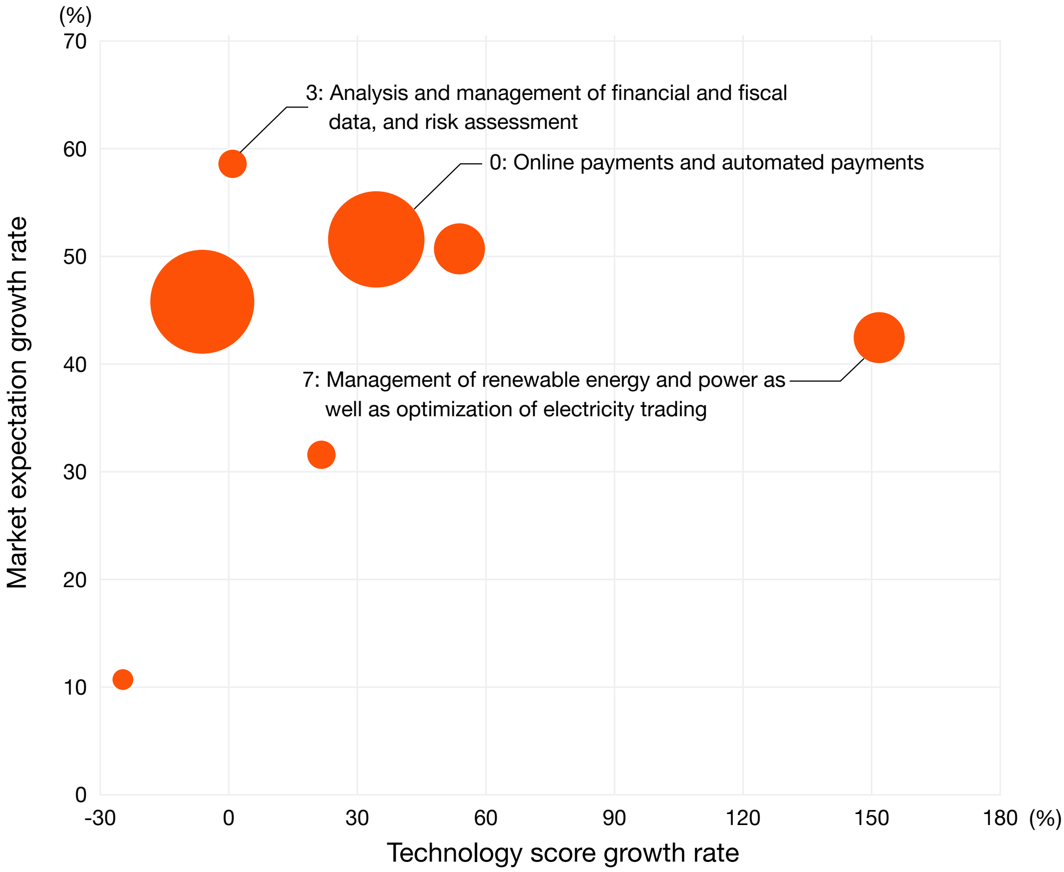
Figure 15: Market expectations, technology scores and patent application counts for technologies in the Financial Services sector



Source: PwC

Figure 16 presents an analysis of technology score growth rates and market expectation growth rates conducted using IBA. The horizontal axis represents the growth rate of technology scores, the vertical axis represents the growth rate of market expectations, and the size of the circles indicates the number of patents included in each cluster. The growth rate of technology scores is particularly high in 'Management of renewable energy and power as well as optimization of electricity trading,' indicating that this area is experiencing significant technological growth. The item with the highest growth rate in market expectations is 'Analysis and management of financial and fiscal data, and risk assessment,' and this rise in attention is presumed to reflect recent developments such as rating agencies using AI to evaluate companies' integrated reports and financial institutions utilizing AI to analyze climate-related financial risks.

Figure 16: Technology scores, market expectations and patent application counts in the Financial Services sector



Source: PwC

05

GHG Capture, Removal and Storage Sector

As shown in Figure 17, the GHG Capture, Removal and Storage sector includes technologies related to carbon capture, utilization and storage (CCUS), as well as technologies addressing GHGs other than CO_2. In CCUS, the CO_2 that has been separated and captured can be used in various ways: it may be directly utilized through methods such as carbon dioxide use or enhanced oil recovery; it may be used for the production of chemical products, including polymers, and synthetic fuels through reductive or non-reductive carbon recycling; or it may be used as carbonates in concrete or cement. Alternatively, once separated and captured, it is safely and securely stored.

