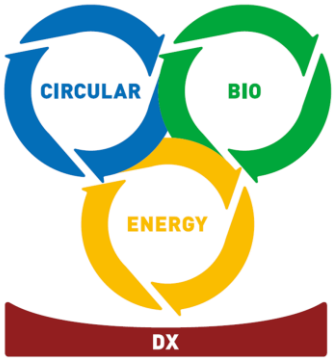
TSC Foresight

NEDO

Directions of Innovation in a Post-COVID-19 Society

–Three years have passed since the outbreak of COVID-19 pandemic. How has the world and Japan changed during the years in which the Russian invasion of Ukraine has also occurred, and what will be required from now on?–

Excerpt From the Original Report in Japanese



New Energy and Industrial Technology Development Organization (NEDO)

Technology Strategy Center (TSC)

Preface

In June 2020, as COVID-19 became a global pandemic, the TSC released a report titled “Social Changes and Expected Innovation Visions after the COVID-19 Crisis.” Since then, we can say that it has been a tumultuous three years in which the global situation has changed dramatically and various issues have been highlighted, such as the new crisis of the Russian invasion of Ukraine, as we fight against the fear of the virus.

TSC Executive Director
Dr. KISHIMOTO Kikuo

Under these circumstances, people are becoming increasingly anxious, and the social situation is becoming increasingly uncertain. NEDO’s Technology Strategy Center (TSC), whose mission is “to catch moves, design our future, and show strategies forward,” conducted a survey and analysis to look back and reassess how the world and Japan have changed over the past three years, and what will be required in the future.

The world will continue to change from moment to moment, and we hope that the issues outlined in this report will serve as a basis for discussion toward a better society and the realization of people’s wellbeing, even if only a little.

NEDO’s TSC will continue to provide timely information from global and diverse perspectives to help solve the social issues we face in the future.

If you have any questions or comments, please feel free to contact us at the TSC.

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Introduction

- At the time when humankind faced the unknown novel coronavirus (COVID-19) and uncertainty for the future, NEDO published a report titled “Social Changes and Expected Innovation Visions after the COVID-19 Crisis” (hereinafter referred to as the “COVID-19 Report 2020”) in June 2020 to predict and outline the social changes and values to be brought by COVID-19 and directions of innovation after the COVID-19 pandemic.

- Three years after the COVID-19 pandemic, the world has changed rapidly not only because of COVID-19 but also due to the Russian invasion of Ukraine, the intensifying of the battle for supremacy between the United States and China, and the growing momentum toward carbon neutrality by 2050. For this reason, in this report, we have surveyed and analyzed the changes and trends over the past three years without limiting ourselves to factors related to COVID-19 to see how much progress has actually been made in the predictions assumed in the COVID-19 Report 2020 and what new trends and innovations are emerging in a post COVID-19 society.

- Specifically, the survey was conducted with the following two themes, based on the six social changes and 13 fields of innovation envisioned in the COVID-19 Report 2020 as the starting points.
  ① Social change in the three years after the outbreak of the COVID-19 pandemic
  How have social and value changes brought during these years after the pandemic began?
  ② Directions of Innovation in the post COVID-19 society
  What key innovations should NEDO focus on in the future?
  What are the possible technologies required to realize them, and what are the technical fields and areas in which Japan needs to collaborate internationally?

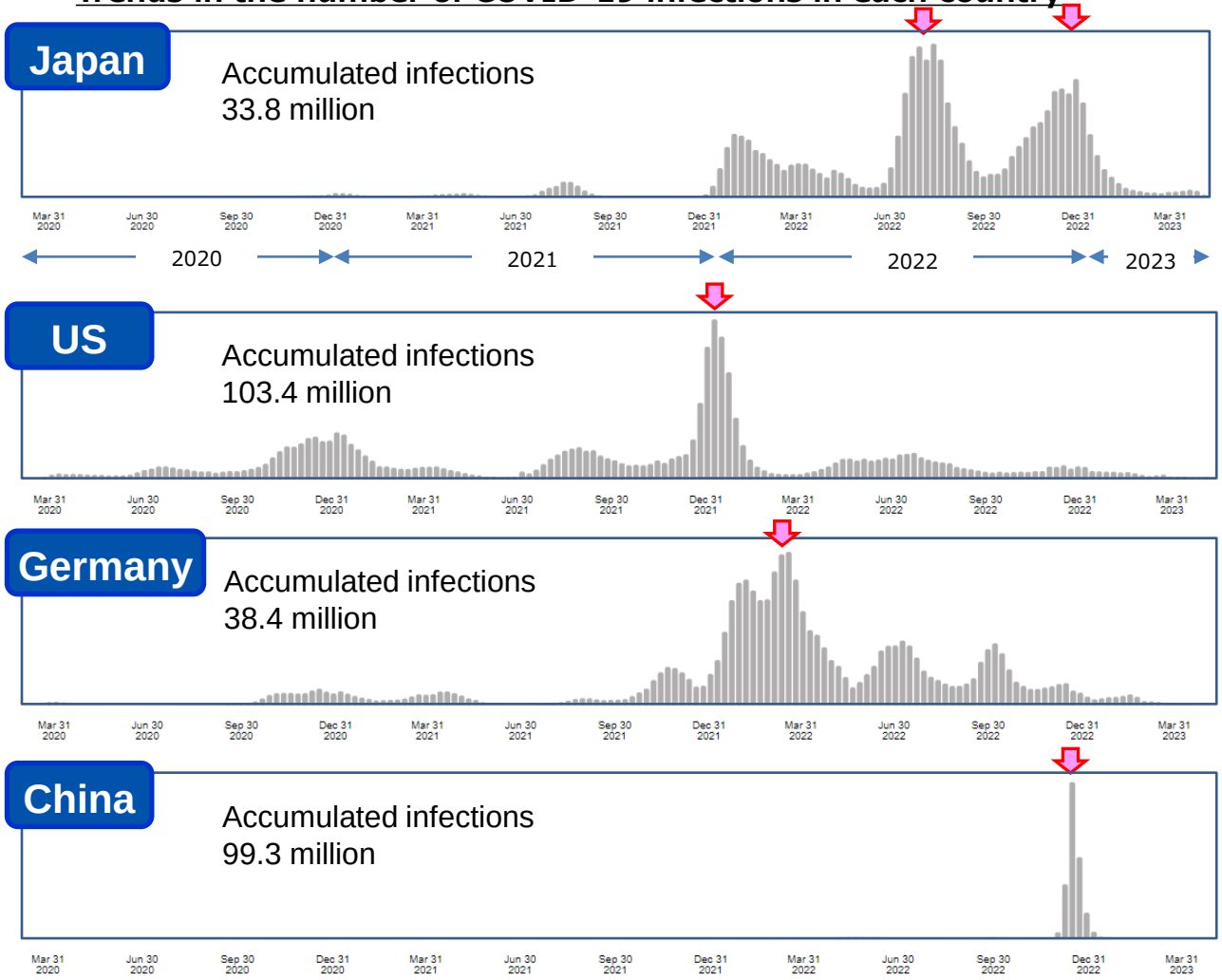
- A survey was conducted on TSC fellows and advisors (hereinafter referred to as the “Fellows”), who are experts in various fields, as well as staff at NEDO overseas offices, and the results were analyzed for this report. (The survey was conducted in February 2023 on 27 Fellows and staff at six overseas offices.)

1. Global Trends in the Three Years Since the COVID-19 Pandemic Outbreak

Situation in Major Countries From the Outbreak of the COVID-19 Pandemic to Its Convergence

- On May 5, 2023, the WHO announced the end of the state of emergency caused by the spread of COVID-19. The peak of infections in Japan came later than in Europe and the United States. As a result, deregulation also came later than in Europe and the United States.

