NISTEP REPORT No.145

Contribution of Science and Technology to Future Society

— Summary on the 9th Science and Technology Foresight —

December 2010

Science and Technology Foresight Center

National Institute of Science and Technology Policy

Contents

Executive Summary

What can science and technology do to bring forth innovations in society? This is the most fundamental question underlying the progress of science and technology in the 21st century. It is expected to make innovation happen with research and development that are pursued under the purpose of contribution to society. Science and technology policy will be merged with innovation policy in the future, in search for new relationship-building between science and technology and society.

What areas should the future science and technology policies focus on? Expectations are running high that the fruits of scientific and technological progress will provide effective solutions, not only for the global challenges linked with the large-scale environmental changes, but also for the national concerns in the era of a rapidly falling birthrate and aging population. To address these extensive challenges, it is required to show a concrete path leading to the goal and effective utilization of the fruits of science and technology. Scientific and technological capabilities that enable Japan to have great presence in the world are also expected to be enhanced.

In the "9th Science and Technology Foresight" conducted from FY2008 to FY2009, three investigative studies were carried out, with the cooperation of around 3200 experts in total, embracing not only each element of science and technology, but also discussion of a social system from such viewpoints as safety, security, and international collaboration, and discussion with due consideration of regional issues and the younger generation's way of thinking. The foresight this time differs largely from its predecessors in that it aims at a problem-solving exercise that employs an interdisciplinary approach, eliminating as far as possible the boundaries of conventional disciplines. The results are summarized as follows.

—Vision of future society brought about by the advancement of science and technology—

The consensus of opinion from 2900 experts by the delphi survey shows that society in around 2025 will have advanced features described below owing to the progress in science and technology.

- ✓ A society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail.
- ✓ A society where individuals can use various types of energy selectively based on their comprehensive evaluation of value and can feel that they proactively contribute to global warming prevention and environmental preservation.
- ✓ A society in the early stage of coping with the various disasters caused by environmental changes.

—Areas of key importance for the resolution of global and national challenges—

In response to the Delphi survey questionnaire that inquired about the key areas most conducive to resolving the challenges, many experts mentioned energy-related areas, medical-care-related areas, ICT-related areas, and social-science-related areas such as human resources and management. Above all, a strong emphasis is put on energy-related technology and socialization of information (construction of a new society system using ICT).

—Themes in which science and technology provide a great potential contribution—

Scenario writing—an effort to explore the path toward the future—was performed by groups of experts. Some of the themes (such as health-information infrastructure, medical environment,

security of resources, stable supply of foods, and a smart grid to realize a low-carbon society) have a clear relationship with elements of science and technology. Subsequent development of these elements as an integral part of the social system is expected to contribute greatly to the visions of the future society, especially “a society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail” and “a society where individuals can use various types of energy selectively based on their comprehensive evaluation of value and can feel that they proactively contribute to global warming prevention and environmental preservation.”

—Directions with large potential for innovation—

Two directions emerged through the process of a similarity analysis of all the texts that describe Delphi topics and group scenarios, and through subsequent mapping. These are expected to embrace forthcoming innovations.

- ✓ Green innovation group is formed that covers wide and loosely linked areas in energy, resources, and environment.
- ✓ Life innovation group is formed that covers health and medical care areas

It is also apparent that base technologies (ICT, infrastructure, etc.) and social scientific areas (management, life style, etc.) are integral to underpin the two directions. Especially, ICT assumes a decisive role in all areas, constituting base technology essential for promoting innovations.

—Requirements to accelerate progress toward visions of future society—

- ✓ International deployment constitutes a pillar for promoting green innovation. What is urgently needed is the cultivation of internationally-minded human resources who are capable of undertaking integration and systematization from a broader point of view.
- ✓ Promotion of preventive healthcare is the mainstay of life innovation. The objective can be achieved through the promotion of tailored health and medical care based on personal lifelong health and medical records, which requires the proactive introduction of human resources from other disciplines.

—Summary—

A comprehensive analysis of the results of the 9th Science and Technology Foresight concludes the following items deserve special emphasis.

- ◆ When we see the large picture of the desired future visions in Japan, green innovation and life innovation define the major directions of our future efforts. ICT shall provide base technology underpinning these efforts, and the process should be promoted through discussions involving such common aspects as infrastructure, management, and life style.
- ◆ Emphasis should be placed on the systematization technologies with institutional design and service delivery, directly linked to the solutions in real-life society.
- ◆ International deployment is one of the key aspects that should be kept in mind from the initial stage of research and development.
- ◆ Particular attention should be paid to the diversified social values depending on localities and generations.

Part I: Integrative Discussion

Chapter 1: Overview of the 9th Science and Technology Foresight

1-1. Transitions in Japanese science and technology policy amid changes around the world

In Japan, science and technology policies have been implemented under the Science and Technology Basic Plans since 1996. In the second and third Basic Plans, which started in 2001 and 2006, a selection of focus has been the basic approach for policies that respond to important issues except for ones related to basic research—the budget for which is handled separately—and the reformation of the science and technology system. In concrete terms, the planning for those policies especially focuses on the following eight fields: life science, ICT, environment, nano-material, energy, manufacturing technology, social infrastructure, and frontiers. It merits attention that, in the third Basic Plan, the promotion strategy for each of these eight fields has been laid down in specific areas, that is, strategically important science and technology areas have been identified explicitly. In conjunction with this policy, a call for innovation through scientific and technological progress was stated clearly.

In the meantime, the global situation surrounding science and technology has undergone a radical change. Expectations for innovation through scientific and technological progress are building up in the face of intensified international competition and the global stagnation in the economy, as well as the spreading awareness of global warming. Advanced countries around the world have shown a clear tendency to place special focus on science and technology policy in their innovation strategies. Especially in Japan, the status of science and technology policy in the national grand strategy has changed significantly as its GDP growth rate stagnates in the face of a falling birthrate and aging population (the population entered into a phase of natural decrease in 2005).

Against these backdrops, expectations are growing high, also here in Japan, calling for the fruits of science and technology to contribute toward solving global and national challenges. In the fourth Basic Plan, which is going to start in 2011, it seems only natural that the focus on a problem-solving approach becomes more apparent: solving grand challenges through the effective application of science and technology. In other words, the “policy challenge oriented approach” comes closer to its original meaning. In this situation, the idea of placing special focus on particular areas has to be phased out, while the following themes will be central in discussion in the days to come: the fusion of dissimilar areas in science and technology, collaboration with the humanities and social science, and the promotion of science and technology viewed as an integral part of social-system reformation.

1-2. Survey design

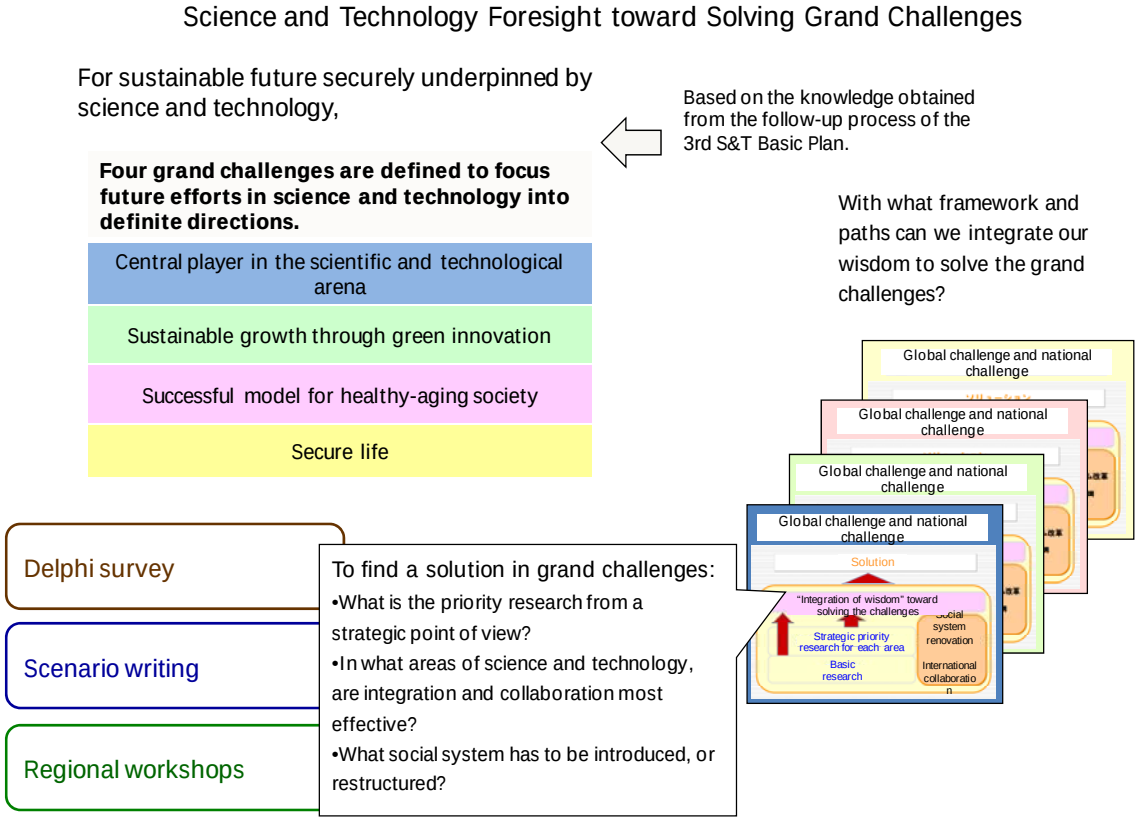
1-2-1. Basic policy

With the manifold drastic changes inside and outside Japan as a backdrop, the 9th Science Technology Foresight sets a focus of discussion on science and technology conducive to solving global and national challenges with a clear view of the direction toward the future. Considering the current global trends and situation in Japan, the survey narrowed down the course of actions, in terms of scientific and technological challenges, into the following four grand challenges.

- ✧ Central player in the scientific and technological arena.
- ✧ Sustainable growth through green innovation.
- ✧ Successful model for healthy-aging society.
- ✧ Secure life.

As a way of approaching the objective, special stress was placed on interdisciplinary out-of-the-box discussion from the viewpoint of constructing a framework for knowledge integration that provides a solution to the grand challenges. In concrete terms, the survey employed a combination of multiple methods including: a Delphi survey regarding the topics extracted through interdisciplinary discussion with the targets for the future society clearly in mind; scenario writing by several methods in view of the paths to be taken toward the desired future; and region-based discussions for the realization of sustainable regional societies; and comprehensive discussion (Figure 1-1).

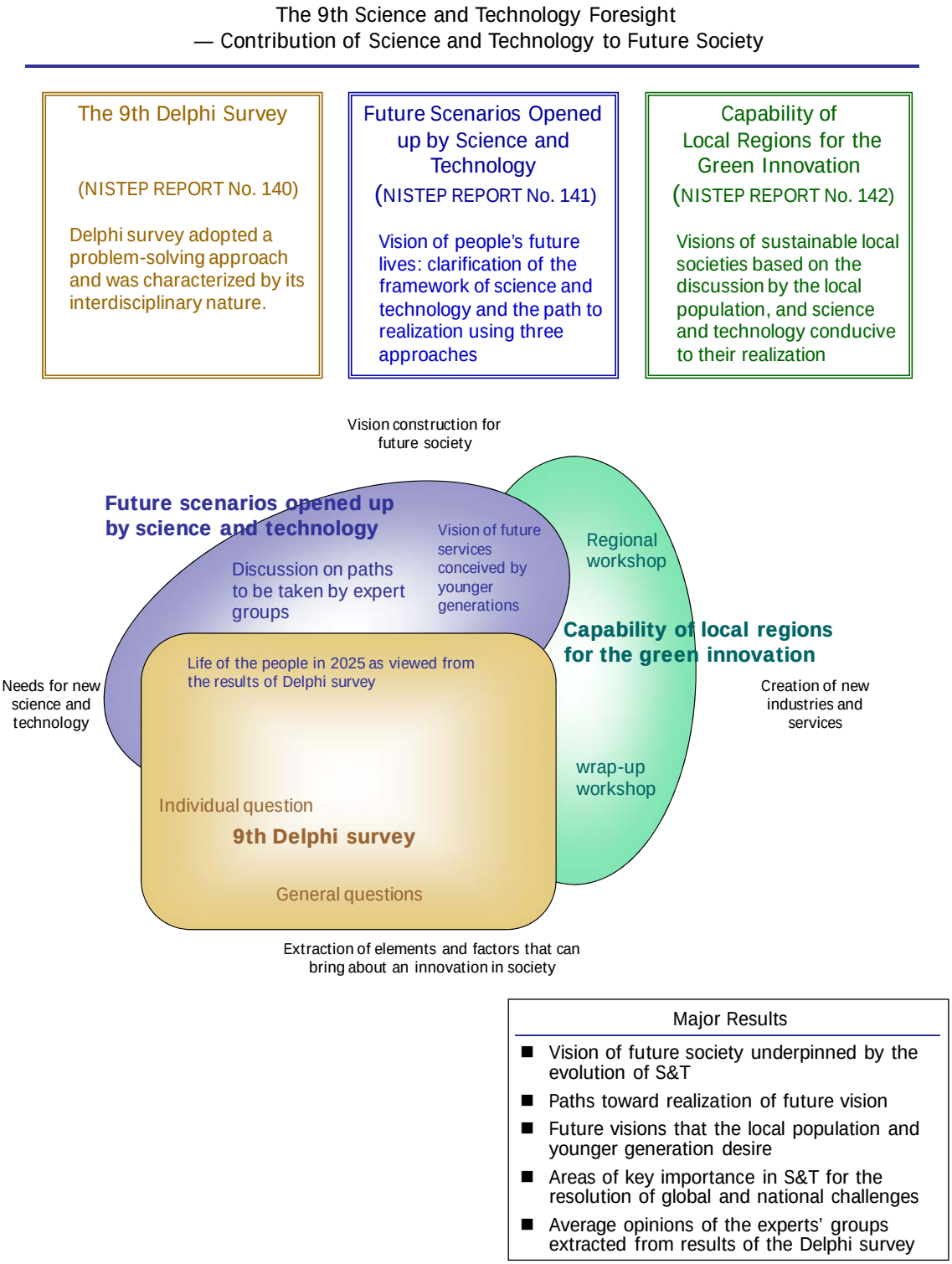
Figure 1-1: General overview of the survey



1-2-2. Three investigative studies that make up the 9th Foresight

The 9th Science and Technology Foresight comprise three mutually complementary investigative studies (Figure 1-2). An overview of each study is described in Part II.