Figure 17: Overview of technologies related to GHG Capture, Removal and Storage sector

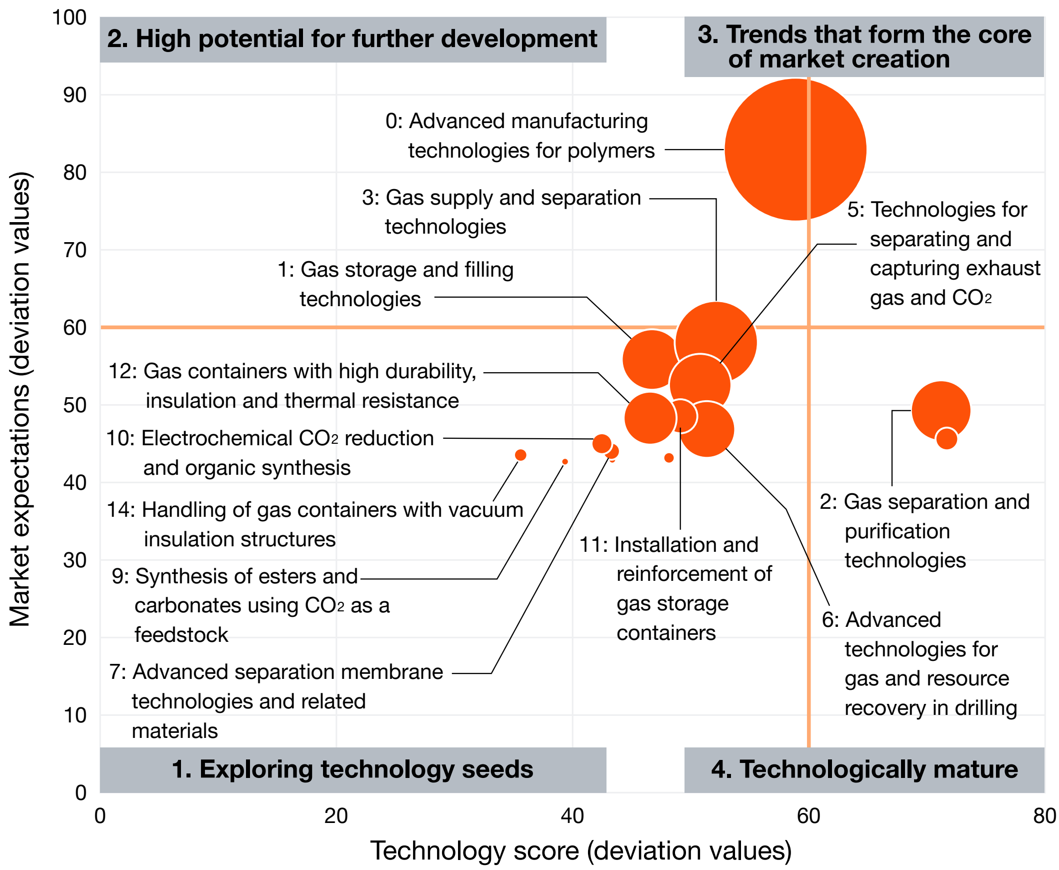
Carbon capture, utilization and storage (CCUS)			Measures for GHGs other than CO_2
Separation and capture • DAC: Direct Air Capture • Chemical absorption • Physical absorption • Membrane separation • Adsorption • Oxy-fuel combustion • Chemical looping …etc.	**Use** • Conversion of CO_2 into hydrocarbons via reduction (methanation, electrochemical synthesis, carboxylation, artificial photosynthesis, etc.; including synthetic fuel production) • Non-reductive conversion of CO_2(urethane synthesis, polycarbonate synthesis, etc.) • Mineralization as carbonates (concrete, cement, steel slag, etc.) • Carbon dioxide utilization (refrigerants, beverages/food, microalgae cultivation, etc.) • CO_2-EOR: Enhanced oil recovery …etc.	**Storage** • Geological storage • Reuse of depleted oil wells • Above-ground mineral storage • Biochar production and landfilling • Biological CO_2 fixation (forests, agricultural soil carbon, urban greening, marine biological systems) • DACCS: Direct Air Capture with Carbon Storage • BECCS: Bioenergy with Carbon Capture and Storage …etc.	**Measures for fluorinated gases, nitrous oxide and methane** • Recovery, decomposition and neutralization of fluorinated gases • Green refrigerants • Reduction of GHGs from livestock and farmland …etc.
Transport • Pressure tanks • Pipeline …etc.			