Trends in the number of COVID-19 infections in each country



Source: Created by NEDO's TSC based on WHO "COVID-19 Dashboard" (as of May 31, 2023)

Deregulation in each country

-October 2022
Relaxation of immigration restrictions
-April 29, 2023
End of border measures
-May 8, 2023
Change of COVID-19's classification

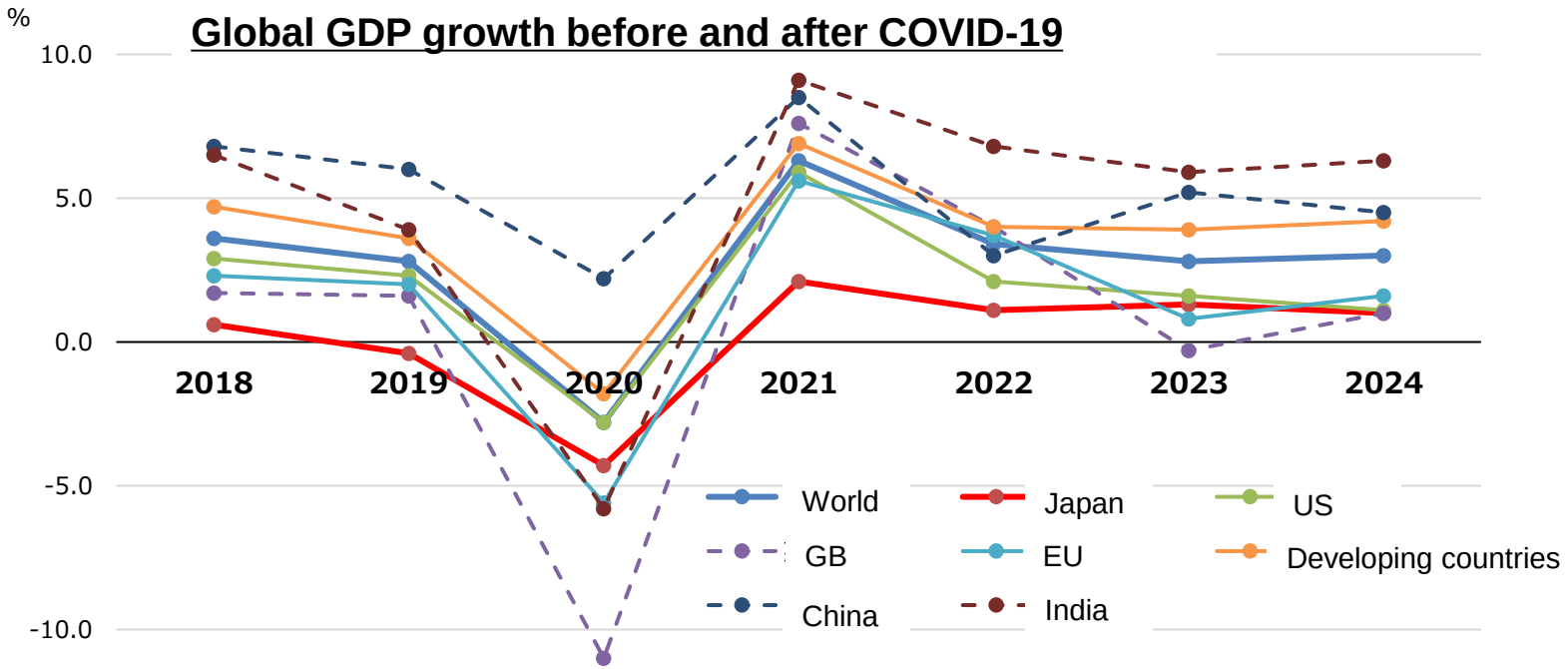
-Beginning of 2022
Restrictions on activities were gradually lifted
-June 2022
Inspection requirements for air travelers were lifted.
-May 11, 2023
State of emergency was lifted

-March 2022
Sequential lifting of restrictions
-June 2022
Elimination of restrictions on entry (excl. China and some other countries)
-April 2023
Mandatory requirement for wearing masks was completely abolished

-December 2022
Zero COVID-19 policy was withdrawn
-May 2023
Restrictions on entry of foreign nationals remained
(Inspection at the time of entry, and so on)

Macroeconomic Conditions and Prospects in Major Countries

- The global economy rebounded sharply in 2021 after falling in 2020 due to the COVID-19 pandemic. However, it has slowed down since 2022 due to rising inflation.
- Compared with the rest of the world and other advanced economies, Japan's recovery has been less robust.



	2018	2019	2020	2021	2022	2023	2024
World	3.6	2.8	-2.8	6.3	3.4	2.8	3.0
Japan	0.6	-0.4	-4.3	2.1	1.1	1.3	1.0
US	2.9	2.3	-2.8	5.9	2.1	1.6	1.1
EU	2.3	2.0	-5.6	5.6	3.7	0.8	1.6
Developing countries	4.7	3.6	-1.8	6.9	4.0	3.9	4.2

Source: Created by NEDO's TSC based on IMF report "World Economic Outlook 2023"

What has Happened in the World in the Three Years Since the COVID-19 Pandemic

- In the three years since the outbreak of the COVID-19 pandemic, the Russian invasion of Ukraine, a struggle for dominance between the United States and China, and an acceleration of decarbonization efforts have all happened simultaneously internationally.
- These developments have led to a variety of global events, including supply chain and energy issues.
- As a result, many countries pursue national sufficiency and show the move to secure a stable supply of energy and other resources, and the world is becoming divided.

COVID-19 pandemic

Commitment to carbon neutrality by 2050

Supply chain dysfunction, Semiconductor shortages

Progress in digital transformation

Progress in renewable energy investment, Manifestation of North-South issues

Countries pursue supply chain resilience policies

World division

Countries implement large-scale economic measures and decarbonization investments

Competition and regulation of advanced technologies

Rapid inflation

Energy issues (Price, supply and security)

Intensified US – China competition for supremacy

Russian invasion of Ukraine

2. Understanding of the Present Situation –Social Change in the Three Years After the Outbreak of the COVID-19 Pandemic–

Six Aspects of Social Change Predicted in the COVID-19 Report 2020

- NEDO's COVID-19 Report 2020 published in June 2020 predicted that the COVID-19 pandemic would drive changes in society and people's behaviors in six aspects.
- We have tried to examine, through a survey of TSC Fellows and staff at NEDO overseas offices, whether such social changes were in line with the predictions, what changes appeared beyond the predictions, and what issues became explicit for Japan against global trends in three years since the beginning of the pandemic.

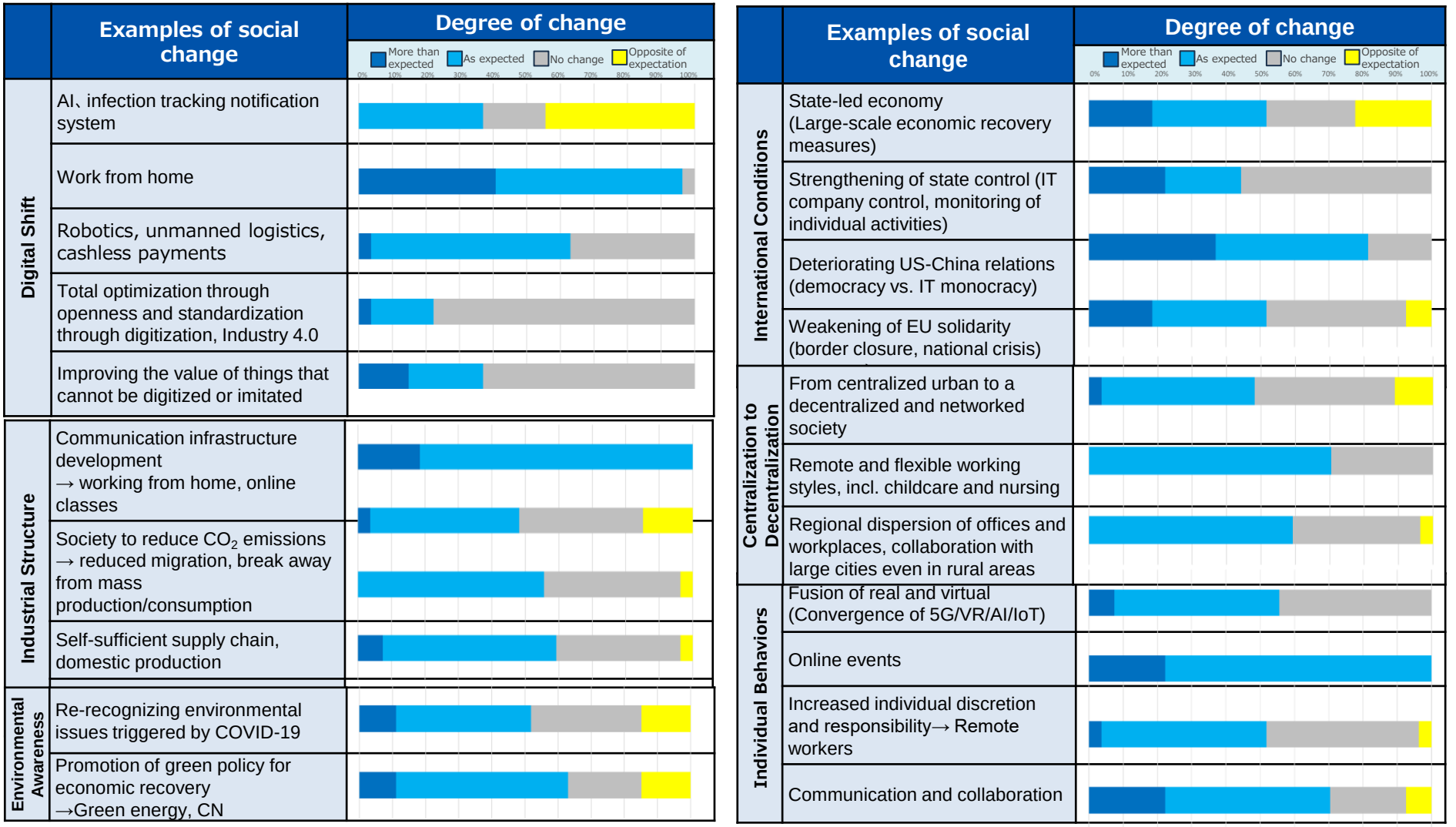
Six Aspects of Social Change From the COVID-19 Pandemic (Predictions as of June 2020)
Digital shift
Changes in political frameworks and international conditions
Changes in industrial structures and corporate actions
Changes in moving from centralization to decentralization
Changes in individual behaviors
Changes in awareness of environmental issues

Source: NEDO, "COVID-19 Report 2020"

i. Social Change in the Three Years After the Outbreak of the COVID-19 Pandemic

- “Working from home," “Deteriorating US-China relations," “Communications infrastructure development," and “Online events" have progressed more than expected.
- No progress was seen in "AI, infection tracking notification systems," “Total optimization through openness and standardization through digitization," “Society to reduce CO_2 emissions," and “From centralized urban to a decentralized and networked society."