Figure 1-2: Positioning of the three investigative studies

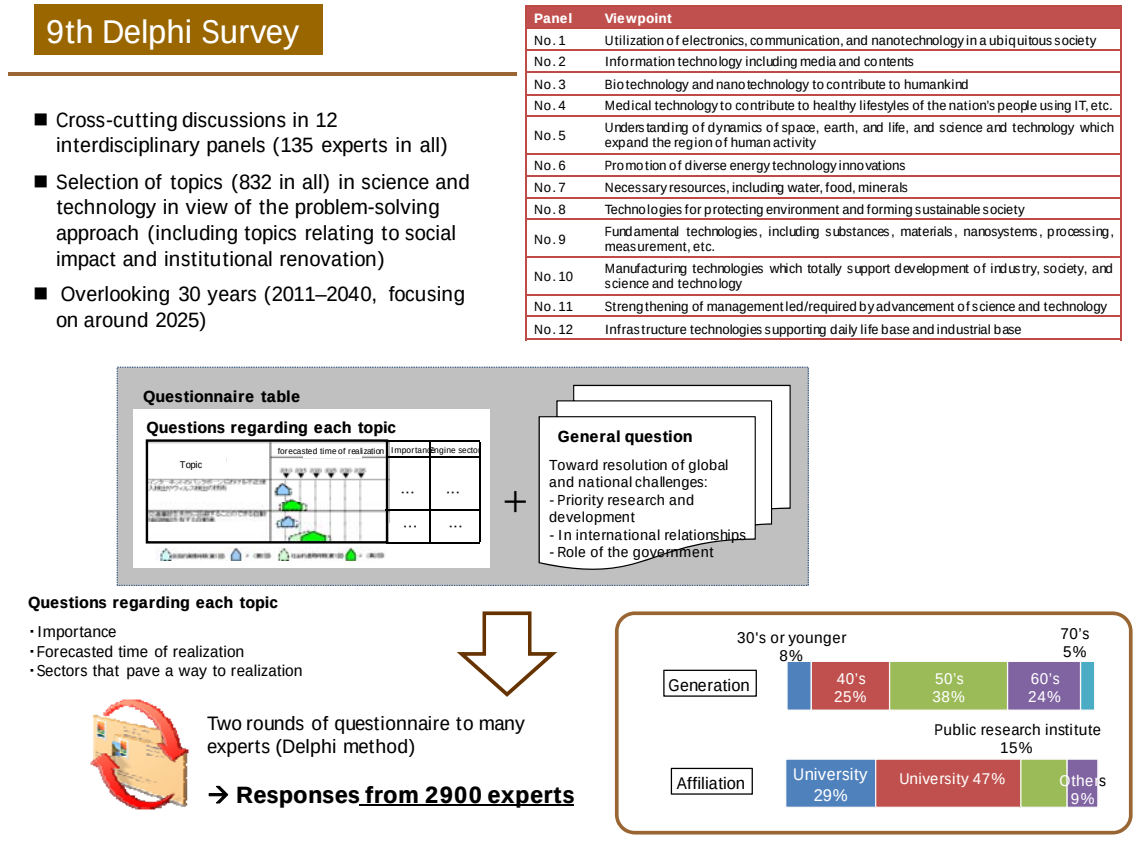


(1) The 9th Delphi Survey

This is the 9th round of the series of successive delphi surveys since 1971, when the first survey was conducted. The delphi method is characterized by repeated questionnaires for gradual and collective convergence of opinions, and it has been used in Japan as a technique for large-scale questionnaires targeted at experts in science and technology. In this round of the delphi survey, the objective was to outline the future prospect of development in science and technology from the viewpoint of "what we should do from now onward" to reach future goals and resolve global and national challenges, whereby the priority items were extracted through interdisciplinary discussions. For this reason, the panels, consisting of members from cross-cutting fields, were designated not by the name of disciplines, but by a number. Through interdisciplinary discussions on science and technology, the panels defined the topics and the question items with a view toward solving global and national challenges. This interdisciplinary and problem-solving approach is one of the most significant characteristics of the 9th Delphi Survey. For the first time in the 40-year history of delphi surveys, the field name was ruled out from the panel's nominal designation.

* The topic represents a description regarding future science, technology, and social system.

Figure 1-3: Overview of the study (Delphi survey)



(2) Future Scenarios Opened up by Science and Technology

Three different approaches were attempted for the scenario writing (Figure 1-4) with a view toward proposing a way leading to and building a framework for knowledge integration, whereby special focus was placed on the social changes brought about by science and technology.

A. Scenario writing by group work (group scenario)

A group consisting of experts made an extensive, interdisciplinary discussion on a theme—a possible solution that can help solve a grand challenge—and constructed a scenario of future changes that may be brought about by science and technology, including a way of path finding and frame building for reaching goals.

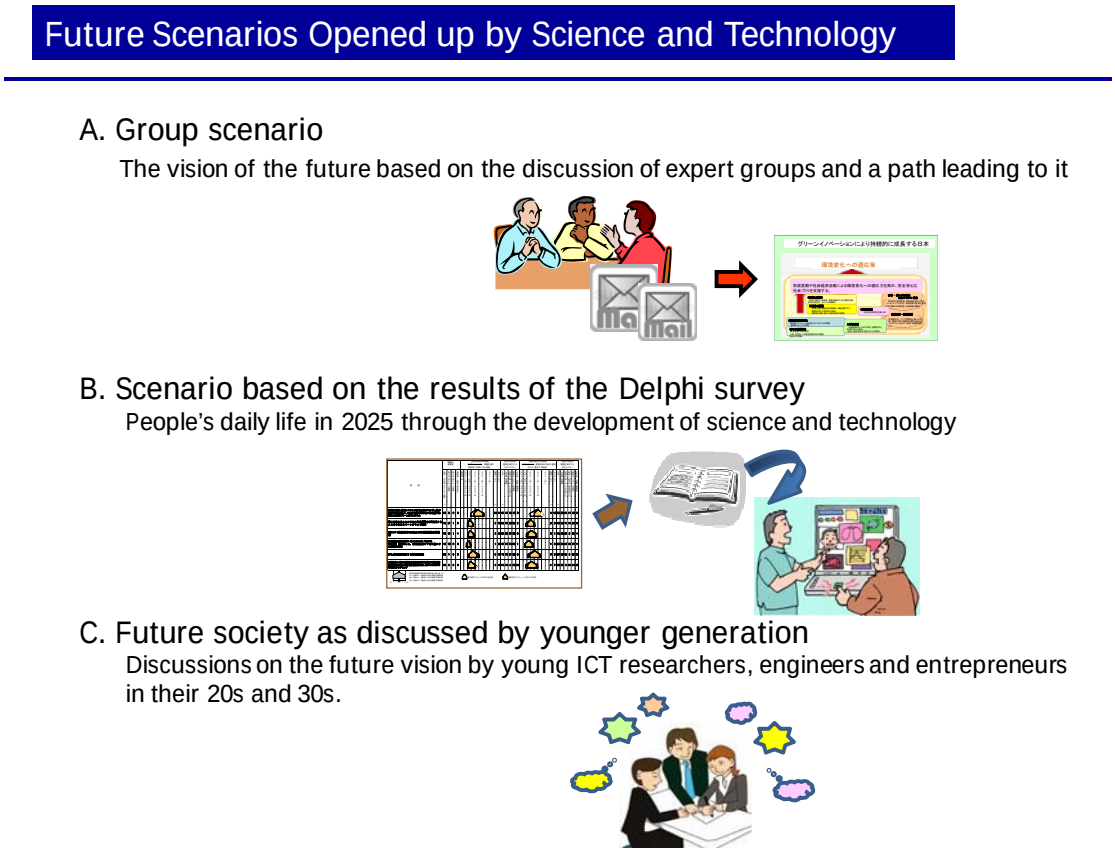
B. Future scenario based on the results of the Delphi Survey

A scenario was developed, based on the average future outlook of many experts (in other words, the results of the 9th Delphi Survey), and it described future changes brought about by science and technology.

C. Future society as discussed by younger generation

Group discussions in which only members of younger generation participated were held for the purpose of extracting different viewpoints for the future. This attempt was made to compensate for the possible bias that may be inherent in approaches above: that, by nature, the experts with a very high level of knowledge and expertise come disproportionately from the older generations.

Figure 1-4: Overview of the study (scenario writing)

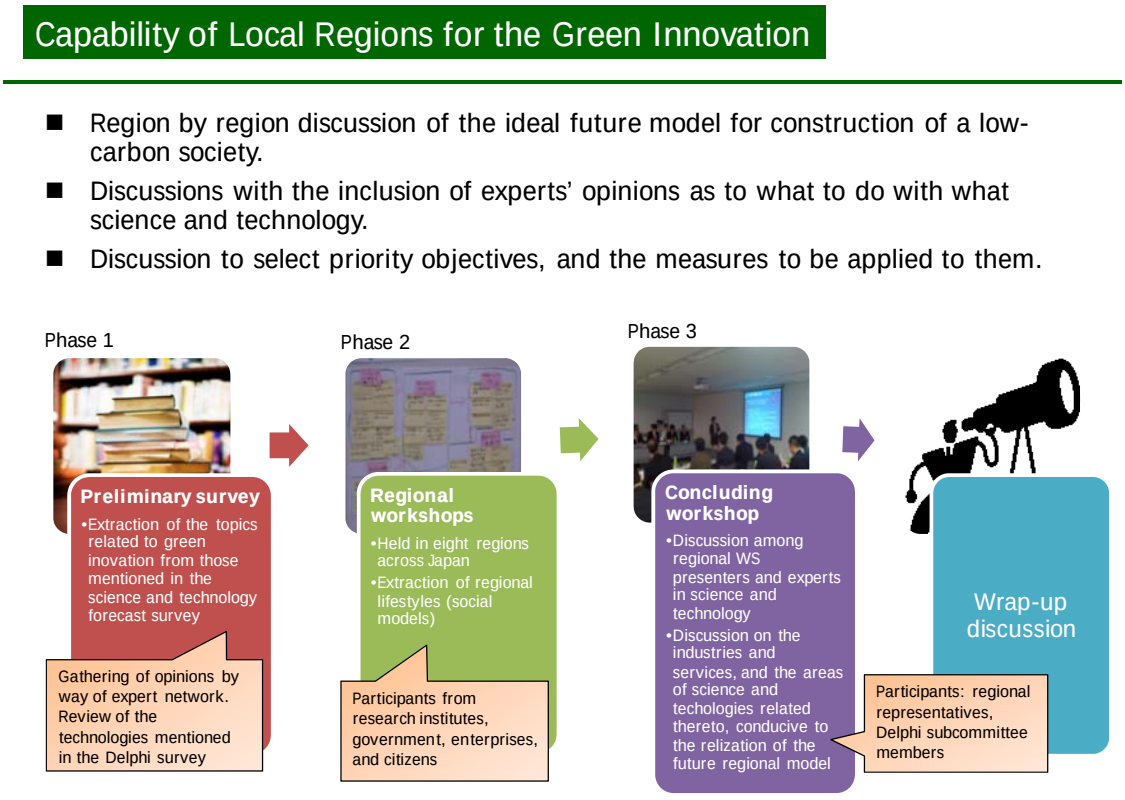


(3) Capability of Local Regions for the Green Innovation

In foreign countries, there are many activities on regional foresight. Here in Japan, also, activities on a regional basis are highly desirable and necessary for establishing a future vision of the regions. The objective of this study is to provide an initial platform on which citizens of the region starts their discussions about their own future vision. The discussions include all aspects required, including institutional renovation, inter-regional cooperation, and the region's place in the era of globalization.

Workshops were held in eight regions in Japan, where the participants discussed the ideal regional lives in the future, and what kind of science and technology will be required to realize them (Figure 1-5). The discussion placed special emphasis on the promotion of green innovation, in view of the creation of new industries and job opportunities through efforts to construct a low-carbon society. Experts in science and technology also provided their views in the discussion.

Figure 1-5: Overview of the study (regional workshops)



(4) Preliminary study

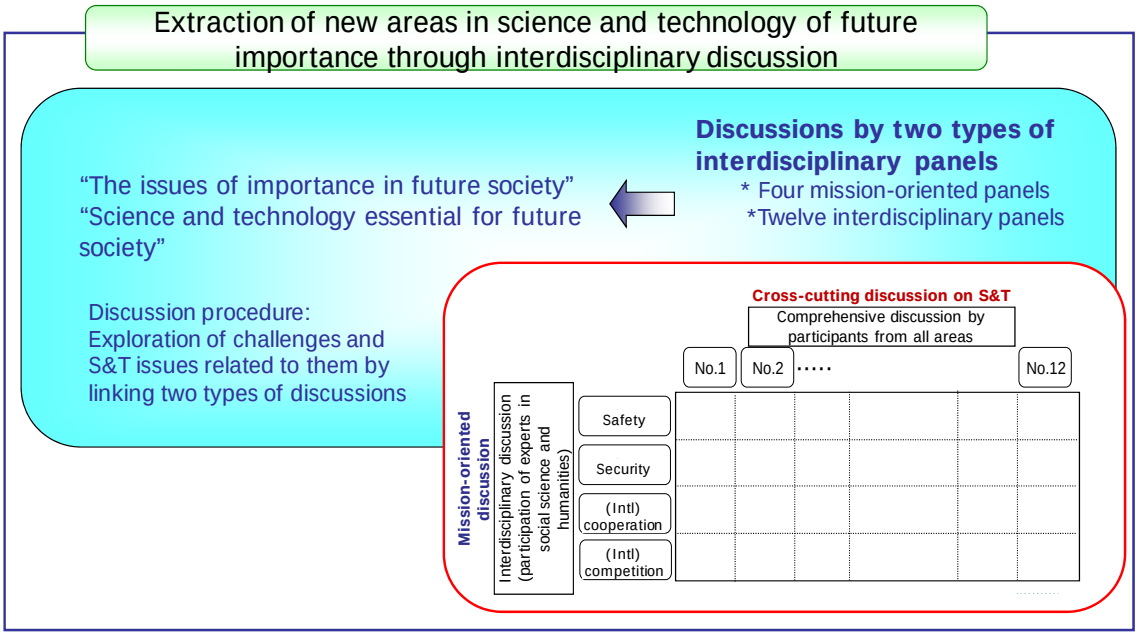
This science and technology foresight has adopted a problem-solving approach in which discussion was focused on the science, technology, and social system that are integral for the realization of future visions. Before implementing the 9th Foresight, a preliminary study was needed to discuss the expectations for science and technology with a view toward bringing the future vision into reality.

The preliminary study, "Emerging Fields in Science and Technology for the 4th Science and Technology Basic Plan," was conducted to discuss on missions of science and technology that would play an important role in drawing up the picture of future society. The objectives of the preliminary study included identifying the relevant issues of science and technology.

The four panels organized for mission-oriented discussion were designated as "Reassurance on safety," "Security," "International collaboration," and "International competitiveness." They reviewed the missions of science and technology, and identified 24 priority issues. Then, twelve interdisciplinary panels took the discussion one step further, and examined relevant science and technology in concrete areas (Figure 1-6).

The preliminary study clearly indicated the importance of systematic integration, that is, the incorporation of science and technology into the society as a "socialized system." The following were pointed out as being important in socializing science and technology: the systematic promotion of research and development linking mutually-related areas in science and technology, dealing with a group of mutually-related technologies as an integrated system, careful discussion on how to apply science and technology to society, and a broad review of the social system including institutional reform.

Figure 1-6: Overview of the preliminary study



1-2-3. Development for the implementation

It has been about 40 years since the period from 1970 to 1971, during which the first foresight exercise was conducted in Japan. Since then, only the expert questionnaire, on the direction of development in science and technology, had been conducted without interruption. However, in recent years, the foresight exercises took another turn to embrace a wider view, looking into the future society.

The 8th Foresight (2005) marked a significant turning point. Up to this point, only a partial view was taken on cross-cutting issues, and the discussion in conjunction with future society was limited. In the 8th Foresight, in addition to the conventional delphi survey, multiple methods were introduced to cover a much broader perspective, including an investigation of social and economical needs, scenario writing, and an exploration into emerging areas based on research paper citation data. However, a comprehensive study based on results from each study was not carried out. The focus of attention was placed mainly individual areas of science and technology even in the 8th Foresight.

A comprehensive study was first attempted in the investigative research, “Social vision toward 2025”, which was intended to contribute to the drawing up of the “Long-term strategic guideline: Innovation 25” (decided by the cabinet in June 2007). This research used results from the 8th Foresight as a starting point, and developed them constructively with a view toward future society. The findings indicated that a combination of multiple methods would be conducive to effective discussion on future society and related science and technology.

Meanwhile, during the period of the third Science and Technology Basic Plan (2006 – 2010), awareness of drastic changes in the situation inside and outside Japan became increasingly stronger. As a result, when the discussion began to plot out the fourth Basic Plan, it was well prospected that the focus of discussion would shift to the possible effect science and technology could have on global and domestic social issues. Therefore, it was natural that the discussion on the relationship between society and science and technology was high on the list in the 9th Foresight. In Europe, foresight activities are traditionally more active in terms of future society, rather than in terms of science and technology. In line with this trend, experimental joint research with the Finnish Funding Agency for Technology and Innovation (Tekes, which had conducted a foresight research project called “FinnSight 2015” to extract the elements that triggered social changes) was carried out, focusing on science and technology conducive to society. Three themes were set up for the research, and the effectiveness of a combined multiple method approach was evaluated, where the combination included such methods as panels, delphi, scenario writing, workshops, and road mapping. The results indicated the importance of the following for a successful implementation of the multiple method approach: a unified framework of investigation used in different methods, an investigation procedure involving mutual interaction between the methods, and the creation of an executive summary document in the last phase of the investigation process for integration.