Source: PwC

Technology trend

Figure 18 shows the technology trends in the GHG Capture, Removal and Storage sector. 'Advanced manufacturing technologies for polymers' is in Quadrant 2, where further technological development is highly likely, indicating that strong market expectations are growing for carbon utilization technologies for chemical products. Technologies related to gas separation, capture and purification are located in Quadrants 4 and 1, where the market expectations for them are relatively high. Technologies related to gas storage and gas containers are located in Quadrant 1. 'Electrochemical CO_2 reduction and organic synthesis' and 'Synthesis of esters and carbonates using CO_2 as a feedstock' are also located in Quadrant 1, but these technologies rank among the highest in the separately analyzed growth rates of technology scores and market expectations. Including both reductive and non-reductive approaches, technologies for converting CO_2 into chemical products can be regarded as technologies that will continue to merit attention.

Figure 18: Market expectations, technology scores and patent application counts for Technologies in the GHG Capture, Removal and Storage sector



Source: PwC

06

Food, Agriculture and Land Use Sector

As shown in Figure 19, the Food, Agriculture and Land Use sector covers the design, development and control of equipment and materials, the production of agricultural products, and technologies related to food processing and storage. With respect to the design, development and control of equipment and materials, the scope includes machinery that improves the efficiency of agricultural operations and low-GHG, high-energy-efficiency equipment. In agricultural production through food processing and storage, the scope includes not only crop cultivation technologies but also a wide range of technologies that contribute to GHG reduction in food systems and sustainable land use, as well as technologies such as alternative foods, low-GHG proteins and cellular agriculture that contribute to reducing GHG emissions from livestock.

It should be noted that the 2024 research report, "Transformations and Alternatives at the Dining Table: Nature Positive and the Food Value Chain*[17]" analyzes areas further downstream in the food value chain, including distribution, sales and consumption, and therefore does not fully coincide with the scope of the present analysis. Because a different scope is covered, differences arise between the two analyses in the granularity and positioning of technology clusters in the trend analysis.

Figure 19: Overview of technologies related to Food, Agriculture and Land Use sector

Design, development and control of agricultural equipment and materials	Crop production	Food processing and storage
Agricultural efficiency equipment, and low-GHG or high-energy-efficiency equipment • Design, development, control and auto-steering of agricultural machinery • Robotics • Design, development and control of ICT and IoT devices …etc.	**GHG reduction in the food system and sustainable land use** • Land-use management in agriculture • Land and marine conservation • Cultivation management (soil management, planting management, growth management, etc.) • Precision agriculture and smart farming • Urban agriculture (including plant factories, vertical farming, hydroponics, greenhouse cultivation, aquaponics, etc.) • Fertilizers • Agricultural biotechnology and genomics …etc.	**Reduction of GHGs from livestock** • Alternative foods • Low-GHG proteins • Cellular agriculture • Livestock feed …etc.