〈From the TSC fellow survey results〉



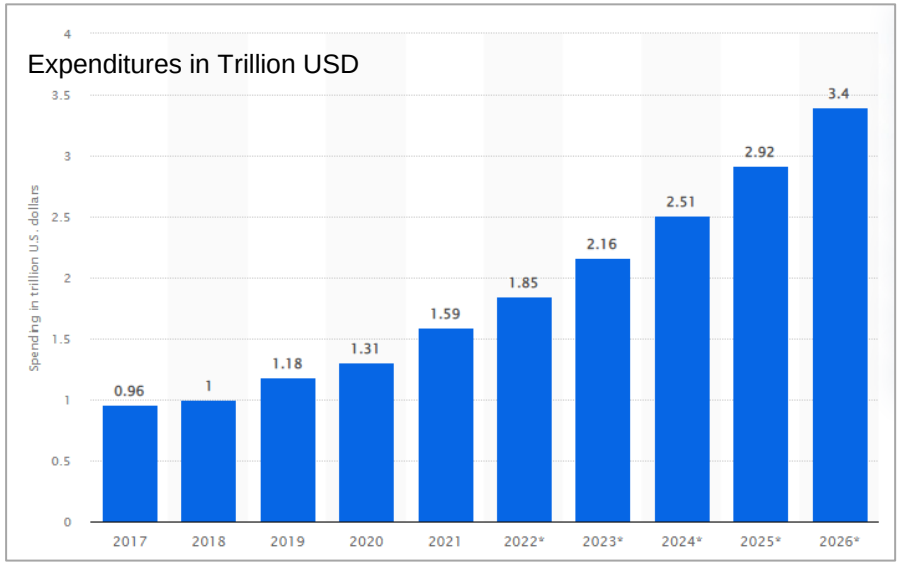
i. Social Change and Challenges for Japan as Seen Through the Survey

Changes	Key Comments from the Survey on Social Change and Issues for Japan
Digital Shift	• Working from home and online meetings became popular in Japan and were established as new lifestyles, while some issues became apparent regarding the digital transformation (DX) in a society as a whole. • Issues include a human resource shortage, a disparity of SMEs, inconsistency between IT use and social systems, and partial improvements in operational efficiency. The conservatism of Japanese society was exposed. • It is necessary to develop human resources who drive DX overall and in a strategic manner and to implement digital technologies that match with the needs of people and organizations.
Changes in International Conditions	• Changes in international conditions are largely affected by the situation in Ukraine. • The perspectives of economic security (supply chains), energy security, and food security became essential. • It is high time to consider who Japan shall partner with in the midst of a divided world with a block economy, as it cannot survive on its own.
Changes in Industrial Structures	• Japan is lagging behind in greening its industrial structure and transitioning to a society that limits CO_2 emissions. • Supply chains have become increasingly fragmented since COVID-19 began, making economic security ever important. • Reconstruction of industrial supply chains that are not restricted to specific regions is required in all sectors, including food, raw materials, and goods.
Moving from Centralization to Decentra-lization	• Regional distribution was limited. Measures for decentralization, measures by region, infrastructure development, and so on are necessary for further progress. • For a networked society, it is necessary to spread DX to SME's and in rural areas. • For a happy society, the participation of women, diversity, and digitalization in childcare and nursing care are necessary.
Changes in Individual Behaviors	• The fusion of the real and the virtual requires virtual technology that matches human sensibilities with a sense of realism and the speedy linkage of elemental technologies to services. It is also necessary to discuss what happiness and well-being look like in the virtual world. • Remote work strengthened the management of the supervisors and reaffirmed the importance of face-to-face communication.
Changes in Environmental Awareness	• Not only COVID-19 but also the Ukraine crisis has brought about a rise in environmental awareness. • The COVID-19 crisis brought about increased plastic waste with increased home delivery. No major changes seen in people's individual environmental awareness. The realization of sustainability and a circular society are essential.

ii. Before and After COVID-19 in Data –Digital Shift–

- During the pandemic, the world's expenditures on DX technologies and services increased.
- Investment in AI also jumped, and it is expected to increase further.

World's Expenditures on DX Technologies/Services

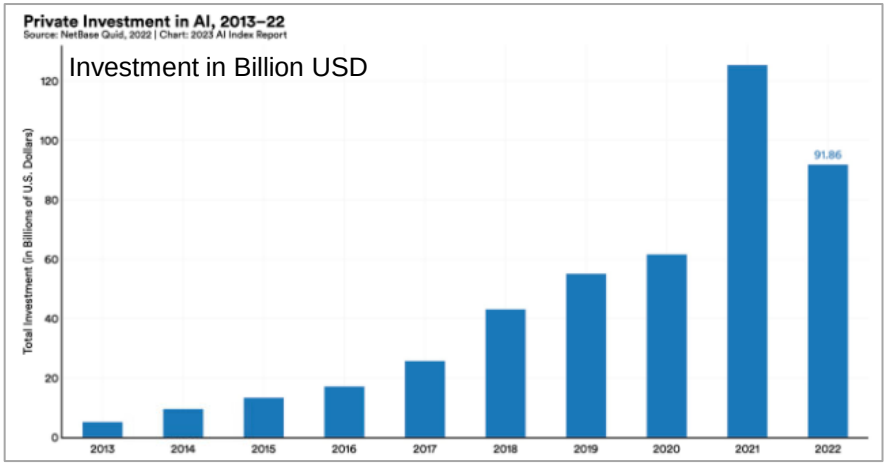


Source: IDC (from Statista, with a comment added by NEDO TSC)

Key comments from the survey:

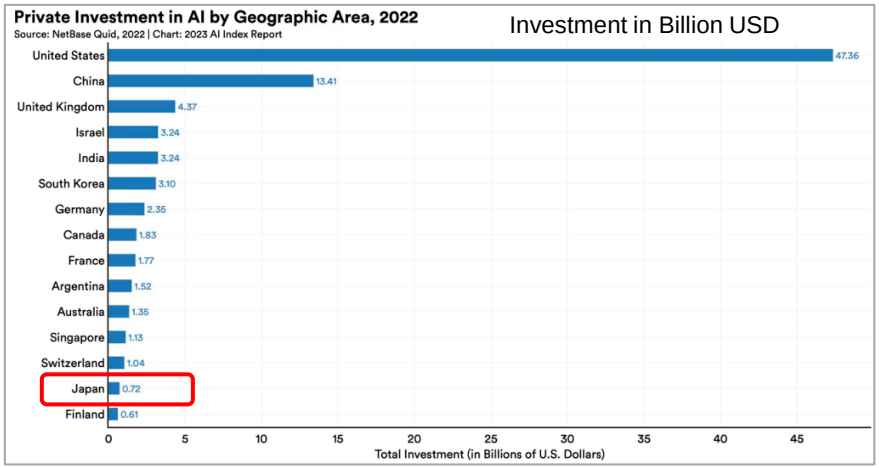
- TSC Fellows expressed concerns about Japan's delay in global trends of digital shift due to insufficient ability to adapt DX technologies to society, people, and organizations.
- Also, NEDO overseas offices pointed out the lack of social systems in Japan for deploying digital technologies.