Based on the knowledge accumulated from these experiences, the 9th Foresight employed totally different approach; the relationship between the future society and the fruits of scientific and technological development came to the fore. Interdisciplinary nature was the key this time, eliminating as completely as possible the conventional boundaries of existing disciplines. In addition, the main focus was placed on strategic thinking, where the relationship to society was emphasized.

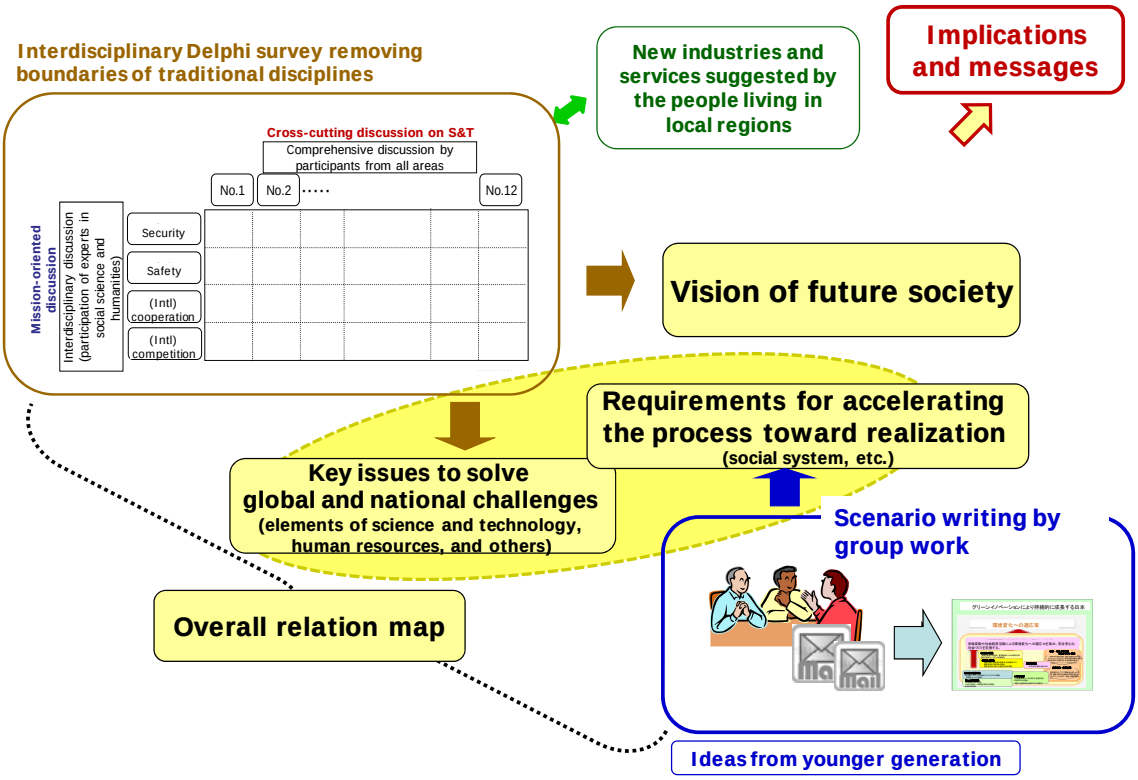
For past delphi surveys, each forecast was evaluated as to whether it had been realized, and to what degree, after twenty years from the time of the survey. This evaluation effort provided valuable suggestions regarding the requirements conducive to advancing science and technology.

1-3. Framework for integrative study

From Chapter 2 onward, the three studies carried out in "The 9th Science and Technology Foresight" (described in 1-2-2) are analyzed and general implications are extracted from them (Figure 1-7).

The first step is to create a vision of the future society from the results of the Delphi Survey. This future vision based on the forecast made by experts in science and technology, provides a possible goal. The next step is to identify the areas in science and technology that are considered to have major contributions toward the realization of the future social vision. This process utilizes results of the Delphi Survey ("areas of key importance for the resolution of challenges") and the relation map linking the delphi topics with the scenarios created by expert groups. Subsequently, an attempt is made, based on the results of the three studies, to extract and discuss social requirements essential for promoting changes toward the future.

Figure 1-7: Framework for integration



<Reference A: List of reports>

"The 9th Science and Technology Foresight- Contribution of Sciecne and Technology Policy to Future Society: The 9th Delphi Survey," NISTEP REPORT No.140, March 2010

"The 9th Science and Technology Foresight- Contribution of Sciecne and Technology Policy to Future Society: Future Scenarios Opened up by Science and Technology," NISTEP REPORT No.141, March 2010

"The 9th Science and Technology Foresight- Contribution of Sciecne and Technology Policy to Future Society: Capabililty of Local Regions for the Green Innovation," NISTEP REPORT No.142, March 2010

"Emerging fields in Science and Technology for the 4th Science and Technology Basic Plan," Research Material 168, March 2009

* Related investigative surveys conducted up to now:

"Foresight for Our Future Society—Cooperative Project between NISTEP (Japan) and TEKES (Finland)," Policy Study No.14, February 2009

"Trial of new science and technology foresight by several integrated foresight tools—Collaboratory research project between Japan and Finland (Japanese results)," Policy Study No.13, November 2008

"Social vision toward 2025—Scenario Discussion based on S&T Foresight, March 2007," NISTEP REPORT No.101, March 2007

"The 8th Science and Technology Foresight – Study on Social and Economic Needs," NISTEP REPORT No.94, May 2005

"The 8th Science and Technology Foresight – Study on Rapidly-developing Research Area" NISTEP REPORT No.95, May 2005

"The 8th Science and Technology Foresight –Scenario Analysis," NISTEP REPORT No.96, May 2005

"The 8th Science and Technology Foresight - Delphi Analysis," NISTEP REPORT No.97, May 2005

"The 8th Science and Technology Foresight - Summary," NISTEP REPORT No.98, May 2005

"Comperhensive analysis of Science and Technology Benchmarking and Foresight," NISTEP REPORT No.99, May 2005

"The Seventh Technology Foresight - Future Technology in Japan toward the Year 2030," NISTEP REPORT No.71, July 2001

"The Sixth Technology Forecast Survey- Future Technology in Japan Toward The Year 2025 -" NISTEP REPORT No.52, June 1997

"The 5th Technology Forecast Survey - Future Technology in Japan," NISTEP REPORT No.25, November. 1992

Chapter 2: Vision of Future Society, and Areas of Science and Technology Conducive to Realizing It

2-1. The vision of future society brought about by advancement of science and technology - People's lives in 2025: a vision derived from the results of the Delphi Survey

What can we expect of future society by advancement of science and technology? Of all the delphi topics, those that meet the following conditions are extracted: the topics expected to be widely available in society in 2025 (social realization by 2025), and the topics expected to become widely known through publications of research results, thus providing the population with hope for the future (technological realization by 2025). According to the experts' prediction, the future population around 2025 will be living in a society more advanced than now in the following three aspects.

- A society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail
- A society where individuals can use various types of energy selectively based on their comprehensive evaluation of value and can feel that they proactively contribute to global warming prevention and environmental preservation
- A society in the early stage of coping with the various disasters caused by environmental changes

Figure 1-8 illustrates scenes in daily life, the pictures of which are created by associating their lives with the major extracted topics. From these images, we can see that the scientific discoveries and invention we know today and the technologies currently in their early stages of practical application will become widely available in 2025, 15 years from now. With the help of such science and technology, life in the future is expected to be much more satisfactory. The images show, for example, that each individual will be closely linked with a health care management system, enabling self-management of health on a daily basis, and that the health professionals will be able to engage in medical services, including mental support, in a systematic way. The images also show that a social system has been constructed in which each individual can use energy in an environmentally-friendly way and live in an environment well-prepared for natural disasters and environmental changes (see Appendix B).

The vision depicted here is a realistic representation of the future society based on scientific and technological feasibility. It is forecasted that about 90% of the topics that inquired about the period of technological realization and about 40% of those that inquired about the period of social realization will be realized by 2025. These topics are quite indicative of the direction toward the desired future vision.

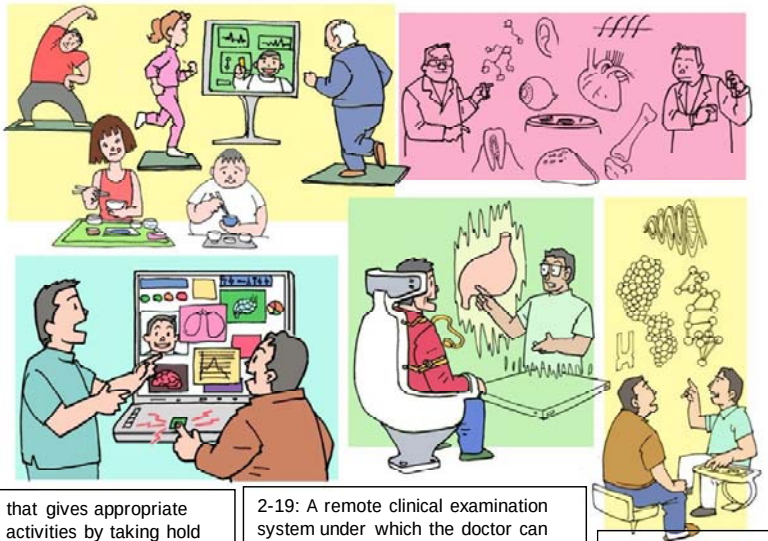
What is required in the next stage is the identification of the areas in science and technology that are most conducive toward the realization of the social vision in the future, and it is also desirable that the measures that help these areas evolve steadily are mentioned, as well as the social system to promote efficient diffusion and application. These combined multifaceted measures will ensure that the future vision will become reality, possibly enabling us to relish the fruits of the efforts earlier than expected. These approaches are considered more constructive than those with strategies that are based only on considerations of the problems of the present and the past.

Figure 1-8: Scenes in daily life in 2025

Society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail

1-16: Ubiquitous computing technology supporting health control to maintain and to improve one's health in daily life using computer software (2018)

3-33: Artificial organs which include human cells or tissues derived from iPS cells (2033)
3-34: Technology for regenerative medicine using iPS cells (2032)
3-35: Therapeutic technology using functional cells induced from stem cells, including iPS cells, without risks of carcinogenesis (2030)
4-10: Technology for the regeneration of muscles and organs using stem cells (2031)



2-05: A system that gives appropriate advice for daily activities by taking hold of information on the lifestyle, health conditions and working situation of each individual, in a continuous and comprehensive manner (2022)

2-19: A remote clinical examination system under which the doctor can use a stethoscope and palpate the patient or smell the patient's breath from a distance, as if they were face to face (2029)

4-51: Diagnostic methods for the risks of acquiring diseases through genome data (2023)

4-80: Integrative medicine in which a lifelong regional electronic health record is introduced and community-based care is possible (2023)

11-17: In Japan, the medical records containing motion video will be converted into electronic form and entrusted to patients, and the medical information, including the results of examination, will be shared among all medical institutions. Based on this environment, a health care agent business will be formed between patients and medical institutions (2024)

12-20: Diffusion of logistics services that deliver medicine and food for medical treatment, without requiring a hospital visit, to support the lives of elderly persons and patients of lifestyle diseases living in inconveniently located areas, such as mountainous regions, by establishing a remote consultation system and health care system using IT technologies (2020)

4-83: Medical ethics education for healthcare professionals (2017)

4-84: Medical safety education for healthcare professionals in which simulation technology is introduced (2018)

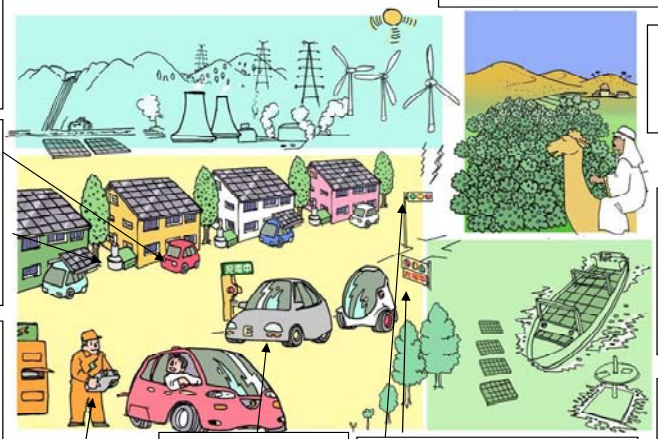
4-66: Regional medical care system that can take prompt actions and correct regional disparities in regard to emergency medical service (2021)

Society where individuals proactively contribute to global warming prevention and environmental preservation

6-53: Next generation energy transmission and distribution network technology enabling stable, low-cost and low-carbon power supply through the optimum management of the entire demand and supply balance of large power supplies such as nuclear power, distributed power supplies such as solar energies and power demand equipment, by utilizing information and communications technology (2025)

8-64: Technology and know-how for operating water supply and recycling systems overseas, including in emerging countries, which is strategically developed based on the all-Japan framework, while incorporating material, structure, operating process, finance and the other factors thereto to obtain a 30% market share in this area (2024)

6-49: A demand and supply control system for customers and a distribution system by using batteries for Plug-in Hybrid Electric Vehicles (2022)



7-12: New technology for vegetation regeneration in deserts (2029)

6-67: A micro turbine cogeneration system featuring ultra-lean combustion for high efficiency, enhanced pressure ratio for high power and downsizing, and low-NOx combustors (2023))

6-20: A large-scale thin-film solar cell with a conversion efficiency of 20% or higher (2027)
6-41: Low-cost secondary cells for (2025)

6-35: Spread of a residential energy system integrating renewable energies such as solar cells, and fuel cells (2019)
6-52: A home energy management system where electric appliances, solar power devices, and storage cells are integratedly controlled via an inhouse communications network to reduce CO2 emission (2019)

6-41: Low-cost secondary cells for vehicles (2025)

1-43: Long life and highly reliable electric vehicle battery technology with high energy density that enables electric vehicles to have a total driving distance on a single charge that is equivalent to that of current gasoline vehicles ((2025)

1-49: Successive contactless charging technology that charges electric vehicles and/or hybrid vehicles when they are parked at public parking lots and/or stopped at roads and intersections (2023)

6-21: Power generation technology based on ONE of ocean energy resources with 1MW capacity or more (2030)

12-44: Promotion of vehicles that control the speed and operation of the engine to minimize fuel consumption by detecting the timing of traffic signals, as well as a traffic control system enabling the operation of such vehicles (2025)

Society where people have begun to cope with various disasters

8-23: Forecasting technology for the future global environment on a time scale of several decades based on a global system model that simultaneously takes into account the material cycles within the atmosphere, oceans and land (2028)
8-43: Technology to estimate the amount of each nation's emission and absorption of CO2 using accurate data derived from observation by artificial satellites (2025)

8-34: Information analysis techniques to efficiently determine water use and the materials cycle in urban areas, using information from the results of a inter-industry analysis and industry logistics information, etc (2024)

12-17: A system is working to support the evacuation of citizens, elderly persons, patients and injured persons in the case of a disaster exceeding that forecasted (2022)

12-18: Establishment of an institution supporting the improvement of urban function, the control of social and economic activities, food stockpiling, and priority precedent evacuation of some citizens in accordance with the establishment of forecasting technology for a magnitude 6 or larger earthquake (2026)

8-21:Sophisticated simulation for atmospheric environment forecasting, providing an atmospheric chemical weather map that indicates information about particulate matter, oxidants, nitrogen compounds and so on and that will be used even by citizens, like weather forecasts are now (2024)
5-25: Development of seamless land and sea observation data (2026)

12-16: Establishment of real-time damage recognition and forecast technology enabling the national and municipal emergency operation center to take emergency measures immediately and effectively in the case of a large-scale natural disaster that requires prefecture-level measures (2024)
12-21: Cooperative framework involving citizens and administration for disaster prevention and mitigation based on communication and education, enabling local residents to recognize the risk of natural phenomena such as volcanic eruptions, earthquakes and floods, and human-caused accidents (2020)

2-2. Areas of key importance in S&T for the resolution of global and national challenges —Keys to solving challenges: proposals from delphi respondents—

2-2-1. Setup process for the survey

For continuous development and effective utilization of science and technology, the interdisciplinary discussions removing the boundaries that separate existing fields are required. In the 9th Delphi Survey, the panels that consisted of the members from a variety of fields were called by number because names of disciplines were ruled out of the designation of panels to eliminate stereotyped discussion. Each panel decided their own viewpoints.