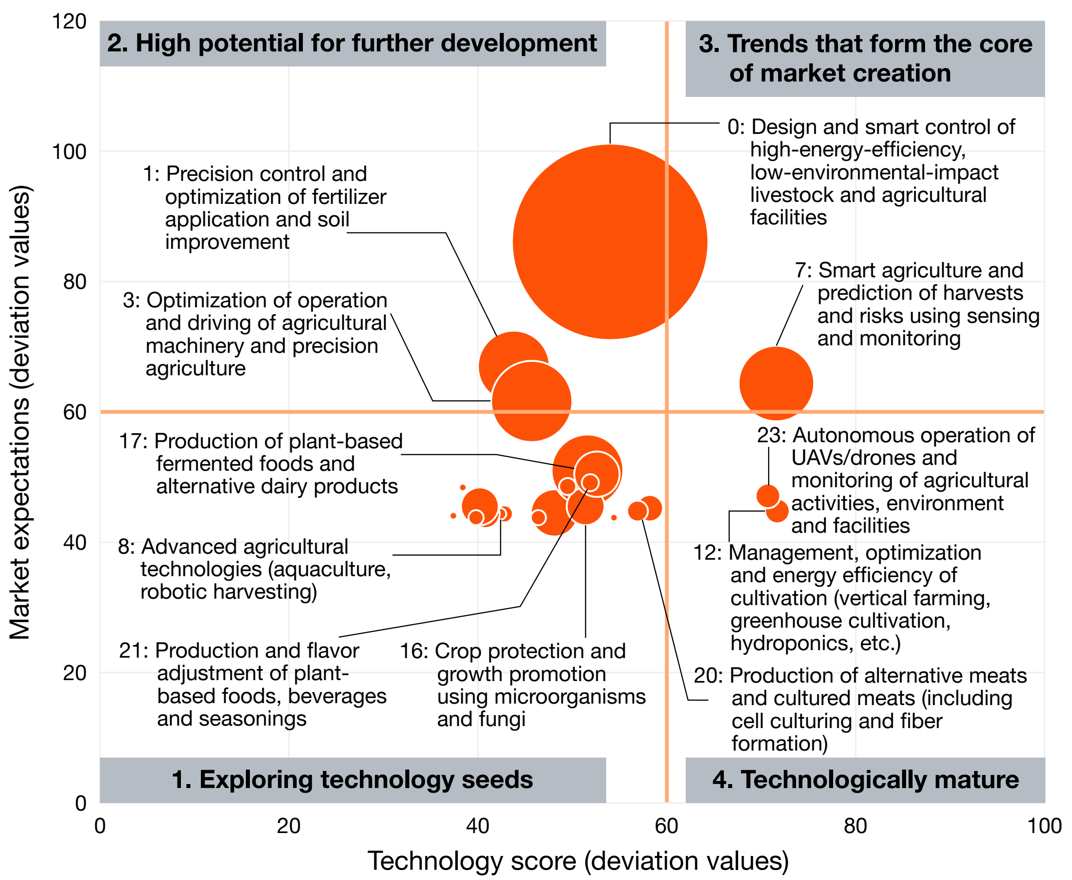
Source: PwC

*17 PwC Consulting LLC. 'Transformations and Alternatives at the Dining Table: Nature Positive and the Food Value Chain.' 22 July, 2024.
https://www.pwc.com/jp/en/knowledge/thoughtleadership/nature-positive-food-value-chain.html

Technology trend

Figure 20 shows the technology trends in the Food, Agriculture and Land Use sector. 'Smart agriculture and prediction of harvests and risks using sensing and monitoring' is located in Quadrant 3, with both high technology scores and high market expectations. This includes the use of drones, sensors and IoT, as well as predictive technologies based on artificial intelligence and machine learning. 'Design and smart control of high-energy-efficiency, low-environmental-impact livestock and agricultural facilities,' which includes equipment control through environmental monitoring, and 'Precision control and optimization of fertilizer application and soil improvement' are located in Quadrant 2, where technologies are attracting significant investment and are highly likely to see further development. In addition, 'Optimization of operation and driving of agricultural machinery and precision agriculture' is located in this quadrant, and it includes driving and autonomous control of agricultural vehicles and agricultural robots, as well as technologies that improve the accuracy of agricultural operations by utilizing sensors, image recognition, and field data. It can be said that technologies related to the smartization of agriculture and precision control are attracting investment. In Quadrant 1, the scope includes advanced agricultural technologies such as aquaculture, technologies for crop protection and growth promotion using microorganisms and fungi, as well as technologies related to the production of alternative and cultured meats and to plant-based alternative dairy products, foods and beverages. The development of alternative foods is analyzed in detail in the aforementioned research report*[17].

Figure 20: Market Expectations, technology scores and patent application counts for technologies in the Food, Agriculture and Land Use sector



Source: PwC

07

Industry, Manufacturing and Resource Management Sector

As shown in Figure 21, the Industry, Manufacturing and Resource Management sector includes technologies related to low-environmental-impact material and product design, efficiency and optimization of manufacturing processes and production, and the management, treatment and recycling of waste. These technologies are expected to reduce GHG emissions and waste across all production activities.

Figure 21: Overview of technologies related to Industry, Manufacturing and Resource Management sector

Design

Low-environmental-impact materials and product design
- Low-GHG chemicals
- Low-GHG metals (iron, steel, aluminum, etc.)
- Low-GHG composite materials (concrete, cement, etc.)
- Alternative plastics
- Alternative refrigerants
- Modular design
- Life cycle assessment

…etc.

Manufacturing and production

Manufacturing process efficiency and optimization
- Energy-saving or high-energy-efficiency processes
- High resource-efficiency processes

…etc.

Production efficiency and optimization
- Demand forecasting and production scheduling optimization
- Maintenance efficiency

…etc.

Waste and circularity

Waste management, treatment and circularity
- Waste sorting, separation and collection
- Waste management
- Waste treatment and neutralization
- Recycling and resource circularity

…etc.