Private AI Investment in Pre-COVID-19 Times



Source: Stanford University, "2023 AI Index Report" (comment added by NEDO TSC)

US Leads World Private AI Investment, Japan in 14th

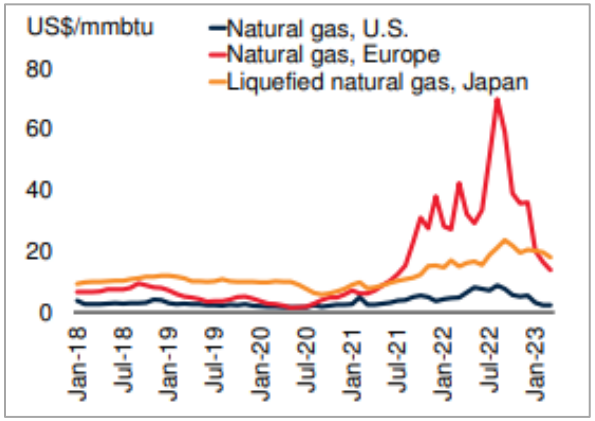


Source: Stanford University, "2023 AI Index Report" (Red frame added by NEDO TSC)

ii. Before and After COVID-19 in Data –Changes in International Conditions–

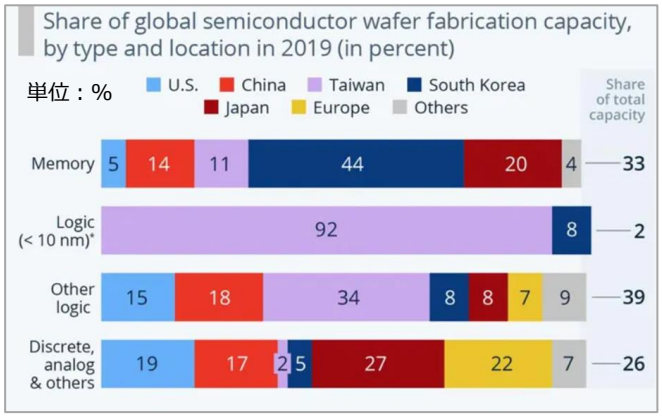
- These changes over the last three years have emphasized the importance of energy security, economic security, and food security. They have reminded us of the need of not being dependent on specific countries in a supply chain.

Natural Gas Price Increases due to the Ukraine Situation



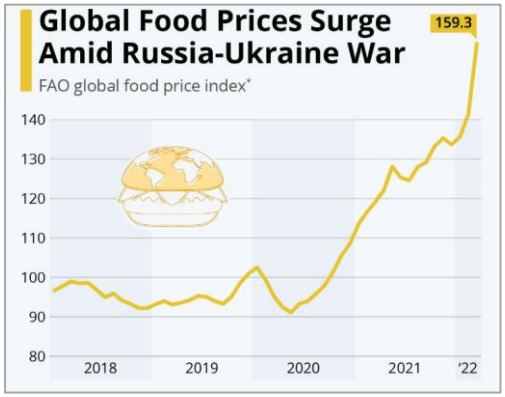
Source: World Bank, “Commodity Market Outlook April 2023”

Advanced Semi-Conductor Manufacturing Dependent on Taiwan



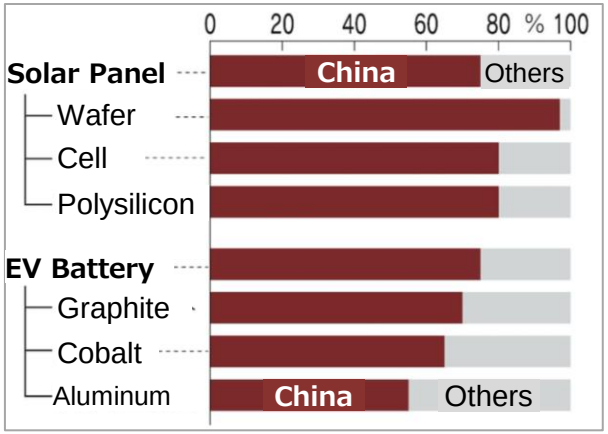
Source: Boston Consulting Group, SEMI Fab Database (from Statista)

Global Food Prices Have Surged



Index: 100 = Average price during 2014–2016
Source: Food and Agriculture Organization of the United Nations (from Statista)

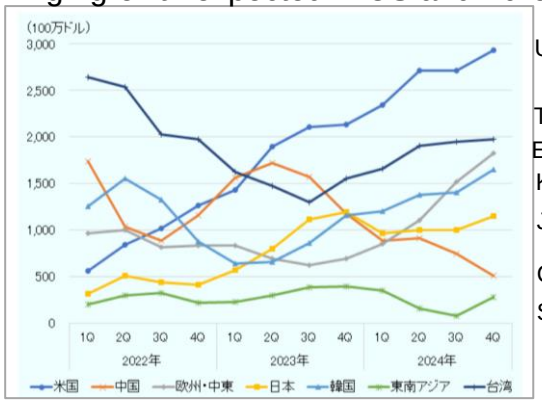
Clean Energy Device Manufacturing Dependent on China



*Country share of processing, smelting, manufacturing
Source: Nikkei Newspaper, "New decarbonization framework by G7 within this year" (Translation added by NEDO TSC)

World Competes for Investment in Semi-Conductor Plant Building

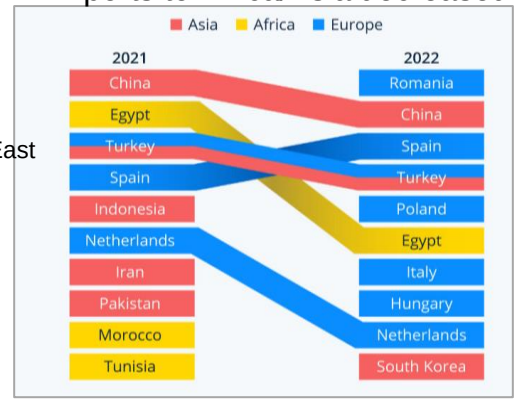
High growth expected in US and Europe



*Front-end processes, Country/Regions where investment executed
Source: JETRO, "World semiconductor market outlook and US strategy"

Rapid Change in Destinations of Ukraine Grains

Exports to Africa/Asia decreased



Source: UN Comtrade (from Statista)

ii. Before and After COVID-19 in Data –Changes in Industrial Structure–

- In response to changes in international conditions over the last three years, the US, Europe, and Japan have recently introduced policies for energy, climate change, and strengthening supply chains with large budgets.
- They tend to be new industrial policies that promote technology development in an integrated manner.

Large Scale Policies for Energy, Climate Change, and Supply Chains over the last three years

Energy/ Climate Change | Supply Chain

EU (↓Announced)

Green Deal Industrial Plan — Jan. 2023
Develop net zero industries incl. the financial support for manufacturing plants inside EU. (EU budget €250B)

REPowerEU — May 2022
Accelerate renewable energy and energy efficiency to break away from the dependency on Russia (€300B)

EU Chips Act — Apr. 2022
Strengthen semiconductor industry with R&D and manufacturing inside EU (€43B)

Japan (↓Established)

Green Innovation Fund — Mar. 2021
R&D and demonstration projects towards CN (￥2,754B)

Specified Semiconductor Funding Program — Mar. 2022
Support advanced semiconductor manufacturing facilities (￥1,067B)

Program on Technologies for Economic Security — Mar. 2022
R&D for key technologies of economic security (￥250B)

Project for Supporting a Secure Stable Supply — Mar. 2023
Support stable supply of goods for living and economy (￥828B)

US (↓Legislated)

Inflation Reduction Act — Jul. 2022
Incentivize climate change actions in production and deployment through tax credits and so on ($437B)

Infrastructure Investment and Jobs Act — Nov. 2021
Infrastructure investments and large-scale demonstrations for climate change and so on ($555B)

Chips and Science Act — Aug. 2022
Support “made in America” semiconductors and advanced science /research ($52.7B)

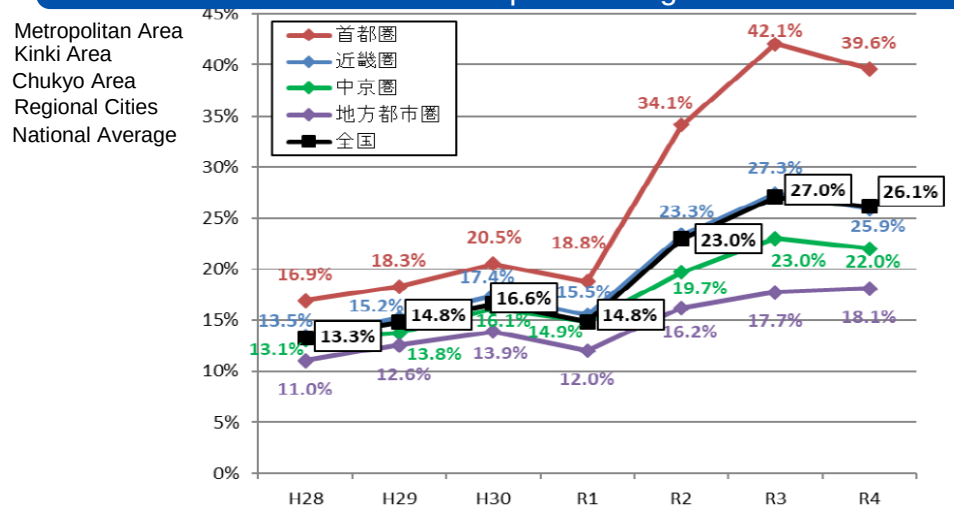
In addition, cooperation with the Global South in various formats has expanded.
G7 Hiroshima Summit (Leaders’ Statement on Economic Resilience and Economic Security),
IPEF（Indo-Pacific Economic Framework for Prosperity), Mission Innovation,
AZEC (Asia Zero Emission Community, led by Japan), Clean Energy Ministerial (led by the US).