The twelve interdisciplinary panels, with 135 experts in all, set up 832 topics following three steps: 1) keywords are selected that represents the issues to be focused on, 2) areas are set up by grouping together the closely related keywords, and 3) topics are set up for each area. In parallel to the topic setup process, another four panels—named "Security," "Safety," "International collaboration," and "International competitiveness"—held meetings to identify priority issues for drawing up future objectives of science and technology. The former twelve panels proceeded with their steps with due consideration of the discussion by the latter four panels (Figure 1-9, Table 1-2).

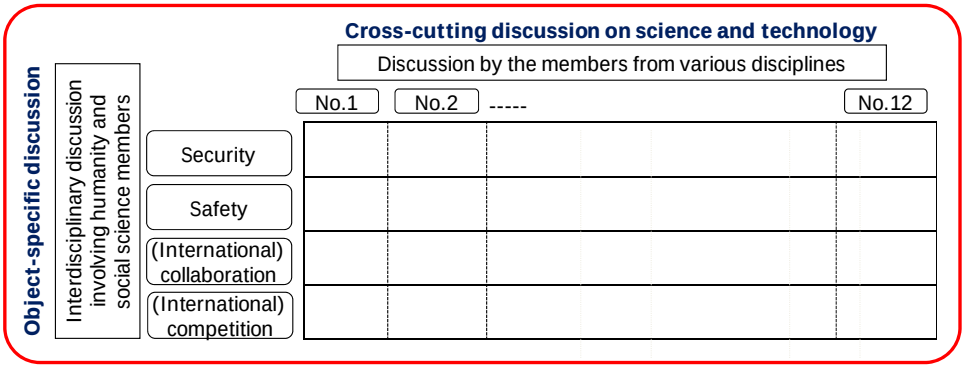
What characterized these discussions is the prioritization from a strategical standpoint, rather than complete coverage of science and technology. Based on this policy, overlapping discussions were allowed because they were regarded as a cross-cutting viewpoint of importance. The viewpoints of these twelve panels can be considered to represent the whole picture of the targets on which the future science and technology policy should focus.

Table 1-1: Twelve viewpoints for the interdisciplinary panels

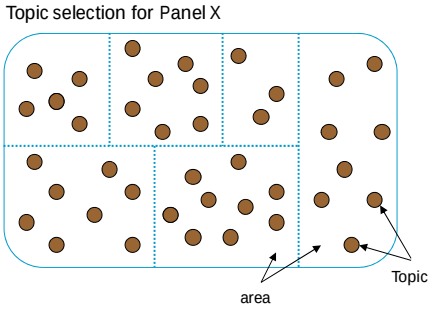
Panel	Viewpoint (defined by each panel)	Areas	Topics
No. 1	Utilization of electronics, communication, and nanotechnology in a ubiquitous society	6	70
No. 2	Information technology including media and contents	12	76
No. 3	Biotechnology and nanotechnology to contribute to humankind	8	58
No. 4	Medical technology to contribute to healthy lifestyles of the nation's people using IT, etc.	5	85
No. 5	Understanding of dynamics of space, earth, and life, and science and technology which expand the region of human activity	7	64
No. 6	Promotion of diverse energy technology innovations	13	72
No. 7	Necessary resources, including water, food, minerals	7	59
No. 8	Technologies for protecting environment and forming sustainable society	10	68
No. 9	Fundamental technologies, including substances, materials, nanosystems, processing, measurement, etc.	5	84
No. 10	Manufacturing technologies which totally support development of industry, society, and science and technology	8	76
No. 11	Strengthening of management led/required by advancement of science and technology	8	58
No. 12	Infrastructure technologies supporting daily life base and industrial base	5	62
Total		94	832

Figure 1-9: Processes for setting up the topics

Relationship with twelve interdisciplinary panels and four object-specific panels



Method of setting topics



* Each area represents a group of keywords that were listed for topic setting. Therefore, conceptually similar topics exist within an area. The areas were reviewed after the topics were finally defined.

Table 1-2: Preliminary discussions

Discussion on "Security"

Issue	Content
Construction of dependable public system	System tectonics (dependable basis technology, open system), overall optimization (balance between efficiency upgrade and redundancy), decision-making system based on science and evidence, integrated information
Transparent system	Transparency in systems (construction of open system, prediction and evaluation), security engineering, control technology (counter technology, PDCA)
High quality of health	Customization, Quantification of health quality, diffusion and enlightenment of health information (risk communication), comprehensive medical care system
Realization of society free of age-barriers	Self assistance, mutual assistance, public assistance (universal design, infrastructure compatible with aged society), QOL recession (infrastructure compatible with people who have dementia)
Realization of sustainable life	Food (traceability, risk of chemical substances, stable supply), resources (element strategy, secure procurement), energy (renewable energy, recycling, low-carbon society)
Realization of permanent peace	Defense system, soft power, homeland security

Table 1-2 (continued)

Discussion on "Safety"

Issue	Content
Linkage, integration, provision of data and knowledge	Understanding of human behavior, sophisticated safety knowledge system; Creation of safety map with a view to life environment and age; Quantification of safety items
Construction of social system	Defense, life line, food, water, atmosphere, medical care, welfare
Personal safety	Technology for mutual understanding of humans and computers
Allocated responsibility	Legal system, safety industry
Culture for safety	Safety knowledge system, safety concept, defect-mode analysis of human behavior
Safety of man-made objects	Long service life; Safe housing (no need for evacuation at the time of disaster); Risk assessment for new technology (identification, evaluation, analysis, and coping techniques); Safety considerations; Understanding of human behavior
Human safety	Coping with rapidly changing crime, investigation support; Safe driving system (Drive-blocking, automatic judgment of driving, technology development to eliminate bodily injury)
Safety from environment and disaster	Safety assessment in industry and society; Rescue and evacuation technology; Capability to identify and avoid danger; Prevention of panic and secondary disaster; Prediction and assessment, visualization of danger; Post-disaster safety and security

Discussion on "International Cooperation"

Issue	Content
Development of undiscovered/untapped resources and energy	Correct understanding of data, development of untapped resources and energy, resources in the polar region; Exploration of the next generation energy resources, resource exploration in the seabed of the Japan Sea; International rules for resource management
Global monitoring and control of human activities	Population control for stable society; Prediction and measures against disaster; Technological and institutional measures against global warming; Appropriate allocation of water and food resources; Earth-friendly energy, energy conservation; Addressing global challenges on a regional basis
Life-long maintenance of health	Health risk management and cooperation; Realization of health through mutual understanding with developing countries; Countermeasures against infectious diseases including risk assessment; Design of healthy and comfortable residential space
Industrialization of original technologies	High quality manufacturing; Bio-/nano- technology; Transportation and telecommunication
Deployment of educational functions	Cultivation of leaders in the international arena; Education compatible with individual's capacity; Cultivation of educators and overseas dispatch; Provision of training techniques
Methodology for resolving international issues	Science and technology diplomacy, consensus building

Discussion on "International competition"

Area	Content
Intellectual toughness compatible with international society	Enhancement of application capability, higher evaluation of intellectual labor, establishment of international intellectual community, establishment of application-oriented professional school, cognition sharing in multi-language environment, cultivation of tough human resources
Cognition sharing	Techniques for perception sharing (communication technique in international arena, augmented reality, tangible interface), implicit knowledge of cultural value, enhancement of comprehensive cultural knowledge, cross-culture cognition method
Proposal of Japanese-style methodology	Method proposal (cognition technique in medical diagnostics etc.); New sustainability approach (Japanese space layout, harmony between humans and nature); measurement, regeneration and repair technology; social techniques (traceability of goods in and out of Japan, reducing the amount of disposed food and agricultural products)
Technology transfer donation to explore future demand	Technology transfer (environment and energy, countermeasures against infectious diseases, transparency from production to consumption, understanding of actual state of the world); Humanity (beneficial donation, augmented sharing, revitalization of humanity through donation, enhance competitiveness triggered by donation, creation of information hub

2-2-2. Key areas in science and technology with an eye toward solving challenges

In the Delphi Survey, a question item was set up asking, “What is the area of key importance in science and technology for the resolution of global and national challenges?” The respondents set by panel selected two areas from the options defined by the corresponding panel. Table 1-3 shows the most-supported 36 key areas, which correspond to about one-third of all areas.

It is to be noted that 18 areas, half of the upper key areas, are related to energy, resources, and environment. This implies that the areas that have much to do with and are conducive to the realization of one of the future social visions (i.e. “a society where individuals can use various types of energy selectively based on their comprehensive evaluation of value and can feel that they proactively contribute to global warming prevention and environmental preservation” [see section 2-1]) gathered much attention from experts in a variety of fields. In health and medical-care related areas, the areas relating to preventive medicine are selected in addition to those relating to medical treatment. In the areas classified as “Others,” it merits attention that many of the social scientific areas (e.g. human resources and management) and ICT-related areas are mentioned.

Ten of all the areas, which gathered votes from about half of the respondents, are broken down as follows: energy-resource-environment related (4 areas), health and medical care related (2 areas) and others (4 areas). Of these ten areas, “Socialization of information” (Panel 2) and three energy-related areas of “Energy” (Panel 1), “Space and ocean management technology” (Panel 5), and “Energy, resources and environment” (Panel 10) gained an especially high vote ratio (a ratio in reference to the average rate that would result if the votes were equally distributed among the areas in a panel), indicating that their importance is widely recognized. The area that gained the highest vote rate was “Socialization of information,” which addresses the issue of constructing a new information society system where ICT underpins the basic infrastructure of society, and all the people living in the society benefit from it. In specific terms, this area includes such topics as the green ICT system, advanced medical information system, global food traceability system, inheritance system of technology and culture, and intelligent robotics system for life and communication assistance.

Table 1-3: 36 areas of key importance for the resolution of global and national challenges

Energy, resources, and environment (18 areas)

		Area (Front number indicates the panel that set the said area)	Vote rate (%)	Vote ratio
*	*	**1: Energy-related**	**68**	**2.0**
		3: Industrial bio-nanotechnology related to energy and environment	34	1.4
*		5: Geo-diagnosis technology	49	1.7
*	*	**5: Space and ocean management technology (incl. observations)**	**58**	**2.0**
	*	6: Nuclear energy	39	2.6
		6: Fossil energy	20	1.3
	*	6: Renewable energy	39	2.5
		6: Efficient power storage system	16	1.0
		6: Energy saving	16	1.1
		7: Agriculture, forestry, and fisheries resources)	43	1.5
		7: Water resources	38	1.3
		7: Environment, recyclable resources, recycling, LCA	32	1.1
		7: Hydrocarbon resources, mineral resources, and CCS	38	1.3
		8: Lifestyle and environment (including environment ethics)	25	1.3
		8: Evaluation of and countermeasures to global warming	22	1.1
		8: Technology for urban waste minimization / material circulation for environmental conservation / resource- and energy- saving products	33	1.7
		8: Pollution prevention for atmosphere, water and soil / circulative use technology for water resources	22	1.1
*	*	**10: Energy, resources and environment**	**61**	**2.5**

Health and medical care (5 areas)

		Segment	Vote rate (%)	Vote ratio
		3: Applied bio-nanotechnology	28	1.1
		3: Medical treatment	32	1.3
*		4: Medical treatment aiming at safety and security	47	1.2
*		4: Creation of new medical technology	53	1.3
		4: Development of predictive and preventive medicine	44	1.1

Others (13 areas)

		Segment	Vote rate (%)	Vote ratio
		2: Cloud computing	22	1.3
		2: New principle for information and communication	18	1.1
*	*	**2: Socialization of information**	**48**	**2.9**
		5: Space technologies (including space medicine)	41	1.4
*		9: Base materials for Nano-technology	67	1.7
*		9: Output (device, systemization and applied technology)	67	1.7
		10: Globalization, value-adding and market creation	37	1.5
		10: Unpopularlity of science and engineering, human resource problem, the declining birth rate and aging population	31	1.2
		11: Management to prevent the decrease of competitiveness in the international market, human resource development to compete with foreign workers, and cross-cultural cooperative management.	38	1.5
		11: Service management, management in education and research field, environment business management, governmental institution management	30	1.2
		11: Framework for facilitation of social innovation and network building	32	1.3
		11: Management of humans (e.g., to cope with disparity and diversity), creation, management, and transfer of knowledge, education, and maintenance of education level by standardization	40	1.6
*		12: Strategy for maintenance of infrastructures	65	1.6

Note) 36 areas were extracted based on their vote ratio (> 1.0). The vote ratio is a ratio of the number of votes given to an area divided by the average number of votes (i.e. the number that would result if all the votes were equally distributed among all the areas). "*" in the first column indicates that the segment gathered votes from about half of the respondents (vote rate > 45%). Ten areas belong to this category. "*" in the second column indicates that the segment gained an especially high vote ratio (> 2.0). Six segments belong to this category.

2-3. Areas deserving special focus in terms of future contribution to society —Integrated analysis: delphi topics and scenario writing—

2-3-1. Themes in which science and technology can make a contribution

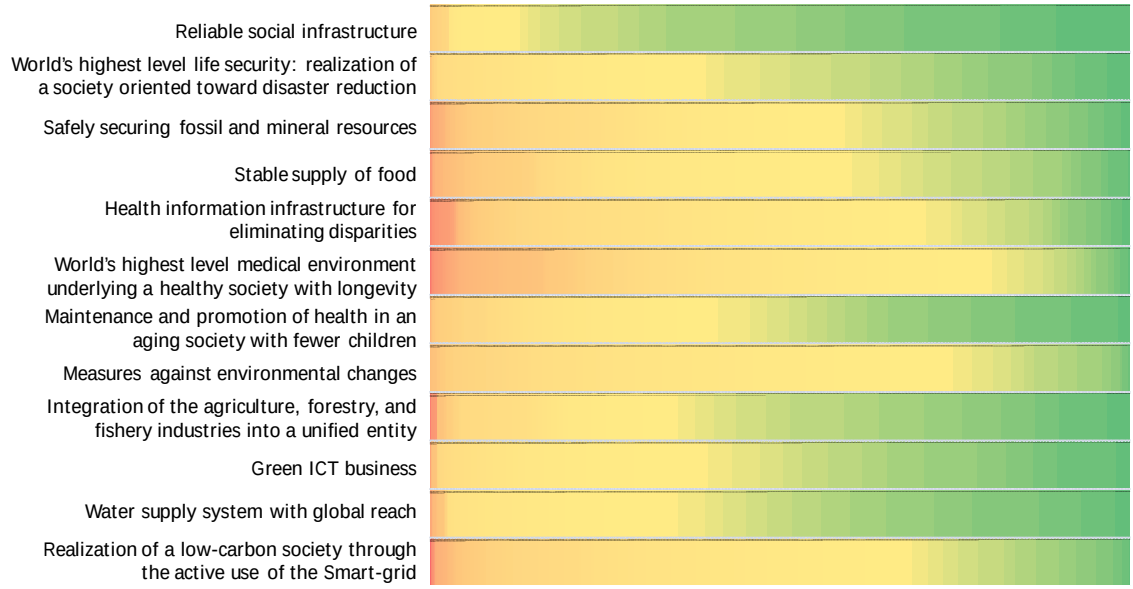
The scenario created by group work and delphi topics both included the keywords that were distilled through the course of discussions for solving the grand challenges. Inevitably, the keyword descriptions from the two sources were not necessary the same, because of the differences in viewpoints and the processes of discussion. The Delphi Survey has more of an emphasis on scientific and technological aspects: 80% of the topics assume technical feasibility in the future. Therefore, if a keyword in a scenario has multiple appearances in delphi topics as well, the theme of the scenario can be considered to allow substantial space for contributions from science and technology. The keywords that have frequent appearances in and are characteristic to an experts' scenario were extracted and compared with those descriptions in delphi topics. A higher score was given to a delphi topic if it contained many such keywords and showed a high level of similarity (for the details of the method, see Reference B (1)).