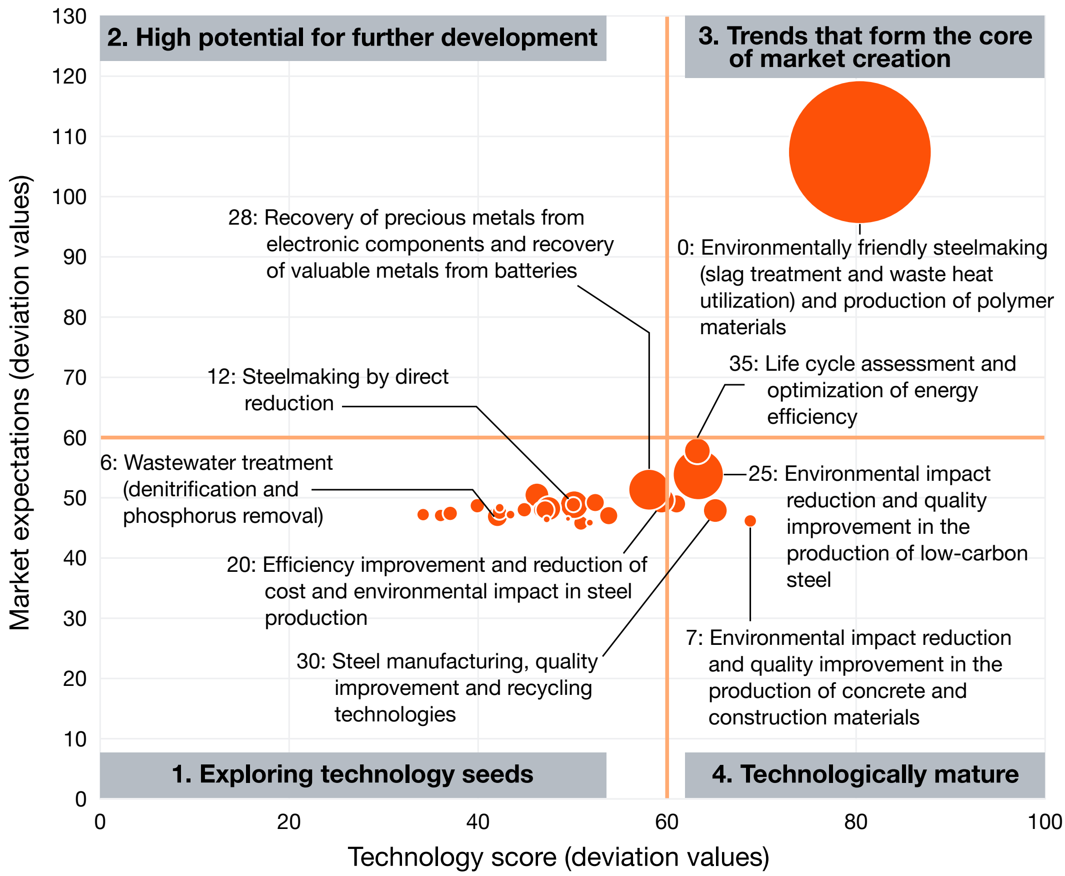
Source: PwC

Technology trend

Figure 22 shows the technology trends in the Industry, Manufacturing and Resource Management sector. 'Environmentally friendly steelmaking (slag treatment and waste heat utilization) and production of polymer materials' with the largest number of patents shows both high technology scores and high market expectations, indicating that it is a core technology area in market formation. 'Environmental impact reduction and quality improvement in the production of low-carbon steel,' 'Environmental impact reduction and quality improvement in the production of concrete and construction materials' and 'Steel manufacturing, quality improvement and recycling technologies' are located in Quadrant 4, indicating that many technologies with high technology scores are related to low-environmental-impact material and product design and manufacturing processes. In addition, Quadrant 4 also includes technologies related to 'Life cycle assessment and optimization of energy efficiency,' which encompass virtual power plant technologies for improving energy efficiency and optimizing power supply. Among the technology clusters in Quadrant 1, those with the largest numbers of patents include 'Recovery of precious metals from electronic components and recovery of valuable metals from batteries,' 'Steelmaking by direct reduction' and 'Efficiency improvement and reduction of cost and environmental impact in steel production.' Steelmaking by the direct reduction method, which reduces iron ore directly using gases such as hydrogen without the use of coke, is attracting attention as an important decarbonization technology, and technological development is being actively pursued in Japan as well.*[18] In addition, Quadrant 1 also includes technologies such as 'Wastewater treatment (denitrification and phosphorus removal),' which encompass biological methods.

*18 New Energy and Industrial Technology Development Organization 'Green Innovation Fund Project / Hydrogen Utilization in the Steelmaking Process: FY2025 Working Group Report.' 16 April, 2025. https://www.meti.go.jp/shingikai/sankoshin/green_innovation/energy_structure/pdf/028_04_00.pdf

Figure 22: Market expectations, technology scores and patent application counts for technologies in the Industry, Manufacturing and Resource Management sector



Source: PwC

Built Environment Sector

As shown in Figure 23, the Built Environment sector encompasses a wide range of technologies that reduce environmental impact across the entire lifecycle of a building. These include the selection of materials, fixtures and equipment that promote efficient energy use and energy conservation; design approaches that support efficient energy use and reduced environmental impact; technologies that improve efficiency and reduce energy consumption at construction sites; technologies that enhance efficiency and energy conservation in operations and facility management; and technologies for the management, treatment and recycling of waste.