Source: Created by NEDO TSC, referring to government announcements, JETRO and other news coverage

ii. Before and After COVID-19 in Data
–Moving from Centralization to Decentralization–

- There was a large disparity in the development of working from home during the pandemic between metropolitan areas and regional cities. It can be said that the transition to decentralized offices and workplaces did not necessarily progress as expected.
- Various digital infrastructure investments are expanding globally. This is one key element that may lead to eliminating disparities.

Significant Difference Between Metropolitan Areas and Regional Cities in the Ratio of People Working From Home



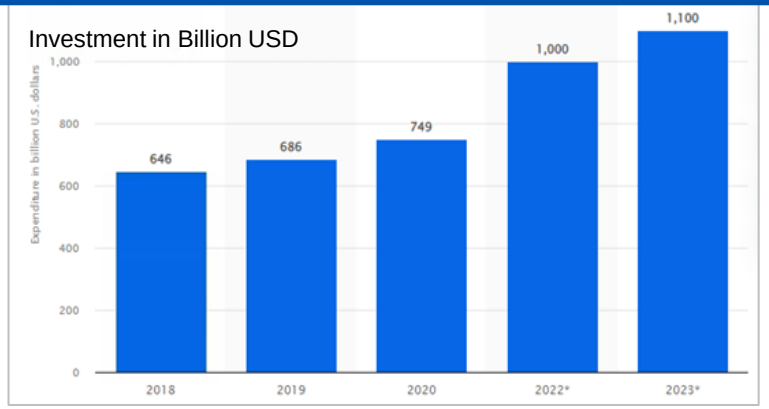
Source: Ministry of Land, Infrastructure, Transport and Tourism, “FY2022 Telework Population Survey”

From various news reports:

- COVID-19 has brought about progress in working from home worldwide, leading to diverse work styles, especially among large companies.
- Meanwhile, U.S. Big Tech was quick to mandate a return to the office.
- Globally, there are regions with high office occupancy rates at the end of 2022: Asia Pacific, about 85%,; and Europe/Middle East, about 70%; in the U.S. it is about 45%.
- Even Tokyo, which temporarily experienced an excess of out-migration, showed a trend of centralization, with an excess of nearly 40,000 people moving into the city in 2022.

Source: Nikkei Newspaper and other news media

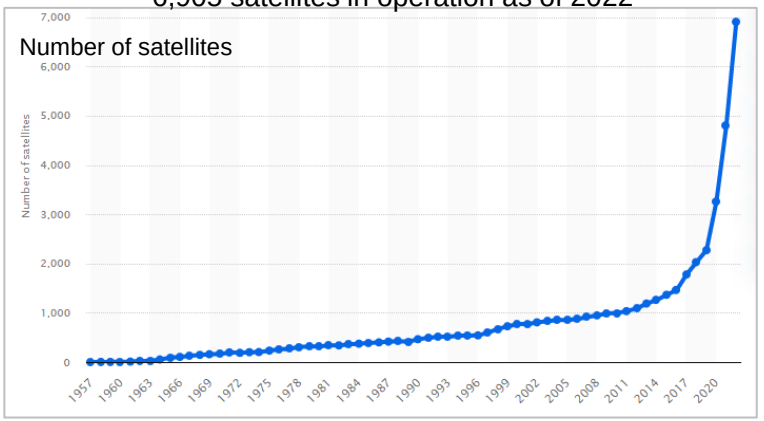
IoT Investment Increases Worldwide



Source: JSR (from Statista, a comment added by NEDO TSC)

Dramatic Expansion of Commercial Satellites
–New Communication Infrastructure–

6,905 satellites in operation as of 2022

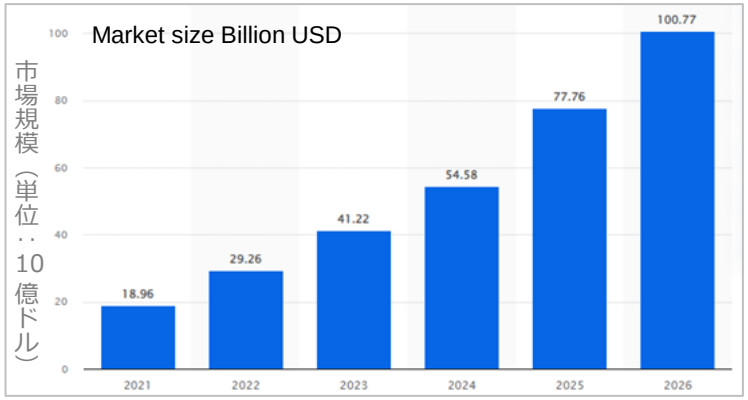


Source: IDC; Exploding Topics (from Statista, a comment added by NEDO TSC)

ii. Before and After COVID-19 in Data –Individual Behaviors–

- The XR market is expected to expand worldwide and there are signs that virtual reality, symbolized by online events, will further develop. Cashless payments are progressing in Japan as well.
- At the same time, the number of home deliveries, which can increase environmental impacts, has rapidly increased, and food delivery has also rapidly become popular.

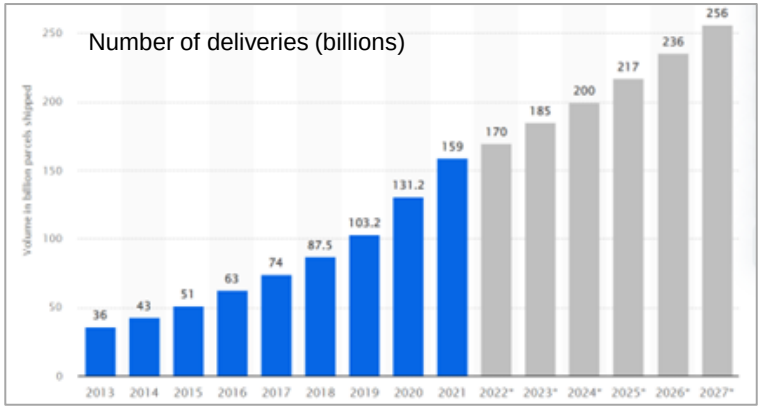
Global XR Market Will Expand in the Future



Source: ARtillery Intelligence (from Statista, Comment added by NEDO TSC)

Home Deliveries Increased Rapidly

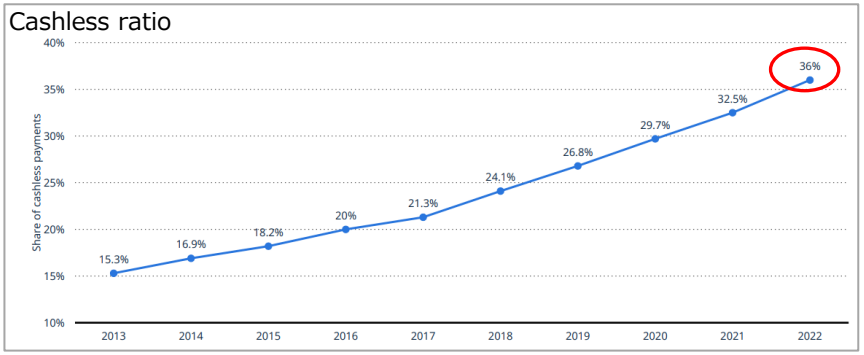
Increase of more than 1.5 times from 2019 to 2021
159 billion parcels shipped worldwide in 2021



Source: Statista; Pitney Bowes (Comment added by NEDO TSC)

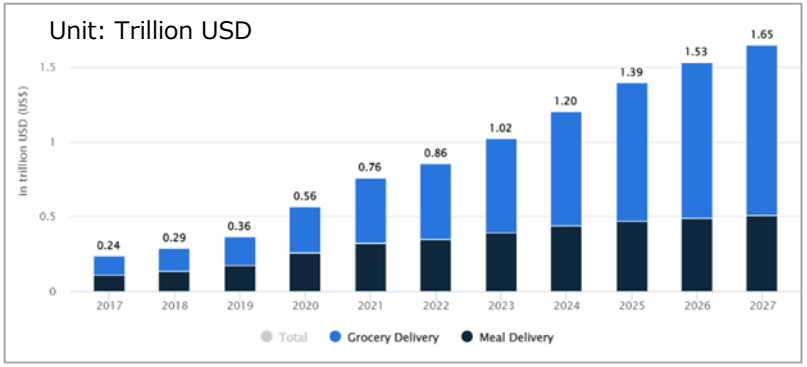
Cashless Payments in Japan are Increasing Year by Year