In Figure 1-10, the topics for each scenario are arranged in the order of decreasing score, from red (high score) to green (low score). The scenario themes that contain many red and orange topics are associated with many closely linked delphi topics, and can be considered to offer a greater scope for contributions from science and technology. This means that cross-cutting development efforts by the experts from different disciplines are expected to have a greater effect for solving social challenges. Such scenario themes include: "Health information infrastructure for eliminating disparities," "World's highest level medical environment underlying a healthy society with longevity," "Safely securing fossil and mineral resources," "Stable supply of food," and "Realization of a low-carbon society through the active use of the Smart-grid." In terms of these themes, the importance of each scientific and technological element has already gained a common understanding among those concerned. It appears that the effort to gasp these elements systematically in a framework will gain importance in the future. It may be worthy to note here that many of these themes belong to the following future vision categories (see the description in section 2-1): "a society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail" and "a society where individuals can use various types of energy selectively based on their comprehensive evaluation of value and can feel that they proactively contribute to global warming prevention and environmental preservation."

On the other hand, the scenario themes with many green topics are characterized by a low level of matching, which may indicate a lack of concrete measures and proposals in the scenario or a shortage of relevant Delphi topics. The scenario theme of "Integration of the agriculture, forestry, and fishery industries into a unified entity" is an example of this type, and may require a total review by the experts. For such themes with less matching, an out-of-the-box discussion will be needed on the contributions science and technology can offer.

For the five scenario themes with many linked delphi topics described above, the distribution of high score topics (red and orange) is shown in Table 1-4. That shows that many panels have a stake in the themes related to medical care and resources, indicating that these themes require an especially extensive interdisciplinary approach. The panel-by-panel breakdown of delphi topics indicates that those related to infrastructure (Panel 12) have links with the largest number of themes. The management-related topics (Panel 11) also have links with a variety of scenario themes, implying the need for considerations on social-scientific aspects (e.g. management) in many situations.

Figure 1-10: Relations between the group scenarios and Delphi survey topics



- Vertical axis: the themes of the group scenarios
- Horizontal axis: relation diagram between the keywords contained in each scenario and delphi topic (832 in all). Arranged and color coded according to the relation strength (red: strong, yellow: medium, green: weak)

Score and color: 400 300 200 100 50 10 0

Table 1-4: Distribution of topics closely related to scenarios (score >100)

Scenario theme	Delphi panel 1	2	3	4	5	6	7	8	9	10	11	12
Safely securing fossil and mineral resources					4	6	20	6	1	3	1	1
Stable supply of food			12		1	1	9	3		12	9	5
Health information infrastructure for eliminating disparities	2	2	1	11				2	1	8	21	4
World's highest level medical environment underlying a healthy society with longevity	3	12	28	68			1		31		3	2
Realization of a low-carbon society through the active use of the Smart-grid	9		3			24			3	1		2

Scenario theme	Keywords of frequent appearance in delphi topics
Safely securing fossil and mineral resources	Resources, utilization, energy, recovery, mineral resources, conventional fossil resources, fossil resources, CS, disposal
Stable supply of food	Production, resources, energy, utilization, industry, living organism, management, biotechnology, information, crop
Health information infrastructure for eliminating disparities	Health, management, database, information, education, utilization, service, medical care, value, utilization
World's highest level medical environment underlying a healthy society with longevity	Medical care, information, biotechnology, function, healing, diagnostics, device, application, basic infrastructure, communication
Realization of a low-carbon society through the active use of the Smart-grid	Energy, battery, electric power, network, solar, efficiency, power generation, supply, material, renewable

2-3-2. Directions with large potential for innovation

Based on the similarity analysis described in the previous section, relations between the themes of the scenarios created by group work and delphi areas (groups of inter-related topics) are summarized in two-dimensional map (Figure 1-11). Using this technique, the items with higher similarities and closer relationships are plotted near. Therefore, items in common generally come relatively near to the center of the map, while the items with stronger heterogeneity go to the periphery. In the map, the scenario themes and delphi areas with a closer relationship (i.e. arranged in the vicinity) are grouped together and circled (for the details of the process, see Reference B).

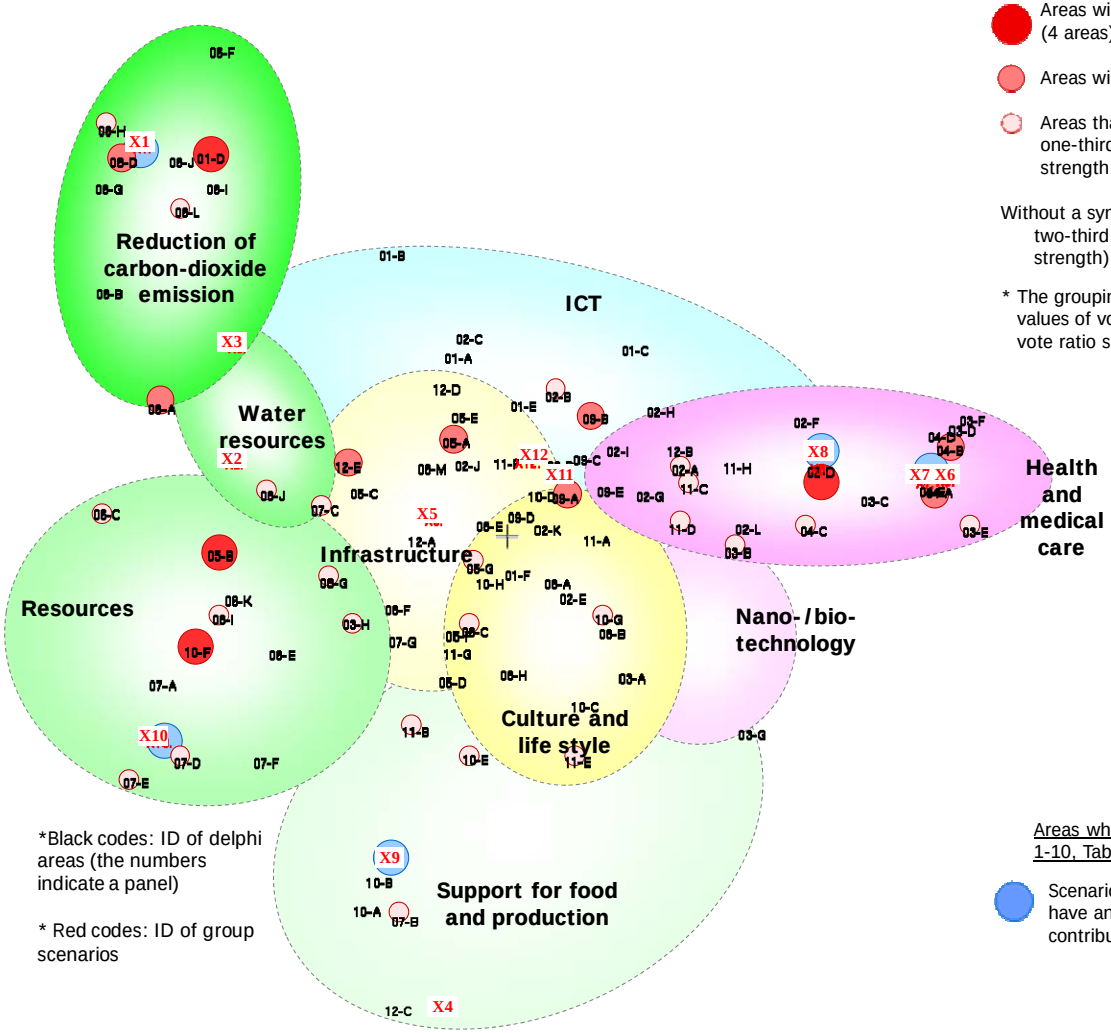
As shown in the map, the scenario themes and delphi areas related to energy, resources, and environment gather on the left side of the map, forming a cluster of broad and relatively loosely-linked groups. On the other hand, those related to health and medical care gather on the right side of the map, forming a set of clearly different groups. Those related to ICT, infrastructure, and management gather in the central part, indicating their status as common infrastructure. The grouping of the two clusters (energy, resources and environment, and health and medical care) is in good accordance with the future social visions described in section 2-1.

Viewed in conjunction with the key areas for the resolution of the global and national challenges (Table 1-3) and scenario themes where science and technology are expected to have a greater effect for solving challenges (Table 1-4), two clusters can be regarded as directions of innovation toward resolving the challenges in the future society from the viewpoint of contribution of science and technology. A cluster of the groups related to energy, resources, and environment includes two scenario themes in Table 1-4 and many delphi key areas in Table 1-3. It concludes that it can be regarded as the first direction of innovation. On the other hand, only a small number of key areas belong to a cluster of the groups related to health and medical care. However, it has also two scenario themes out of five themes in Table 1-4. This cluster can be regarded to constitute the second direction in conjunction with ICT and management areas. As indicated by the locations of the two directions above, separated spatially in the map, innovations evolving along these directions are expected to cover a wide range of problem-solving approaches in science and technology.

Other elements that possibly assume a high level of importance come from such clusters as fundamental technology (e.g. ICT and infrastructure) and sociological science (e.g. lifestyle and management). It is noteworthy that they are arranged in the central part of the map, overlapping the two clusters described above. In other words, when focusing attention on the two directions, it would be beneficial to develop an argument including them. Above all, ICT takes up a crucial position that has a decisive impact on the whole area of science and technology, thus it will constitute a basic infrastructure in all aspects of future development.

The next chapter searches for factor to promote the two directions of innovation efficiently, based on all the results from three investigative studies.

Figure 1-11: Relation map: based on the similarity analysis between Delphi areas and scenario themes



*Black codes: ID of delphi areas (the numbers indicate a panel)

* Red codes: ID of group scenarios

The areas of key importance for the resolution of global and national challenges (Table 1-3)

- Areas with especially strong focus (4 areas)
- Areas with strong focus (8)
- Areas that belong in the upper one-third in terms of focus strength (24)

Without a symbol: Others (lower two-third in areas of focus strength) (58)

* The grouping above is based on the values of vote ratiorate of voting and vote ratio shown in Table 1-3.

02-D: Socialization of information
10-F: Energy, resources, and
05-B: Space and ocean management technology (including observations)
01-D: Energy
06-A: Nuclear energy
06-D: Renewable energy
05-A: Globe-diagnosis technology
09-B: Output (device, systemization and applied technology)
09-A: Base materials for Nano-
12-E: Strategy toward sustainable infrastructure system
04-B: Creation of new medical
04-A: Medical treatment aiming at safety and security

Areas where science and technology can have a contribution (Figure 1-10, Table1-4)

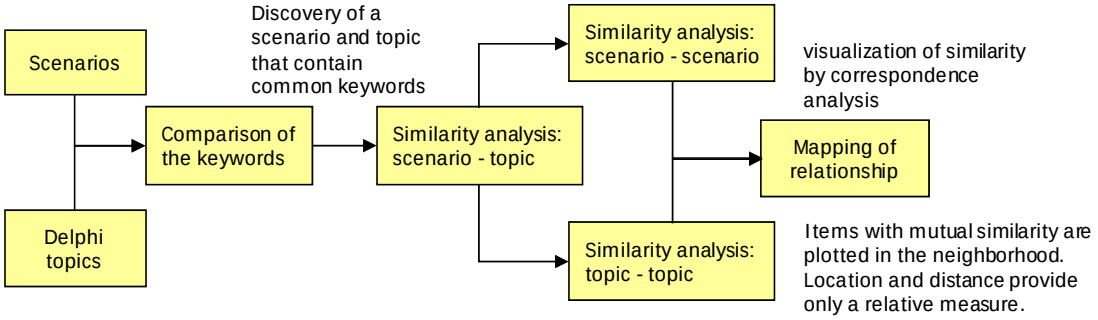
- Scenario themes expected to have an especially large contribution

X1: Realization of a low-carbon society through the active use of the Smart-grid
X7: World's highest level medical environment underlying a healthy soceity with longgevity
X8: Health information infrastructure for eliminating disparities
X9: Stable supply of food
X10: Safely securing fossil and mineral resources

<Reference B> Technique used in section 2-3

Based on the comparison between the text of the scenarios by group work and the description of delphi topics, science and technology were reviewed from the viewpoint of contribution to future society. The procedure employed is as follows:

Figure R1: Analysis flow



(1) Calculation of similarity score: between the group scenarios and the delphi topics

The keywords that frequently appear in and are characteristic to scenarios by group work were extracted and compared with the description of delphi topics.

1) Keywords are extracted from each scenario's text, and a keyword list was compiled on a scenario-by-scenario basis. A keyword was defined as consisting of more than two alphabetical characters, more than two Katakana characters, or a combination of multiple Kanji characters and a Hiragana character.
2) Weight is assigned to all of the extracted keywords by the TF-IDF (term frequency-inverted document frequency) method. This is a method generally used to derive a characteristic keyword from a group of texts based on the term frequency (TF) and the number of scenarios in which the term appears (DF). Using this method, a high score is given to a keyword that appears in specific scenarios, and a low score is given to a general keyword that commonly appears in many scenarios.
3) For each scenario, a matching procedure is performed linking the keywords extracted in 2) above to the descriptions of delphi topics. When the description of a topic includes keywords, the total keyword score is the topic's score. Therefore, a high score implies a high level of similarity between the topic and scenario. Figure 1-10 and Table 1-4 were prepared based on these scores.

$$W_R(i) = tf_R(i) \cdot \log\left(\frac{n}{df_R(i)} + 1\right)$$

$W_R(i)$: Score of the keyword
$tf_R(i)$: Appearance frequency of a keyword
$df_R(i)$: The number of scenarios where a keyword appears

	With regard to scenario 1	With regard to scenario 2	With regard to scenario 3	…….
Score of topic 1	15	10	8	
Score of topic 2	83	7	4	
Score of topic 3	0	58	3	
…….	……..	……		

(2) Positioning of the scenarios and the delphi areas

A two-dimensional map was created (see Figure R2, left) by correspondence analysis based on the score matrix (see (1) for the calculation procedure). Correspondence analysis is a widely used method to grasp the correspondence relations between two different categories of data.

In this case, multidimensional score matrix—12 dimensions (scenarios) × 94 dimensions (delphi areas) are used. All the text in an area, a group of related topics, was considered to constitute a single group for analysis because the description of a topic was generally short and contained relatively little information. In the relation map, the scenarios and the delphi areas with mutual relation are positioned near each other, and those with no mutual relation are positioned separately. Therefore, items with many aspects in common with others are relatively near the center, while those with stronger heterogeneity go to the periphery.

The procedure is as follows: First, the rows and columns of the score matrix are rearranged automatically so that the correlation between them is maximized. Then two axes with the largest and second-largest eigenvalues are selected from the rearranged matrix, along which the scenarios and the delphi areas are positioned. The map is regarded as the most appropriate two-dimensional map because it has the highest sum total of contribution ratios (an axis' eigenvalue divided by the total of eigenvalues).

(3) Grouping of scenarios and delphi areas

In the two dimensional arrangement of scenarios and delphi areas, those near each other are grouped and named. The grouping is performed in reference to the inter-scenario and inter-areas relation analysis described below:

Relevancy among the scenarios: a cluster analysis extracted two scenarios as a distinct single cluster: "Health information infrastructure for eliminating disparities" and "World's highest standard of medical environment underlying the healthy society with longevity."

Relevancy among the delphi areas: a cluster analysis classified the delphi areas into the following groups: medical system service; bio-medical; energy; environment and resources; environment, water and soil; production technology and system; and other technologies.

Following the grouping procedure based on the relevancy analysis above, the scenarios and delphi areas related to energy, resources, and environment can be found on the left side of the map, forming a set of large-area groups with relatively loose relations to each other. On the other hand, the scenarios and delphi areas related to health and medical care gather on the right side of the map, forming a set of groups with characteristics more distinguished than those related to energy, resources, and environment. These groupings are well in accordance with the future social vision described in Section 2-1. Those related to ICT, infrastructure, and management gather in the central part, indicating their status as the common infrastructure.