Figure 23: Overview of technologies related to Built Environment sector

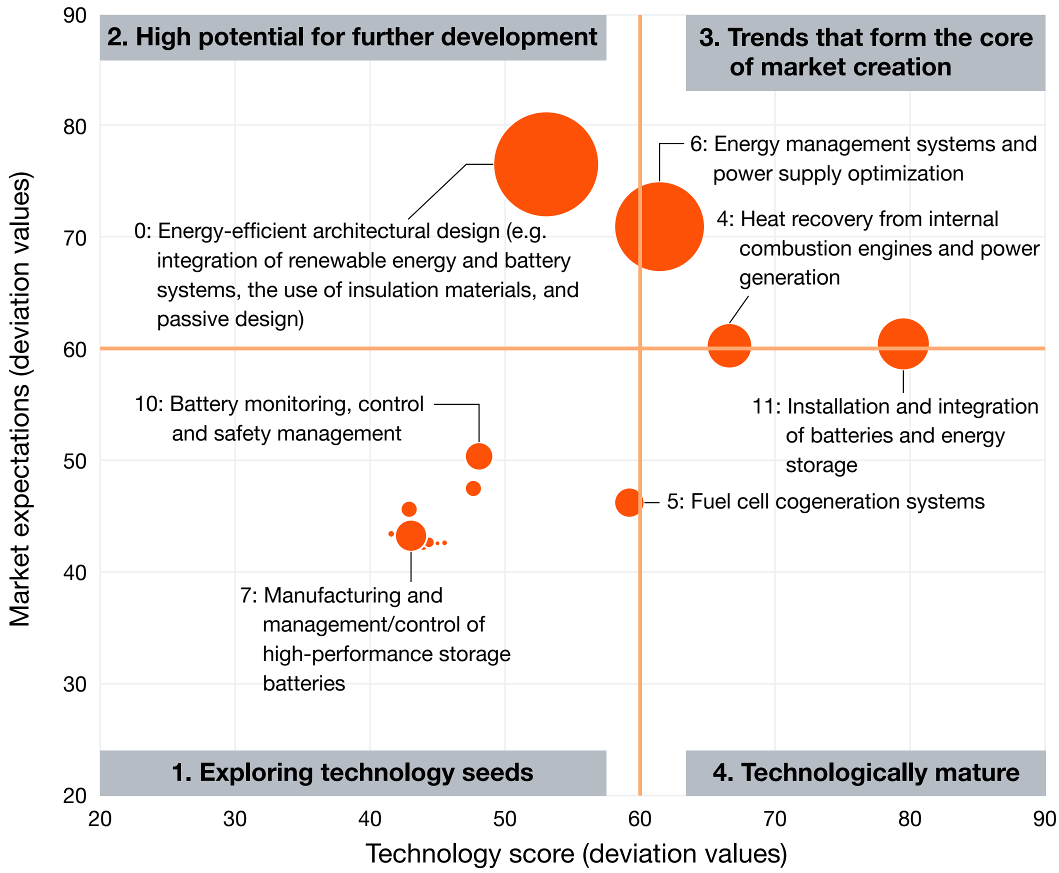
Design		Architecture	Operation and management	Waste and circularity
Selection of materials, fixtures and equipment for effective energy use and energy conservation • High-performance insulation materials • High-efficiency lighting • Low-emissivity window glass • Secondary batteries (storage batteries) and fuel cells • Thermal storage systems • Life cycle assessment …etc.	**Design for efficient energy use and reduced environmental impact** • Introduction of renewable energy • Energy-saving design • Passive design • Greening …etc.	**Efficiency and energy-saving at construction sites** • Construction efficiency through the use of ICT • CO_2 reduction from heavy machinery through fuel-efficient operation and next-generation fuels …etc.	**Energy-efficient operation and energy-saving measures** • Smart building systems(including HVAC systems: heating, ventilation and air conditioning, as well as lighting and elevator control) • Smart management of equipment and devices • Energy management system • Energy efficiency across urban spaces and communities …etc.	**Waste management, treatment and circularity** • Waste sorting, separation and collection • Waste management • Waste treatment and neutralization • Recycling and resource circularity (including CO_2 mineralization in cement) …etc.