Cashless ratio in 2022 in Japan was 36%



Source: Statista, “Ratio of Cashless Payments in Japan 2013-2022”
(Red circle and comment added by NEDO TSC)

Online Food Delivery is Popular Around the World



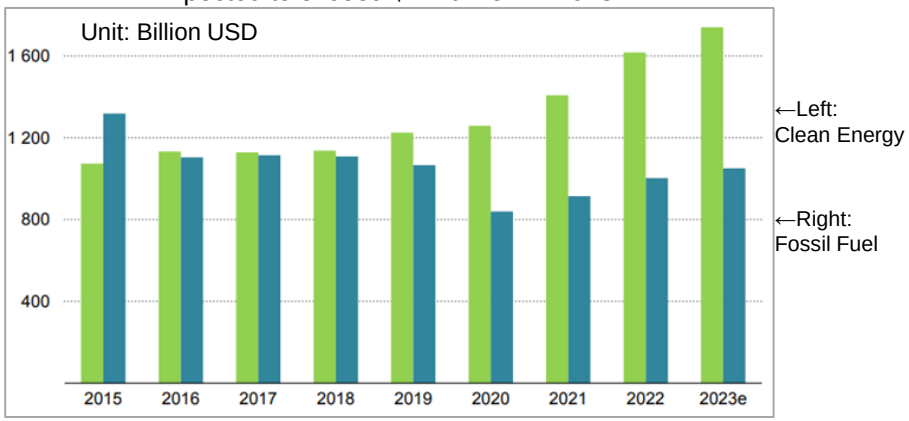
*Blue: Food delivery, Black: Meal delivery
Source: Statista, Market Insights, “Online Food Delivery” (A comment added by NEDO TSC)

ii. Before and After COVID-19 in Data
–Changes in Awareness of Environmental Issues–

- Since 2021, global clean energy investment has expanded. Climate tech attracts funding.
- Recycling of ever-increasing plastic waste remains at a negligible level. There has yet to be a major change in people's environmental awareness.

Global Clean Energy Investment Increasing

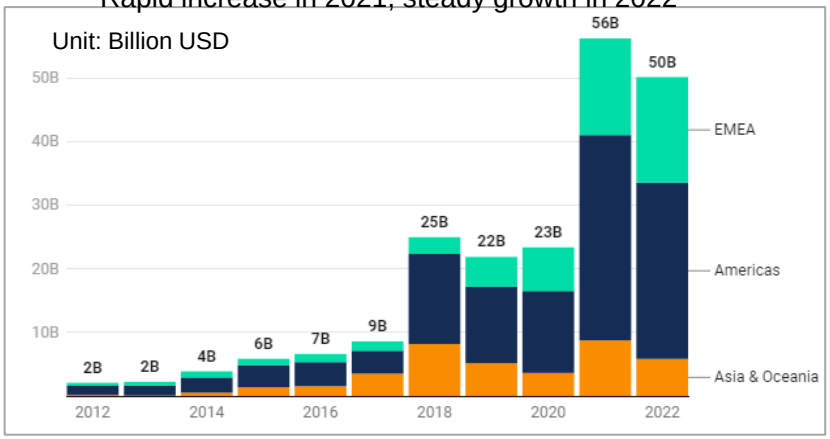
Expected to exceed $1.7 trillion in 2023



Source: IEA, "World Energy Investment 2023"

VC Expanding Funding to Climate Tech Companies

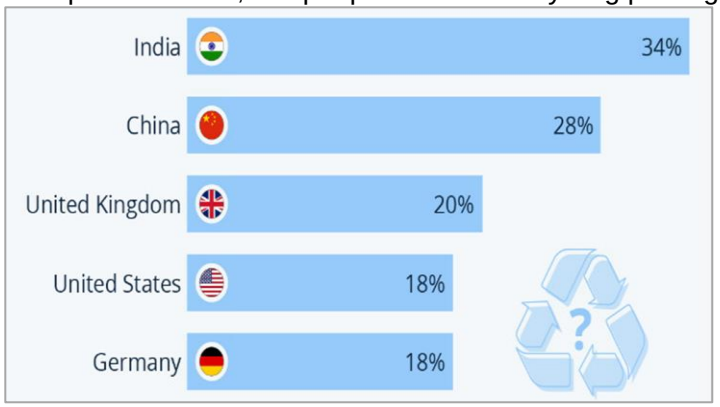
Rapid increase in 2021, steady growth in 2022



Source: Dealroom.co, "Climate Tech"

Do You Consider Recycling Packaging When Purchasing Food?

Even in developed countries, few people consider recycling packaging

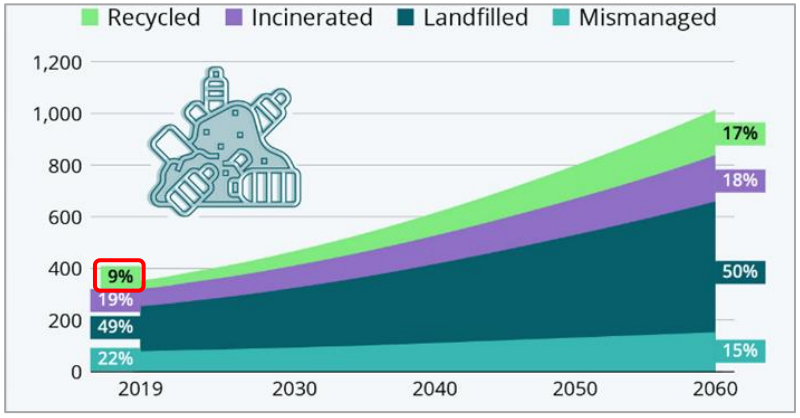


*Survey done in Feb. and Mar. 2021

Source: Statista, "Plastic Packaging Still an Afterthought for Most"

Only 9% of Plastic Waste is Recycled Worldwide

Unit: Million tons



Source: OECD, "Global Plastic Outlook 2019"
(from Statista, red frame added by NEDO TSC)

What We Have Learned From the Survey Results on Social Change

- The characteristics of social changes in the world and Japan during the three years after the outbreak of COVID-19 as seen from the results of this survey are as follows:
  - ✓ A digital shift has steadily progressed globally, including in Japan. Japan, however, is not necessarily enjoying the benefits of such a digital shift in a profitable way, as can be seen in the slight decline of the sales of Japanese IT platforms and services in the global market share.
  - ✓ The international situation over the past three years has also made the world face up to the challenges of energy security, economic security, and food security. At the same time, the world became strongly aware of the need to break away from dependence on specific countries. Many of the major countries and regions have introduced large-scale budgets for addressing energy and climate change issues and supply chain resilience. Japan also created the Green Innovation Fund and a fund for economic security. It can be said that these efforts reflect recent industrial policies in which policy and technology development are being promoted in an integrated manner.
  - ✓ It was pointed out in the survey that Japan tends to fall behind global trends due to the lack of systems and infrastructures for social implementation of technology rather than technological factors. It is, therefore, necessary for industry, academia, and the government to work together to promote not only research and development but also market introduction and commercialization of technology by focusing on industrialization and social implementation in a multifaceted and multilayered manner.
  - ✓ In addition, it was also pointed out that COVID-19 did not lead to changes in behavior of individuals in the environmental field, either in Japan or in the world. Rather, the restrictions during COVID-19 resulted in an increase in plastic waste due to increase in home delivery and policies that focus on individuals may be necessary in the future.