(4) Relation with science and technology conducive to solving the challenges

Figure 1-11 represents the overall positioning map of the delphi areas and scenarios. This map was prepared by plotting, in colored circles, 36 areas of key importance for the resolution of global and national challenges (Table 1-3), and the scenarios where science and technology are expected to contribute much (Table 1-4).

(5) Discussion

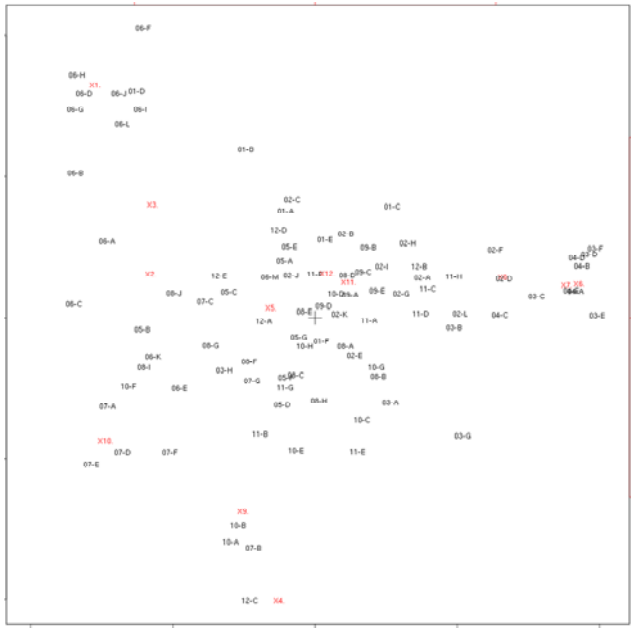
The two clusters of characteristic groups (one for energy, resources, and environment, and the other for health and medical care) showed good correspondence with the two visions of future society (Section 2-1), implying that these two constitute two directions toward the future. Large, distinct groups were not found in the other future vision, namely disaster related vision, meaning that it could not provide a third direction in terms of the degree of attention from the expert groups.

The groups relating to energy, resources, and environment contain many areas of special importance from the viewpoint of solving global and national challenges. Therefore, they are considered to constitute the first direction of innovation toward solving the challenges. The groups relating to health and medical care contain a relatively small number of areas with key importance. However, they have potential for scientific and technological contributions. Therefore, they are considered to constitute the second direction in conjunction with the "socialization of information" and "service management" areas that are positioned nearby. As indicated by the locations of these two clusters of groups, which are separated spatially in the map, innovations evolving along these distinct directions are expected to cover a wide and distinctive range of problem-solving approaches in science and technology.

The scenarios and delphi areas relating to ICT, urban infrastructure, culture, and lifestyle are positioned in the central part of the diagram, overlapping the two directions of innovation described above. These are considered to constitute a field that requires concurrent investigation and promotion along with the two directions of innovation.

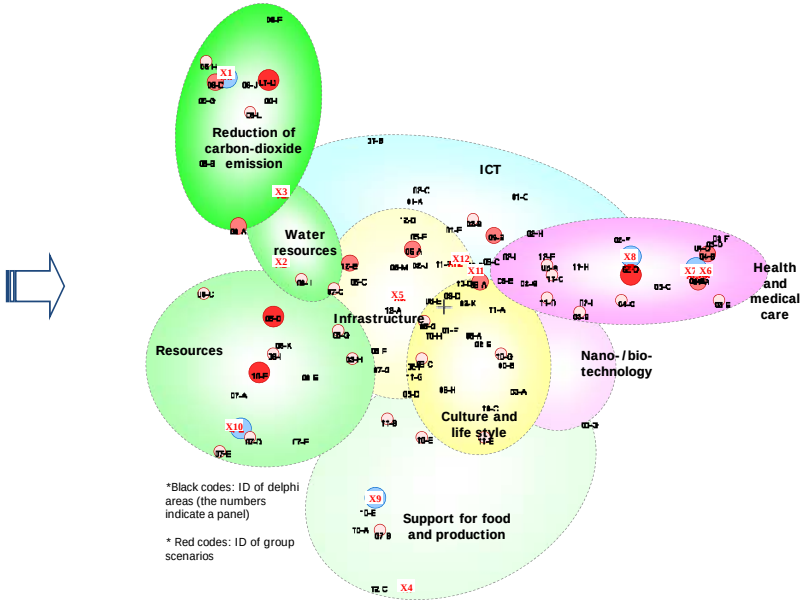
Figure R2: Steps to create the relation map

Arrangement of the scenarios and delphi areas



*Black codes: ID of delphi areas (the numbers indicate a panel)
* Red codes: ID of group scenarios

Grouping



Grouping	Keyword examples
Reduction of carbon-dioxide emission	Energy, battery, electric power, power generation, network, solar, conversion, supply, material, renewable
Water resources	Sewage, resources, water resources, recycle, ground water, piped water, observation, treatment, water management, pollution
Resources	Resources, energy, recovery, mineral resources, conventional/non-conventional fossil resources, CS, disposal, recycle, separation
Support for food and production	Production, industry, energy, resources, living organism, biotechnology, management, information, crop, micro organism
Health and medical care	Medical care, information, biotechnology, management, health, healing, infection, diagnosis, device, prevention
Nano-/bio-technology	Health, production, crop, cell, breed variety, prevention, inheritance, adaptation, stockbreeding, chip
ICT	Database, information, network, information management
Infrastructure	Sewage, resources, ground water, water resources, pollution, water and sewage, infrastructure, construction, atmosphere, observation
Culture and life style	Production, agriculture, disaster, climate change, global, management, education, communication, psychology

Chapter 3: Requirements to Accelerate Progress toward Visions of Future Society

To bring about innovation in society through the effective use of the fruits of science and technology, it is essential for us to clearly define our vision of the future and to show the way toward its realization. Through these processes, many facts and figures will come into view as to what should have priority for promoting innovation, what area of research and development is of special importance and what remains unattended or in a very primitive stage. Naturally, the approach to solve global and national challenges goes far beyond the border of research and development in a single area and discipline, and necessarily involves the integrated or collaborated approach across disciplines. It also calls for reformations of social systems and a discussion of the way in which international deployment should be carried out. One of the weak points in the conventional approach—predominantly focusing on selected disciplines and promotion on a discipline-by-discipline basis—lies in the fact that too much priority is placed on importance within a discipline, rather than the innovation it may bring about in the future society. In the conventional approach, the importance of a research theme is often discussed and judged only in term of the priority in the big picture of the existing discipline to which it belongs, even if the path to solving the challenge and the obstacles in the way are not very clear. In addition, the discussion of the importance sometimes comes short of the extensive consideration in terms of the theme's relative position in the entirety of science and technology, and the meaning it has in relation to society.

In the previous chapter, two major directions of innovation were mentioned as ways toward the resolution of global and national challenges, and the realization of future visions: one for energy, resources and environment, and the other for health and medical care. These two directions have much to do with green innovation and life innovation respectively, both of which appear in the New Growth Strategy (approved by the cabinet in June 2010) and in the discussion on the 4th Basic Plan. In this chapter, we focus on these two directions toward future innovation, and extract the set of requirements for accelerating the emergence of innovations to realize the future social visions from the results of the three investigative studies. In addition, the promotional requirements involving fundamental issues are also mentioned.

3-1. Requirements for promoting green innovation

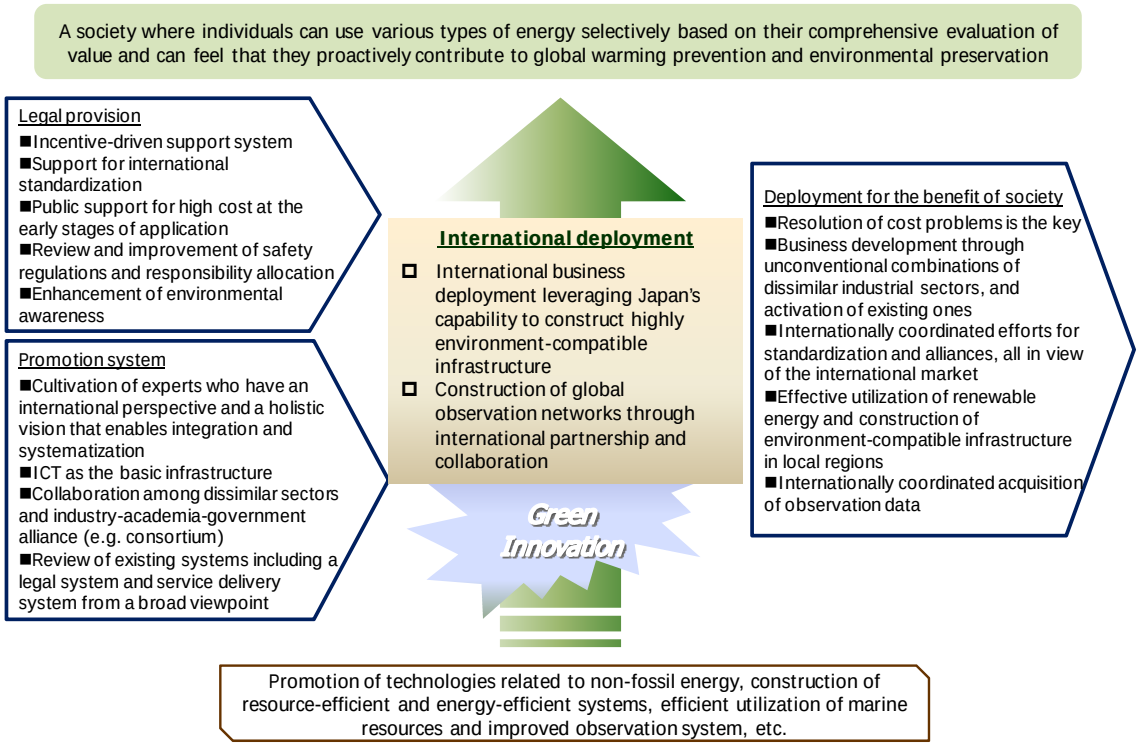
Green innovation is mainly concerned with the realization of one of the future social visions, i.e. "A society where individuals can use various types of energy selectively based on their comprehensive evaluation of value and can feel that they proactively contribute to global warming prevention and environmental preservation" and involves areas related to energy, resources, and environment.

The requirements for promoting green innovation shown below represent the essential conditions toward realization of the future society. The appropriate provision of the requirements listed below will ensure that the fruits of science and technology make a contribution to our life, promoting a sustainable evolution of national resources. This will also have the effect of enhancing the international presence of Japan.

Requirements for promoting green innovation extracted from three investigative studies

- International deployment constitutes the pillar for promoting green innovation. It involves the reconstruction of Japan's essential utilities systems from the viewpoint of green innovation, and the promotion of international business deployment supported by the capability of environment-compatible infrastructure construction. Japan should play a leading role in international collaboration and partnerships in such projects as global monitoring.
- The cultivation of qualified human resources is an urgent task. Those who engage in green innovation should develop a holictic vision that enables them to carry out integration and systematization and also have an international perspective.
- It si requred to construct a system including legal system and service delivery system is requried. ICT provides its basis. The unified approach with collaboration among sectors and diciplinesis essential for appropriately-designed system.
- The government should implement effective measures to prompt a lifestyle change by cultivating people's environmental awareness through education, to provide incentives for improved environment, and to support leadership in international standardization. Political support toward diffusion (including cost reduction support at an early stage) are also essential.
- The areas of science and technology that deserve special focus include: areas related to non-fossil energy, such as renewable energy; the efficiency upgrade of resources and energy usage, and the construction of a utilization system for this purpose; effective utilization of marine resources and an improved observation system therefor; and a global monitoring system.

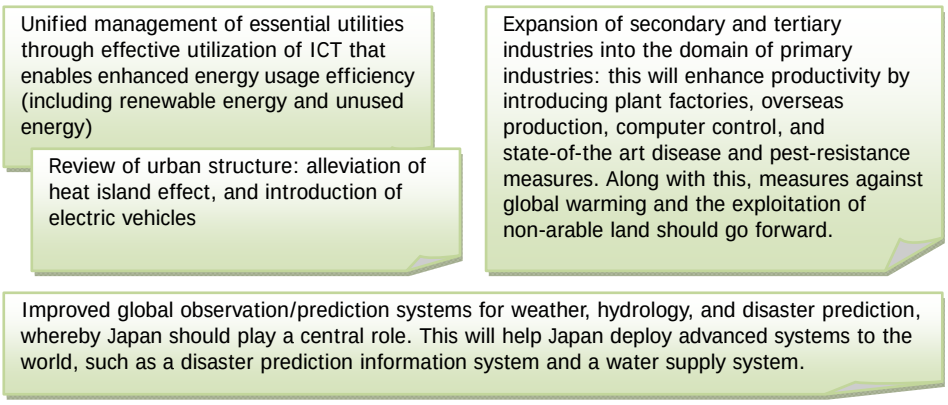
Figure 1-12: Overview of the requirements for promoting green innovation



(1) Direction for implementation: international deployment capitalizing on environmentally compatible infrastructure

Scenarios created by expert groups propose the restructuring of Japan's essential utilities systems, embracing a system design that includes such aspects as service delivery and lifestyle, whereby the viewpoint of green, or environmental friendliness, should provide the direction for implementing green innovation. They also propose proactive international deployment taking advantage of the system-building and management capabilities. To gather and analyze information that underlies green innovation, scenarios also point out the importance of establishing a global observation network for continuous and extensive data gathering, whereby Japan should take leadership in international collaboration (Figure 1-13).

Figure 1-13: Directions for implementing green innovation: examples proposed by the group scenarios



(2) Focus of interest: the views of expert groups for science and technology

In the Delphi survey, to find key items for solving global and national challenges in the future, respondents in a panel is requested to select areas (groups of related topics) from the list defined by panel. Among the 36 areas that were supported most highly by the experts, 23 (approximately 60%) of them contain topics related to green innovation (Table 1-5, 1-6).

The expert groups gave special attention to such subjects as the promotion of non-fossil energy technologies (e.g. renewable energy and nuclear energy), higher efficiency in the production and delivery of energy/resources, the construction of a high-efficiency utilization system of energy and resources (for example on manufacturing sites), the effective utilization of marine resources, and improvements in marine observation and global monitoring that serve as a basis for other technologies (see Appendix 1 for the list of sciences and technologies).

"Socialization of information" area that includes green-related issues gained the highest vote ratio. It indicates that the key is how well ICT is utilized for the implementation of green innovation.