Source: PwC

Technology trend

Figure 24 shows the current technology trends in the Built Environment sector. Technologies related to 'Energy management systems and power supply optimization' are located in Quadrant 3, where both the technology score and market expectations are high, forming the core of the market. This area includes technologies such as energy supply-demand forecasting using smart meters and big data analytics, as well as power control through smart grids. Quadrant 3 also includes 'Installation and integration of batteries and energy storage' and 'Heat recovery from internal combustion engines and power generation.' Here, 'internal combustion engines' primarily refers to those used in cogeneration systems for large facilities, emergency power generators and mobility applications such as private vehicles. Quadrant 2, which is characterized by high market expectations and significant potential for further technological development, includes technologies related to 'Energy-efficient architectural design (e.g. integration of renewable energy and battery systems, the use of insulation materials, and passive design)'. Quadrant 1 includes, in descending order of patent volume, 'Manufacturing and management/control of high-performance storage batteries,' 'Fuel cell cogeneration systems' and 'Battery monitoring, control and safety management.' For batteries, ongoing development efforts are focused not only on improving performance and safety, but also on advancing their integration into high-efficiency energy systems.

Figure 24: Market expectations, technology scores and patent application counts for technologies in the Built Environment sector



Source: PwC

Characteristics of Japan in the Climate Tech and Strategic Directions for Future Efforts

We have reviewed global technology trends and country- and region-specific patterns across the various Climate Tech sectors. Here, we conduct an analysis from the perspective of players (universities and research institutions, startups, companies excluding startups [hereafter referred to as 'companies']) and examine Japan's distinctive characteristics and the strategic directions it should pursue.

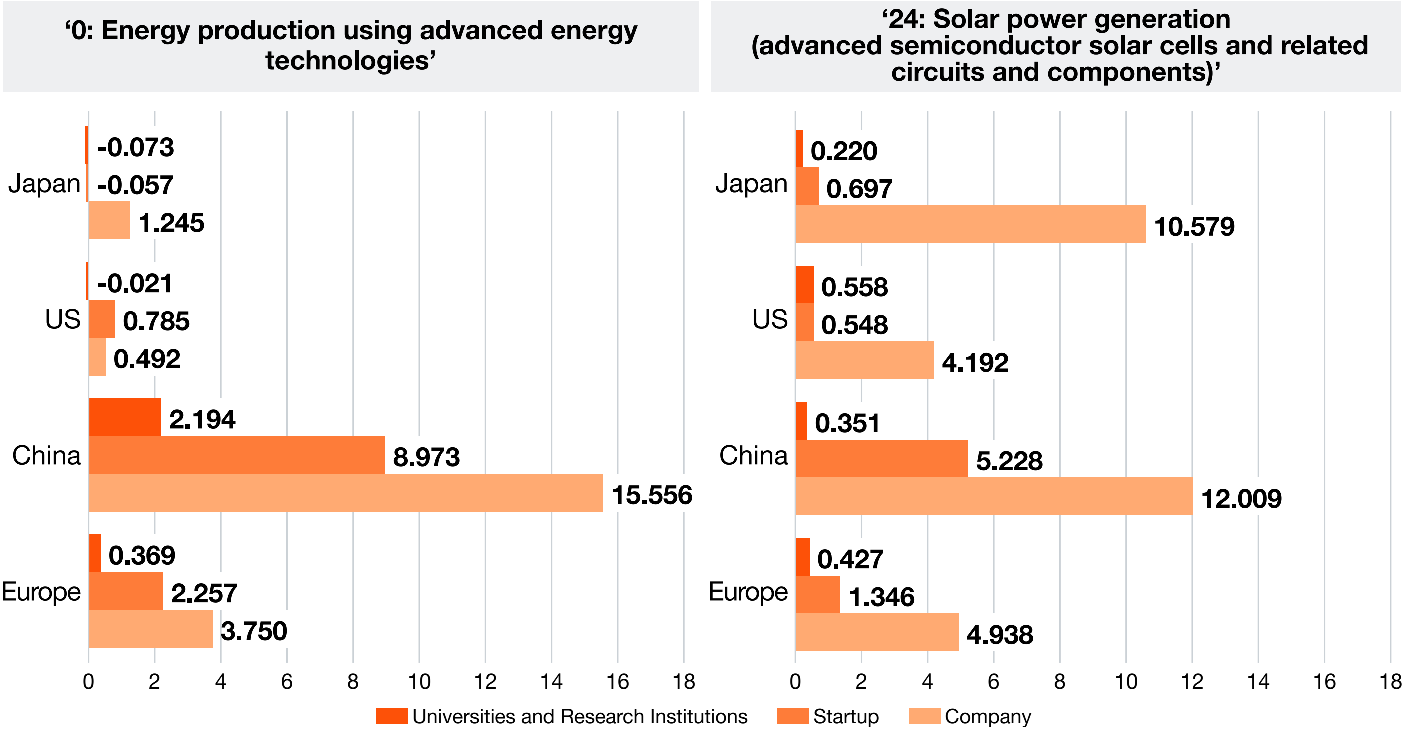
For our analysis, we focused on the Energy sector, which—according to a Climate Tech investment report*[19]—has recently attracted significant attention as a key destination for sector-specific investment. Figure 25 presents the average technology scores by country and region, broken down by player type, for two technology clusters within the Energy sector that rank high in market expectations according to the IBA analysis: 'Energy production using advanced energy technologies' and 'Solar power generation (advanced semiconductor solar cells and related circuits and components).' For each technology cluster, we identified the top 30 players by technology score in each country and region, separately for universities and research institutions, startups, and companies, then calculated the average technology score for each group.