3. Future Prospects

–Directions of Innovation in a Post COVID-19 Society–

Expected Innovations in the COVID-19 Report 2020

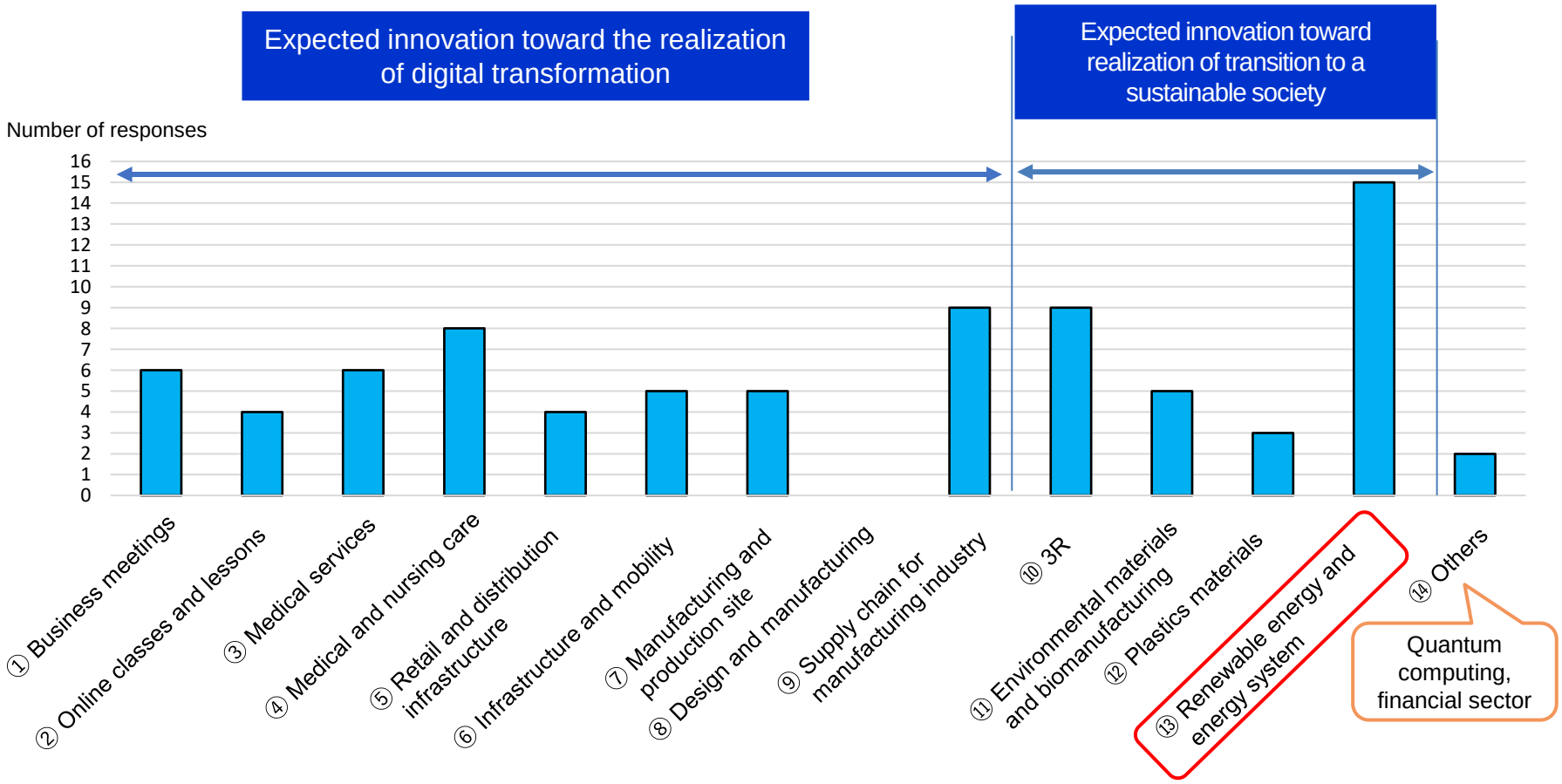
- In this survey, experts were asked to select the top three most important innovations that NEDO should focus on in the future, from the 13 fields of innovation (① through ⑬) envisioned in the COVID-19 Report 2020, and any other fields of innovation (⑭) that were not originally expected.
- Experts were also asked to make comments on possible technologies and issues to be resolved to realize the selected innovations as well as technology fields in which Japan needs to collaborate internationally in the future (e.g., joint research and international deployment of Japanese technologies).

Expected Innovation	Innovation Category	Fields of Innovation
Expected innovation through digital transformation	Services in virtual space	① Business meetings
		② Online classes and lessons
		③ Medical services
	Services in real space	④ Medical and nursing care
	Data-driven industries	⑤ Retail and distribution infrastructure
		⑥ Infrastructure and mobility
		⑦ Manufacturing and production site
		⑧ Design and manufacturing
	Manufacturing and production of goods	⑨ Supply chain for manufacturing industry
Expected innovation toward the realization of a sustainable society	Circular economy	⑩ 3R
	Bioeconomy	⑪ Environmental materials and biomanufacturing
		⑫ Plastics materials
	Sustainable Energy	⑬ Renewable energy and energy system
Other fields of innovation that were not originally expected		⑭ Others

i. Important Innovations in a Post COVID-19 Society as Shown in the Survey

- The survey results showed that “renewable energy and energy systems” was selected by far the most important innovation that are expected to be important in the future.
- The responses for the other fields of innovation were generally balanced, with the results showing that they are of equal importance.
- It was suggested by some experts that it is also necessary to pay attention to recent trends such as “generative AI” (e.g., ChatGPT), “quantum computing,” and “nuclear fusion.”

〈From the TSC Fellow survey results〉



Expected innovations toward the realization of a transition to a sustainable society

Renewable energy and energy systems

〈From the TSC Fellow survey results〉

- Since the conflict in Ukraine began, it has become clear that reliance on foreign products and technologies involves high risk. Therefore, it is ideal to manufacture and maintain infrastructure equipment for renewable energy such as PVs and wind power within a country, creating a value chain of its own in a sustainable manner.
- It was reconfirmed that steady efforts to realize the transition to renewable energy and the resilience of energy systems are crucial in order to achieve carbon neutrality.
- It is difficult for Japan alone to keep the economy going in introducing renewable energy. It is, therefore, also important to develop projects through international collaboration.
- What lies beyond solar and wind power are important technological issues, which include energy storage, efficient conversion of electricity into thermal energy (heat pumps, electric heating, and so on), synthesis of renewable energy-derived liquid fuels (SAF, and the like), and the use of water as a hydrogen source (water electrolysis, artificial photosynthesis, and so on).
- Power generation systems suitable for local production for the local consumption of energy and minimization of energy loss from electricity transmission are necessary.
- In addition to the development of innovative technologies that contribute to expanding the use of renewable energy in urban areas, it is also important to develop system design for the promotion of renewable energy.

i. Technologies and Issues Toward the Realization a Transition to a Sustainable Society

- In light of issues such as energy security and economic security that have been highlighted in social changes over the past three years, there were many comments that we should emphasize circular systems in order to transform to a sustainable society.

〈From the TSC Fellow survey results〉

Fields of Innovation	Technologies to realize the innovation
3R	• DX needs to be deployed to enable reuse and recycle throughout the course of manufacturing, sales, and consumption of all industrial products without limiting it in the field of food and waste. • The 3Rs (reduce, reuse, recycle) of food are important for improving food security and food self-sufficiency. It is particularly important to develop technologies that contribute to reducing food loss by individuals, which accounts for about one-third of food loss. • In addition to the 3Rs, we should consider the 5Rs that include refuse and repair. Accelerating the development of technologies such as the promotion of the blue economy, mass production technology (factories) for land-based aquaculture and cultured meat, and optimization of supply and demand using AI is required in this context.
Environmental materials and bio-manufacturing	• It is necessary to develop technologies and materials in hitherto unexplored areas such as blue carbon and blue resources. For this purpose, we must understand the necessary amount, the availability of raw materials, and consider the regional merits in terms of transportation and consumption. • Biomanufacturing must be incorporated into all manufacturing fields in the future.
Plastics materials	• The development of bioplastics and biodegradable plastics is still in its infancy. There are many issues, including cost, in realizing a cycle of separate collection to reuse. As the USA leads in decomposition technology using microorganisms and enzymes, there is an urgent need to develop technologies utilizing AI to catch up. • The early social implementation of material and chemical recycling is necessary. Regarding chemical recycling, it is important to identify low-temperature and energy-saving technologies.

i. Technologies and Issues Toward the Realization of Digital Transformation ①

- Many respondents emphasized the need to further utilize AI for digital transformation.
- This applies to various kinds of fields including “supply chain for manufacturing industry” to secure a workforce in the face of a declining birthrate and aging population, and “medical and nursing care” to improve medical care quality.