Table 1-5: Key items related to green innovation

Delphi area	Vote ratio *
Socialization of information (Panel 2)	2.9
Nuclear energy (Panel 6)	2.6
Renewable energy (Panel. 6)	2.5
Energy, resources, and environment (Panel 10)	2.5
Energy-related (Panel. 1)	2.0
Space and ocean management technology (including observations) (Panel 5)	2.0
Geo-diagnosis technology (Panel 5)	1.7
Technology for urban waste minimization / material circulation for environmental conservation / resource- and energy-saving products (Panel 5)	1.7
Base materials for Nano-technology (Panel 9)	1.7
Output (device, systemization and applied technology) (Panel 9)	1.7
Strategy toward a sustainable infrastructure system (Panel 12)	1.6
Agriculture, forestry, and fisheries resources (Panel 7)	1.5
Industrial bio-nanotechnology related to energy and environment (Panel 3)	1.4
Fossil energy (Panel 6)	1.3
Hydrocarbon resources, mineral resources, and CCS (Panel 7)	1.3
Water resources (Panel 7)	1.3
Lifestyle and environment (Panel 8)	1.3
Service management, management in the education and research field, environment business management, governmental institution management (Panel 11)	1.2
Evaluation of and countermeasures to global warming (Panel 8)	1.1
Pollution prevention for atmosphere, water and soil / circulative use technology for water resources (Panel 8)	1.1
Energy saving (Panel 6)	1.1
Environment, recyclable resources, recycling, LCA (Panel 7)	1.1
Efficient power storage system (Panel 6)	1.0

* The vote ratio is a ratio of the number of votes given to an area divided by the average vote (i.e. the number that would result if all the votes were equally distributed among all the areas)

Table 1-6: The six areas that gained the most votes from the experts (vote ratio > 2.0)

	Area	Examples of priority topics to develop the area *
Simulation, energy saving	Socialization of information (Panel 2)	◆ A system to predict conditions of global weather, oceans, environment, ecosystems, epidemics, economics, and human activity through a total simulation based on real-time data can tackle unknown global crises. ◆ A Green ICTS system that reduces the energy necessary for the transmission and storage of information to one-millionth of that in 2010 (normalized by the amount of information handled).
Utilization of non-fossil energy	Nuclear energy (Panel 6)	◆ Fast breeder reactor cycle technology. ◆ Geological disposal technology for high level radioactive waste. ◆ Next generation light water reactor standard technology with such merits as the capability for enriched fuel over 5%, 80-year durability, and no location restrictions thanks to the adoption of seismic technology.
	Renewable energy (Panel 6)	◆ A large-scale thin-film solar cell with a conversion efficiency of 20% or higher. ◆ New material technology for solar cells leading to higher efficiency than silicon or GaAs. ◆ Concentrated solar power (central tower, solar trough, and solar heat chemical system, etc.).
Effective utilization of energy and resources in manufacturing	Energy, resources, and environment (Panel 10)	◆ A recycling production system unifying the processes of the "input of resource → design and production → use → disposition" and the "collection → separation → resource recycling." ◆ Efficient application technology for the unused thermal energy that is generated intermittently. ◆ Comprehensive and objective evaluation indices that replace CO2 as an indicator for the environmental load of energy and resource consumption, production processes (plants) and products, and measurement techniques for such indices.
Introduction of clean energy, and energy saving	Energy-related (Panel 1)	◆ Solar cells with energy conversion efficiency of 60% or more. ◆ Smart grid technology that can improve power efficiency and reduce the total Japanese power needs by 20%. ◆ Long life and highly reliable electric vehicle battery technology with high energy density that enables electric vehicles to have a total driving distance on a single charge that is equivalent to that of current gasoline vehicles.
Observation and utilization of marine resources	Space and ocean management technology (including observations) (Panel 5)	◆ Technology for the utilization of ocean energies such as the wind, waves and tides on a commercial basis. ◆ Technology for mining ocean floor resources such as hydrothermal deposits on a commercial basis. ◆ Establishment of technology capable of dissolving CO2 in water or fixing CO2 under the ocean floor.

* The experts specified up to five priority topics effective to advance the area. The three topics that received the most votes (1st to 3rd) are listed in the table. In cases where the area has no more than three topics, all the topics are listed.

Regarding the areas related to green innovation, expert groups scarcely feel any need to shift importance into or out of Japan. International deployment is a matter of course in every aspect, including energy, resources, and global observation, but it may involve international competition or international collaboration. Especially in the resource-related areas, the experts have their eyes on many countries around the world.

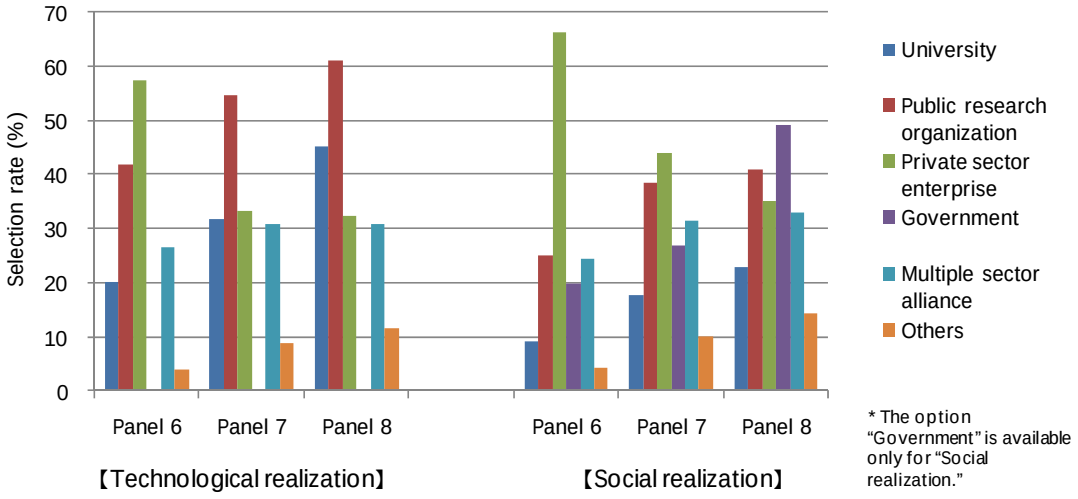
(3) Promotion system

Regarding the promotion of green innovation, expectation runs generally high on the role of the private sector for energy-related areas, and on public research organizations for environment-related areas. For example, the Delphi results from Panel 6 which covers energy related issues support the view that private-sector enterprises serve as an engine driving the process from technological realization to social realization (Figure 1-14). Public research organizations are expected to play a role of the engine for topics that will take ten years or more before realization, e.g. nuclear power, nuclear fusion, and the utilization of hydrogen. Universities are expected to serve as an engine only for the realization of evaluation tools used for technological development. On the other hand, the results from panel 8 which covers environment-related issues expect public

research organizations and universities to serve as the engine for technological realization, and the government and public research organization to serve as an engine for social realization.

Implementation of green innovation requires experts from various disciplines to participate. Group scenarios suggest that collaboration with social science is imperative because green innovation involves many elements that are directly linked to social infrastructure. Along with collaborations within the scope of natural science disciplines, for example, those between science and engineering, and agriculture and engineering, collaborations with social sciences (public economics, business administration, international law, and policy studies) are necessary for reforming the entire framework, including the institutional design. It is desired that emphasis be placed on systematization technology and institutional design as well, without being confined to the development of technological elements. Here, too, ICT is considered to provide basic infrastructure integral for the development.

Figure 1-14: Sectors that serve as an engine for realization (multiple answers allowed)



Experts engaged in green innovation should acquire a broad and cross-cutting view that allows them to perform integration and systematization, as well as an international mindset that enables them to play an active role overseas. A clear image can be obtained from the descriptions mentioned in group scenarios: "an expert with a deep understanding in a specialized field and, at the same time, with insight that enables him/her to lead new research and development" and "a specialist who can see things from the viewpoint of a generalist (a generalist who can see things from the viewpoint of a specialist)." In the Delphi survey, the topic, "Training programs for engineers involved in the development and use of resources and who have knowledge and expertise sufficient to be active in the international arena," was discussed by panel 7, which covers areas related to resources, and about 60% of experts responded that the topic has "special importance to Japan."

A discussion was held, targeted at young ICT engineers and entrepreneurs, in their 20s and 30s, calling for ideas of new industries and services from the viewpoint of the link between ICT and green innovation, but they generally showed relatively low interest in this domain compared to others. Environmental problems looked still not urgent or real to them. This result suggests the need to raise the level of awareness in younger generations through enhanced environmental education and other means.

(4) Improved environment to accelerate innovation

The required environment for promoting green innovation was described in group scenarios, which states that a review and improvement of related laws and regulations shall be implemented on a timely basis in conjunction with changes in social and economic situations, including the consequences of advancement of technology and its widespread use. The review shall cover, for example, safety regulations, the scope of responsibility, and the charging system. In another aspect, an implementation of an incentive provision in the form of a support system is essential to promote practical application and a broader use of the fruits of research and development. Supportive measures are also required to encourage the establishment of a consortium aiming at mutual collaboration between dissimilar industrial sectors or industry-academia-government cooperation.

Especially in local communities, some kind of system is required to facilitate the promotion of renewable energy utilization on a community-by-community basis. This may include such support measures as a subsidiary system (for inter-community cap-and-trade, CO_2 forest absorption, and self-contained renewable energy usage) and a taxation incentive.

Table 1-7: Delphi topics regading environment-related systems and lifestyles

Topic	Forecasted year of social realization	Importance to Japan (%) *
Promotion of a support framework for such matters as U-/I-/J-turn and multi-habitation among urban and rural areas to maintain conservation of farmland and other lands.	2022	83
Promotion of commuting agriculture (agricultural workers will tend to live in urban areas in order to save energy and living costs, and to prepare for the aging society).	2023	68
Technology and a legal system for making the most of natural and renewable energy by region or district and realizing, for goods and material circulation, local production for local consumption will be developed.	2027	59
Establishment of new legal systems and social consensus on the importance of water resource management (flood control, use of water, water environment) for the conservation and rehabilitation of farmlands and forests.	2023	51
Taxation and legislation system to promote a framework to exploit a market mechanism and environmental friendly financing structure for the development and maintenance of public goods and the natural and residential environments.	2020	34
Ownership style shift from possession to lease or sharing that will be caused by the changes in the idea of ownership of energy-consuming durable goods, such as cars.	2024	31
Technology and institution to take countermeasures by analyzing and communicating the environmental risks that occur in each region and office in real time.	2026	21
Introduction of environment education that has an effect of change in citizens' lifestyles through a specific behavior such as practical action to reduce household emissions of CO_2.	2018	17
Institutionalization of the framework for environmental reporting and disclosure according to the corporate social responsibility (CSR) for the environment that is imposed on all companies.	2019	15
Various incentive systems to reduce the peak electric power demand facilitate the leveling of electric power demand and the effective utilization of resources.	2019	13
Institutionalization of risk communication through standardization and promotion of the methodology for environmental risk management.	2020	12
Institutionalization of the consensus building process at the time of development planning that is based on the principle of No Net Loss (the policy to maintain the quality and amount of nature before and after a development project) so as to mitigate the loss of habitat of native species and the ecosystem.	2027	9
Banking system combining the effects of carbon offset and biodiversity offset.	2027	5

*The experts had four options to select from: “important for Japan and the rest of the world,” “Especially important for the world,” “Especially important for Japan”, and “Low importance/priority,” The table above shows the ratios of the “Especially important for Japan” selection.

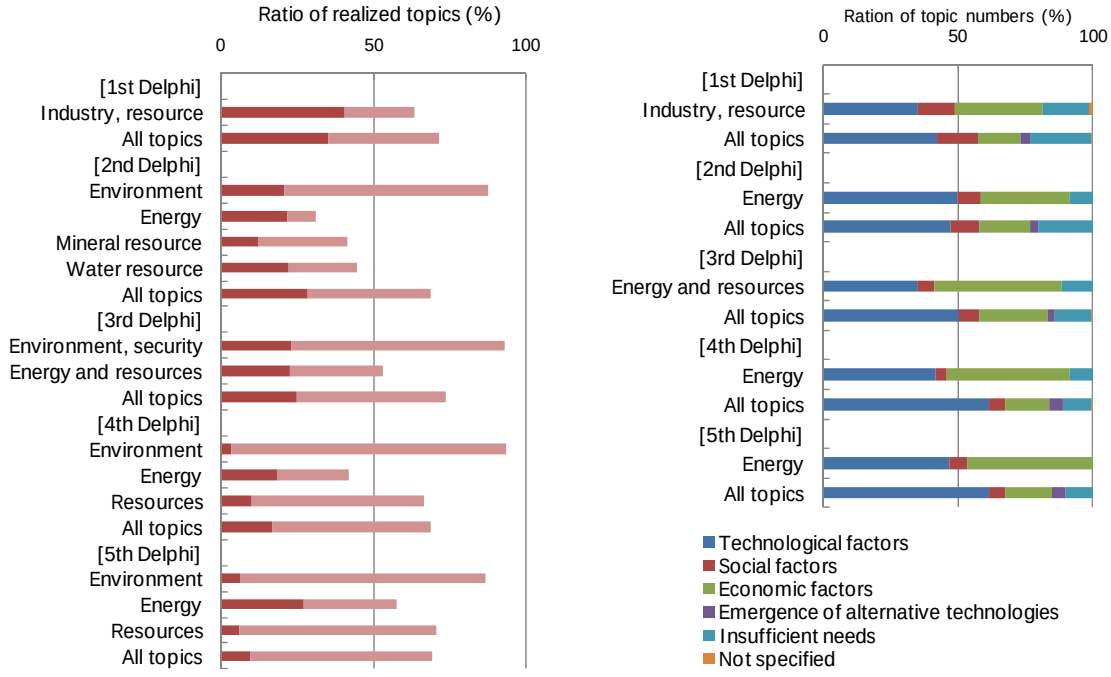
In the Delphi survey, many environment-related topics were mentioned in conjunction with new institutions and changing lifestyle (Table1-7). Along with the improvement efforts toward more relevant institutional systems, there is a need to adopt measures, such as environmental education, to enhance environmental awareness and gradually change the lifestyle of the people. In addition, it is also desirable to implement measures that allow all people, not just those with high environmental awareness, to receive benefits from innovation that suit their individual values and lifestyle.

(5) Deployment for the benefit of society

Promotion of deployment

A look into the realization rates of topics in the past Delphi surveys implemented more than twenty years ago reveals that environment field has shown high rates of realization and energy field has shown low rates (Figure 1-15; also see Appendix C). As the factors that impeded realization, a higher proportion of cost problems were mentioned in energy field than in others. This indicates the importance of continued policy support for the reduction of initial cost until a technology becomes widely applicable and people enjoy the benefit from it.

Figure 1-15: Ratio of realization and the factors that impede realization in energy field



As indicated by the fact that the government is often mentioned as a major engine leading to the realization of technologies related to energy, resources, and environment, it warrants special attention that government policies including policy principles, and environmental regulations, have a huge effect on these areas of Japan where much of the resources come from abroad.

Business prospect

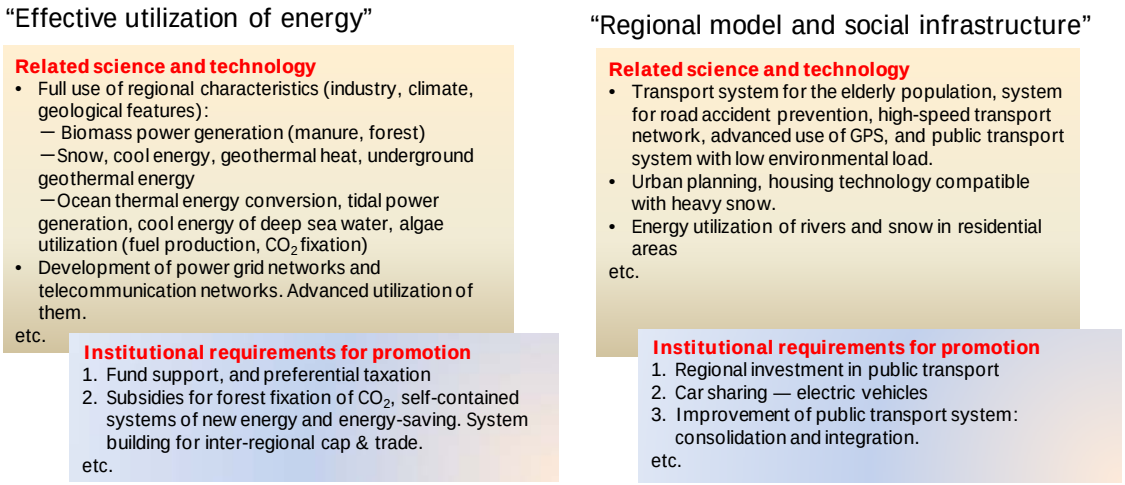
Group scenarios expect the growth of industrial sectors that underlies new infrastructure construction (i.e. electric vehicles and smart meters) through the promotion of green innovation,

and the expanded job opportunities accompanying this move. They also mention the possible evolution of new businesses emerging from a new unconventional coalition between dissimilar sectors, new entries from different categories of businesses, and new collaborations. These moves are expected to activate the conventional sectors of industry as well.