Across both technology clusters, Japan shows a noticeably smaller average technology score for startups compared with companies, relative to other countries and regions. For 'Energy production using advanced energy technologies,' universities and research institutions, together with startups in Japan, show negative technology scores where those of companies are positive. Although the average technology score of US companies is lower than that of Japanese companies, the fact that US startups exceed their own corporate average makes the relative contrast particularly striking. In 'Solar power generation (advanced semiconductor solar cells and related circuits and components),' all countries and regions commonly show the highest average technology scores among companies. However, in Japan, the average score for startups is noticeably smaller relative to that of companies. It also shows that the average scores of universities and research institutions are relatively low in Japan when compared with those in the US and Europe.

These results suggest that, at least for these high-market-expectation technologies, large companies are driving technological development in Japan, while the relative technological capabilities of universities, research institutions and startups have not yet fully developed. Amid concerns about a shrinking economic scale and declining international competitiveness due to Japan's aging population and declining birthrate, it is considered necessary for companies, universities, research institutions and startups to comprehensively strengthen their competitiveness and to collaborate with one another in order to efficiently improve Japan's international competitiveness.

*19 PwC 'State of Climate Tech 2024: Seeking an edge as deal-making slows' 03 Dec 2024. https://www.pwc.com/gx/en/issues/esg/climate-tech-investment-adaptation-ai.html

Figure 25: Comparison of average technology scores by player type across countries and regions



*For each technology cluster, technology scores of the top 30 players in each country and region are averaged separately for universities and research institutions, startups, and companies excluding startups

Source: PwC

As related initiatives, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) has, since FY2023, launched programs that support basic research, talent development and industry-academia collaboration, such as the Innovative GX Technology Creation Program (GteX) and Advanced Low-Carbon Technology Research and Development (ALCA-Next).*[20] At the same time, concerns over the relatively small number of climate-tech startups in Japan, compared with other countries, and the importance of fostering such startups are also being discussed from the perspective of industrial development policy.*[21] In Japan, the government has historically promoted policies related to industrial structure and industrial location since the period of high economic growth. However, in light of increasing uncertainty, a policy direction is now being discussed in which the government shifts to a supportive role for companies aiming to strengthen their competitiveness.*[22] Against this backdrop, industrial location decisions are expected to place greater emphasis on alignment with existing infrastructure, the competitiveness and growth potential of development plans including the participation of startups and venture companies, and the commitment of local governments.*[22] Given this context, it will be essential for companies, startups, universities, research institutions and local governments to work together strategically to formulate a shared vision, drawing on data-driven and objective analyses of technology trends and competitiveness, and to pursue the development of climate-tech and GX technologies as well as competitive industrial location strategies.

*20 Subcommittee on Innovative GX Technology Development. 'Interim Summary of Discussions on the Direction of Research and Development Required of Academia for Achieving GX.' October 2024.
https://www.mext.go.jp/content/20241031-mxt_kankyou-000038563-1.pdf

*21 GX Implementation Promotion Office, Cabinet Secretariat. 'On GX Industrial Location Policy for Realizing a GX-Oriented Industrial Structure — Secretariat Materials for the 4th Meeting of the Working Group on GX Industrial Location for Achieving a GX-Oriented Industrial Structure.' 5 August, 2025.
https://www.cas.go.jp/jp/seisaku/gx_jikkou_kaigi/sangyoritchi_wg/dai4/shiryo.pdf

*22 GX Implementation Promotion Office, Cabinet Secretariat. 'Key Issues in Energy and GX Industrial Location Policy.' 3 October, 2024.
https://www.cas.go.jp/jp/seisaku/gx_jikkou_kaigi/senmonka_wg/dai8/siryou2.pdf

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