〈From the TSC Fellow survey results〉

Fields of Innovation	Technologies to realize the innovation
Business meetings	• Current teleconference systems have advantages and disadvantages, and the basic functions are often insufficient. A completely new and different AI-assisted co-working system for entire meeting workflows such as materials preparation before a meeting, automatic document projection at meetings, and taking meeting minutes after meetings is required. • Solving the problem of time differences in international conferences would be appreciated.
Online classes and lessons	• It is believed that the education system will change completely in the future. For example, by making online classes more realistic, it will be possible to receive a much richer variety of online lectures than are currently available. • In the re-skilling of industrial workers, it seems that rather than quitting their jobs, workers will be required to find ways of working that allow them to balance work with re-skilling. For this to happen, legal reforms and corporate support by the government are necessary. • If we do not analyze the educational effects that can only be achieved by face-to-face teaching, there is a risk that the education system will collapse.
Medical services	• As the population continues to age and the number of medically depopulated areas increases, the first step of DX needs will be at health monitoring devices, followed by medical measuring devices, and finally robots including those for medical treatment. As the latter is more difficult to achieve, if a system that includes machine learning and prediction or health guidance can be developed and disseminated, it will be possible to make a difference in tackling the medical depopulation problem.
Medical & nursing care	• There is a sense of crisis that Japan’s robotics technology is behind that of Europe and America. In particular, the medical and nursing care field is a treasure trove of information. If foreign robots are allowed to enter this field, there is a very high risk that foreign companies will obtain personal information, including genetic information, information about social systems, medicines and diagnostics, and all other information related to the medical system. • Digital health systems for health maintenance, management, and diagnosis using digital technologies such as AI and IoT, are necessary to improve medical quality. The key is how those technologies are friendly to people. • Collecting high-quality data, developing efficient data storage, and establishing rules regarding ethics are important.

i. Technologies and Issues Toward the Realization of Digital Transformation ②

〈From the TSC Fellow survey results (cont'd)〉

Fields of Innovation	Technologies to realize the innovation
Retail and distribution infrastructure	• Research on how to transport goods at low cost is essential. • Because of the growth of online shopping and home delivery, it is necessary to further develop autonomous vehicle and mass transportation technology. Accelerating the involvement of the government is important to reach the practical phase of development. • The problem is that there is a mismatch between new technological infrastructure and existing organizations and systems, which is often a difficult gap to fill.
Infrastructure and mobility	• It is necessary to develop infrastructural mobility that aims to solve social issues rather than provide convenience, and to optimize seamless transportation, including not only automobiles but also railways, ships, aviation, drones, personal mobility, and so on. • Data sharing mechanisms, inexpensive sensors, and deregulation/system reform should be taken care of.
Manufacturing and production site	• Japan's productivity is low; thus, it is necessary to improve productivity in agriculture and fisheries. • Decentralization makes the concept of producers closer to that of consumers. • It is important to strengthen the foundation of Japan's industrial competitiveness through saving labor by robot technology and material DX.
Supply chain for manufacturing industry	• We have faced supply chain problems twice in the last ten years due to the rare earth issue and the Ukraine crisis. Although it is a company issue, using AI to understand and visualize the increasingly complex supply chains (confidentiality is also important) is important for maintaining and developing industry. In addition, horizontal (same industry) collaboration is also important to simultaneously strengthen the commonality and differentiation of technologies. • Currently, data produced by each company's activities is disparate, and translation work is required for companies to communicate with each other. Efforts toward standardization are progressing among large companies, but little progress has been made among small and medium-sized enterprises, making it important to create rules, standardize, and share the future we aim for. • NEDO's efforts are essential, as companies cannot achieve this alone and collaboration with the government is essential.

ii. Direction of International Collaboration to Realize the Innovations From the Survey ①

- Based on the results of the survey, the direction of international collaboration required for Japan in the future in order to realize the important innovations in a post COVID-19 society is as follows:
- Japan will be required to engage in international joint research in the field of basic research, secure international competitiveness in the fields of cutting-edge technologies, and create areas of cooperation. Also, considering the importance of economic security, instead of the conventional omnidirectional international collaboration, it is important for Japan to develop strategic collaboration with countries that share the same values, and promote appropriate cooperation and share technology information proactively in order to create innovations together.

〈From the TSC Fellow survey results〉

Direction of international collaboration to realize the innovations
① International joint research in the field of basic research: • International joint research is essential for accumulating knowledge and advancing it through discussion. Particularly in the field of basic research, international brainstorming can dramatically improve knowledge.
② Ensuring international competitiveness in advanced technology fields: • In the field of advanced technology, it is possible to utilize Japan's cultural background and knowledge of past technological development at a global level, and it is important to ensure international competitiveness with ideas unique to Japan.
③ Creation of areas of cooperation: • When conducting international collaboration, discussions from the perspective of the benefits (technology acquisition, market acquisition, standardization) not only for Japan but also for partner countries should be taken into consideration. From that perspective, collaboration in cooperative fields (technology development/standardization) is more appropriate than in competitive fields.

ii. Direction of International Collaboration to Realize the Innovations From the Survey ②

〈From the TSC Fellow survey results (cont'd)〉

Direction of international collaboration to realize the innovations
④ Economic security: • In the future, from the perspective of economic security, it will become increasingly important to consider how far the risk of dependence on other countries can be reduced, and whether a country can circulate its own resources. • In terms of resources for which there is no choice but to depend on other countries to obtain, it is important to cooperate with the resource-producing countries on technologies that have a low environmental impact and are beneficial to the region, in a fair manner.
⑤ Global talent development and utilization: • In order to create new industries in the future, we need a society where young people (Generation Z and millennials) can demonstrate leadership in promoting research and development. To this end, an urgent issue is how to increase opportunities for young people overseas and increase the mobility of talent with other countries, as well as how to secure the human resources needed for future Japanese industries. • Countries such as the United States and China are drawing in excellent researchers from overseas to create new technologies. It is also important to investigate how the system and benefits for securing highly skilled human resources overseas are structured from a security perspective.
⑥ Problem solving for social system development: • In addition to technological development, it is also beneficial to learn and share know-how through international collaboration for building social systems and standardization that will allow such technology to be accepted by society. • For example, there are many things to learn about citizen consensus building in multi-ethnic countries such as the United States and Canada.
⑦ Further relationship building with ASEAN countries: • In addition to Western countries, Japan, an island nation, is close in culture (food culture, and so on) to Southeast Asia, which also has island nations, and it is considered easy to share values and issues. It is necessary to further accelerate cooperation and collaboration that will lead to a future with trustworthy countries.

What We Have Learned From the Survey Results on Expected Innovations

- The following are important innovations suggested by the results of this survey:
  - ✓ "Renewable energy and energy systems" was considered the most important issue in realizing a sustainable society as energy security and economic security have become critical issues. In addition, circular systems such as "3R" and "environmental materials/biomanufacturing" were frequently mentioned to be considered as important.
  - ✓ For digital transformation, many comments were made on the importance of the further utilization of AI. AI applications for "supply chain for manufacturing industry" to solve future work-power shortages in an aging society with population decline, which is a specific issue to Japan, and "medical and nursing care" to improve medical quality were highly expected. These were also desired in order to prepare for future pandemics and crises.
  - ✓ From these results, this survey suggests that "the realization of a circular and decarbonized sustainable society" and "digital transformation through further utilization of AI" are important innovations in a post COVID-19 society.
- For the implementation of technology development necessary for these innovations, supply chain and economic security, which were not being strongly emphasized before COVID-19, should be considered and for this reason, the importance of international collaboration needs to be highlighted. In particular, the importance of international joint research in advanced and/or basic fields as well as partnerships for building social systems and standardizations were pointed out. Moreover, because economic security will become more critical, it was implied that Japan should strategically build a relationship of trust with nations that have the same values and not the all-around international collaboration that has been the norm so far.

4. Conclusions

–Social Change, Expected Innovations, and NEDO's Efforts–

Conclusions
–Social Change, Expected Innovations, and NEDO's Efforts–

- In the three years since the outbreak of the COVID-19 pandemic, there have been big social changes such as new lifestyles and work styles caused by the progress of digitalization, the growing importance of three securities (energy, economy, and food), and an increased awareness of environmental issues and momentum toward decarbonization.
- "Realization of a circular and decarbonized sustainable society" and "digital transformation through further utilization of AI" targeting a wide range of fields were once again revealed to be important for innovations in a post COVID-19 society. To realize these expected innovations, strategic international collaboration and international cooperation will be important when taking into consideration the perspectives of supply chains and economic security.
- NEDO's TSC is currently working on clarifying the path to social implementation of technologies, such as analyses and development of technology strategies, in the fields whose importance were highlighted in this survey. NEDO's TSC will continue to pursue its mission to "catch moves, design our future, and show strategies forward."

Social change and trends in the last three years

New lifestyles and work styles brought about by the progress of digitalization
(e.g., working from home, cashless payments, online classes)

Growing importance of the three securities:
① Energy security
② Economic security
③ Food security

Increased awareness of environmental issues and momentum toward decarbonization

Expected Innovations and NEDO TSC's Efforts

"Comprehensive R&D Principle for Sustainable Society 2023"

To realize a sustainable society, integrated promotion of three social systems, a "circular economy," a "bioeconomy," and "sustainable energy" with "digital transformation" as the basis of the three are mandatory.

Realization of a circular and decarbonized sustainable society

- ○ **Renewable energy and energy systems**
  e.g., Wind power generation
- ○ **3R**
- ○ **Environmental materials, Biomanufacturing**
  e.g., Biomanufacturing, blue resource

Digital transformation through further utilization of AI

e.g., Social implementation of AI

- ○ **Supply chain for manufacturing industry**
- ○ **Medical and nursing care**
- ○ **Business meetings**

Social system/infrastructure

International collaboration

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Technology Strategy Center Report

TSC Foresight

Directions of Innovation in a Post COVID-19 Society

–Three years have passed since the outbreak of COVID-19 pandemic. How has the world and Japan changed during these years in which the Russian invasion of Ukraine has also occurred, and what will be required from now on?–

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