Group scenarios particularly emphasize international deployment of the businesses, and propose the construction of a social infrastructure based on out-of-the-box thinking, whose underlying systems and industries should become Japan's advantage. In this context, a strategic approach with an eye on the global market is necessary, involving such factors as the secure procurement of overseas resources, crop production in overseas farmland, and international alliances and collaborations for establishing international standards. The need for international partnerships and cooperation will intensify, so measures will be needed, such as enhancing and spreading global awareness on the importance of world-scale data collection (observation and monitoring) and analysis, and enabling research and development activities in overseas countries to pave the way to the multilateral sharing of the achievements.

The keywords "effective utilization of energy" and "regional model and social infrastructure" deserve special attention when considering the industries and services in regional scope (Figure 1-16). Many possibilities are suggested in this context, including: the utilization of resources such as biomass (animal waste, forest), snow and cool energy, and geo- and subsurface-thermal energy, as well as recyclable energy leveraging geographical conditions and regional industrial structure (e.g. power generation and selling to outside regions) to contribute to reducing CO_2 emission of the major local industries of agriculture, forestry, and fishery. The construction of environment friendly and regionally compatible social infrastructure, for example, a compact city and a transportation system with low CO_2 emissions, provides the potential to bring forth an array of new services. The discussions held in each region also proposed ideas for international deployment, such as the establishment of an education hub in Asia taking advantage of advanced primary industries (agriculture, forestry, and fishery), and bringing together human resources from Asian countries, leveraging a region's geographical location.

Figure 1-16: Potentials of region-based industries and services



3-2. Requirements for promoting life innovation

Life innovation is linked, among all the future visions, to the realization of "a society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail."

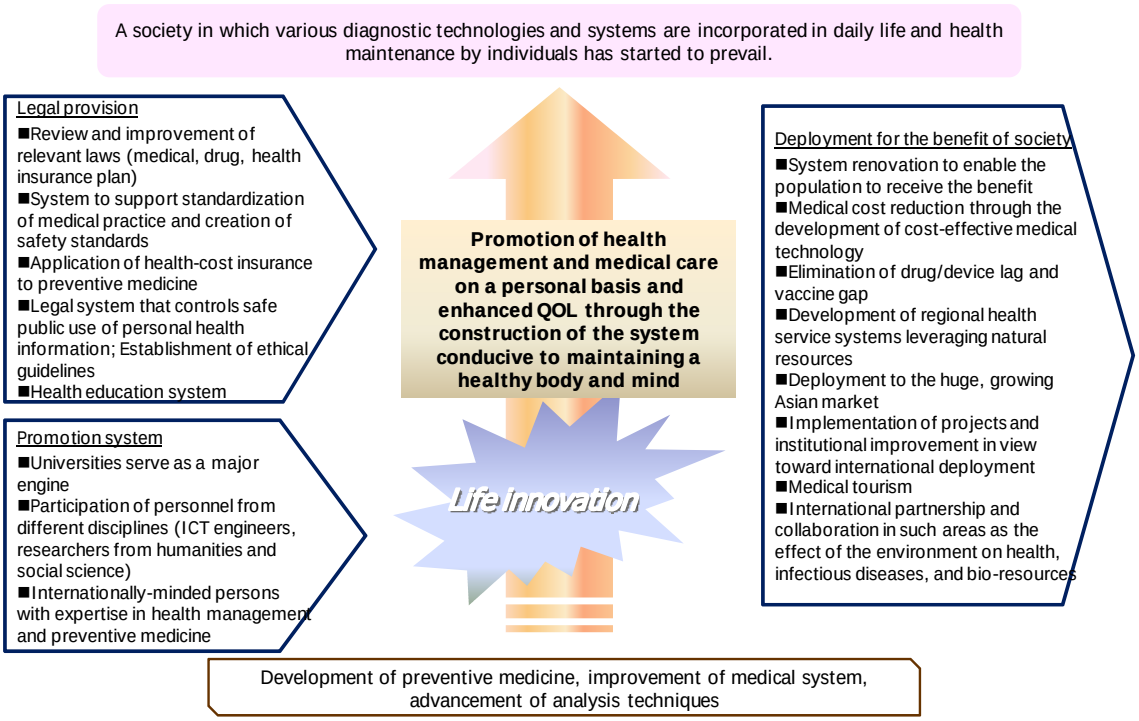
The requirements described below for the promotion of life innovation not only present the conditions conducive to ensuring the realization of such future society, but also have the potential to provide acceleration measures for the widespread application of many medical technologies and systems in society which are forecasted to be technically established in 2025 and thereafter. In the areas of science and technology related to life innovation, experts tend to make long-term perspectives for coming twenty years or more. However, the past Delphi exercises shows that there is possibility of earlier realization than expected, mainly due to the persisting and unfaltering nature of objectives and the eventual occurrences of breakthroughs.

Life innovation is expected to lead to extended healthy lifespan during which people maintain physical and mental health, in addition to the enhanced QOL. With the realization of a society in which the population can lead a satisfactory and fulfilling life, Japan will represent a good, advanced model as an aging society for countries with the prospect of an aging population in the future. Higher competitiveness gained through this process in the domains of health management system, medical devices, and other medical goods will have the effect of enhancing Japan's presence in the world.

Requirements for promoting life innovation extracted from three investigative studies

- The promotion of preventive medicine constitutes the pillar for promoting life innovation, and this can be achieved through the development of personalized health management and medical care based on the health and medical information on a personal basis. The accumulation of life-long health and medical information utilizing ICT serves as the basis for optimized health management, medical care, and the future development of new drugs and medicine.
- The effective operation of health and medical information systems in the real world requires the participation of capable personnel from various fields (ICT, humanities and social science). Participation from dissimilar fields should be proactively promoted. The preparation of the system that allows experts to promptly acquire technical knowledge of different fields is highly desirable.
- The role of the government lies in the improvement of relevant laws and regulations to enable every member of the population to receive the benefit from advanced medical technology: these include the application of health-cost insurance to preventive medicine, a legal system that guarantees safe public use of health information, and the preparation of ethical guidelines.
- To promote economic growth in Japan through the efforts to develop life innovation, the improvement of the research and development environment and systems in Japan is essential with a view to future international deployment, especially to Asian regions with a huge growth potential. Exploration of the possibility of regional development and potential new businesses should accompany this approach.
- Other important areas include: evolution of new medical techniques, improvement of medical care systems, development of analysis systems, and enhanced and secured QOL utilizing ICT. These areas must be promoted along with the development of preventive medicine. The universities are expected to play a major role in the development efforts than in other areas of science and technology.

Figure 1-17: Overview of the requirements for promoting life innovation

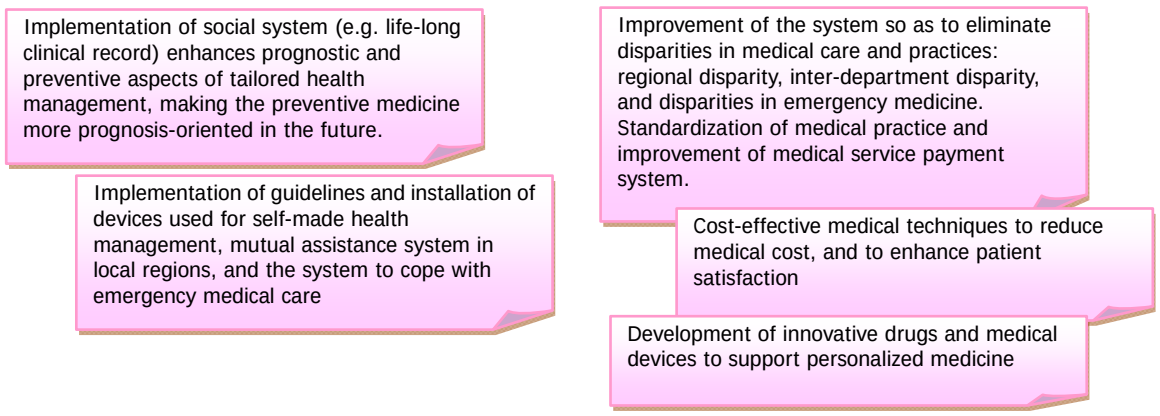


(1) Direction for implementation: personalized health management and medical care based on life-long health and medical information

Scenarios created by expert groups proposed the following aspects as the direction-defining elements of life innovation, ultimately aiming at upgrading the quality of life: the construction of a social system that helps people maintain bodily and mental health based on their individual lifelong health and medical information databases, the implementation of tailored health management and preventive medicine/treatment, the development of medicinal chemicals and devices, and the development of substitute functions and support technology (Figure 1-18).

The outcomes of this approach will become the specialties of Japan, the forerunner of aging societies, assisting the country to deploy the fruits of the development efforts in overseas markets, especially in the emerging colossal market of Asia.

Figure 1-18: Directions for implementing life innovation: examples proposed by the group scenarios



(2) Focus of interest: the views of expert groups for science and technology

In the Delphi survey, to find key items for solving global and national challenges in the future, respondents in a panel is requested to select areas (groups of related topics) from the list defined by panel. Among the 36 areas that were supported most highly by the experts, 10 areas of them contain one or more topics related to life innovation (Table 1-8). These are the topics that are concerned with promoting such subjects as: the development of diagnostic and healing methods for physical and mental diseases; improved quality of life for the aged population; the advancement of preventive healthcare and its widespread availability in society; and the progress of diagnosis, analysis and other technologies.

"Socialization of information" area gained the highest vote ratio. This area contains topics concerned with improvements in health, medical care, and QOL, including advanced electronic medical information system, food product traceability system, simulation system for analyzing the spread of infectious diseases, and life support robotics for elderly and physically disabled people. It is worth noting that "socialization of information" is located near the areas related to life innovation in the relation mapping (see Figure 1-11).

The main point of life innovation is to maintain and improve the safety and quality of life. In this regard, a definitive positioning of the social system for preventive medical care within the frame of the entire medical system is of substantial significance in Japan, where progressive aging of society is in sight. For QOL improvement of the elderly population, new prosthetic technologies will also be of importance, including the system construction that takes full advantage of ICT and the technology that allows direct communication with the brain or nerve system. Development of advanced analysis techniques is also indispensable to support original basic researches.

Table 1-8: Key items related to life innovation

Delphi area	Vote ratio *
Socialization of information (Panel 2)	2.9
Output (device, systemization and applied technology) (Panel 9)	1.7
Globalization, value-adding and market creation (Panel 10)	1.5
Healing (exegenous factor, metabolic disease, and psychiatric disease) (Panel 3)	1.3
Creation of new medical technology (Panel 4)	1.3
Water resources (Panel 7)	1.3
Medical treatment aiming at safety and security (Panel 4)	1.2
Service management, management in the education and research field, environment business management, governmental institution management (panel 11)	1.2
Development of predictive and preventive medicine (Panel 4)	1.1
Applied bio-nanotechnology (Panel 3)	1.1

* The vote ratio is a ratio of the number of votes given to an area divided by the average vote (i.e. the number that would result if all the votes were equally distributed among all the areas)

Contents of each area

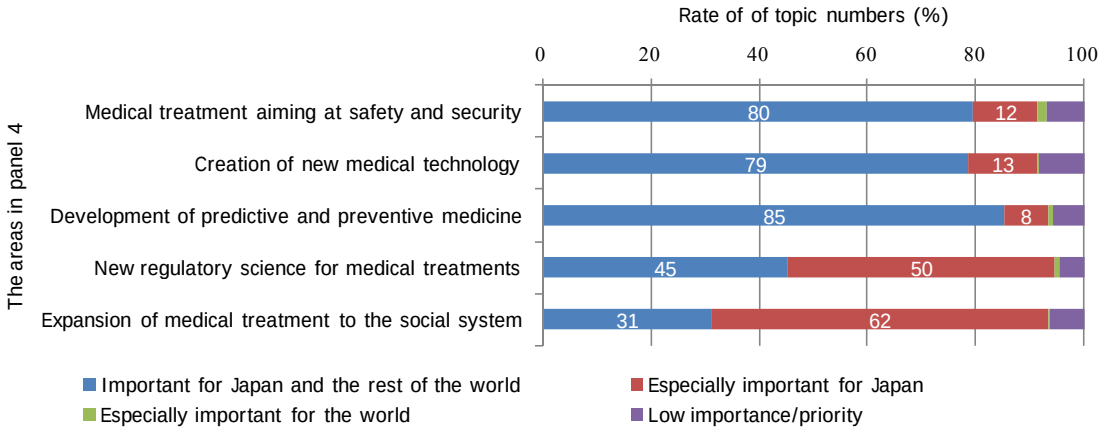
	Area	Examples of priority topics to develop the area *
Advanced healing and diagnostic techniques	Healing (exegenous factor, metabolic disease, and psychiatric disease) (Panel 3)	◆ Elucidation of the pathophysiology of cancer metastasis. ◆ Technology that prevents progression of Alzheimer's Disease and other degenerative diseases, by clarifying the causes thereof at the molecular level. ◆ A treatment method that enables autoimmune diseases be cured.
	Medical treatment aiming at safety and security (Panel 4)	◆ Systematic prevention and treatment methods for dementia that inhibits the decline in elderly people's brain functions. ◆ Assessment and treatment methods for the recovery from motor paralysis through transplantation of nerve stem cells. ◆ Technology for the regeneration of muscles and organs using stem cells.

	Area	Examples of priority topics to develop the area *
Advanced medical devices and enhanced QOL	Creation of new medical technology (Panel 4)	◆ Technology for treatment in body cavities using micro machines ◆ An intelligent communication style living environment system including life support robots for elderly persons and disabled persons. ◆ Medical equipment for functional assessment, functional recovery training and functional assistance for elderly persons and persons requiring long-term care.
	Output (Panel 9)	◆ Implantable health care devices using bioenergy and functioning semipermanently. ◆ Biomaterials with the same functionality level as human bones. ◆ An artificial environment (niche) medium to precisely control stem cell differentiation
	Globalization, value-adding and market creation (Panel 10)	◆ Membrane processing and formation technology that can maintain biocompatibility for 10 years or more within an implanted device.
Advanced medical devices, enhanced QOL, and progress of preventive medicine	Socialization of information (Panel 2)	◆ A system to predict conditions of global weather, oceans, environment, ecosystems, epidemics, economics, and human activity through a total simulation based on real-time data can tackle unknown global crises. ◆ Intelligent robotic technology that enables families and relatives to provide livelihood support to aged and handicapped people safely by remote control from a distance; the robots will be intelligent enough to avoid the risks that a teleoperator is unaware of. ◆ An intracorporeal and extracorporeal system of electronic information for high level medical service is developed for anti-aging, and the average life expectancy becomes 5 years longer than it is in 2010 due to the effects of such system.
Progress of preventive medicine	Development of predictive and preventive medicine (Panel 4)	◆ Diagnostic methods for the risks of acquiring diseases through genome data. ◆ Medical treatment guidance based on biomarkers accurately reflecting the risks of lifestyle diseases. ◆ Effective chemopreventive drugs for cancer.
	Service management, etc. (Panel 11)	◆ In Japan, the medical records containing motion video will be converted into electronic form and entrusted to patients, and the medical information, including the results of examination, will be shared among all medical institutions. Based on this environment, a health care agent business will be formed between patients and medical institutions.
	Water resources (Panel 7)	◆ New detection and removal technology in the clean water supply system, based on the continuous monitoring of traces of hazardous chemical substances and the Noro virus. ◆ Technology for distributed ecological waste water treatment technology that ensures water quality control, the nutrient cycle and the maintenance of sanitation.
Advanced breakdown technique for analysis	Applied bio-nanotechnology (Panel 3)	◆ Technology that predicts in a detailed manner biological activity, including the interaction between proteins, interaction between protein and DNA or RNA, and interaction between protein and synthetic compounds, from the higher order structure of protein. ◆ Technology that analyzes the conformation of protein, which is in a functional state in the body, in a dynamic and detailed manner. ◆ In silico drug development technology that enables simulation of the kinetics and effects of drugs in the body.

* The experts specified up to five priority topics effective to advance the area. The three topics that received the most votes (1st to 3rd) are listed in the table. In cases where the area has no more than three topics, all the topics are listed.

In addition to these areas, the experts rate the importance of improving the medical-care related social system very highly, especially for Japan. Regarding questionnaire answers on domestic and international importance, clear area-to-area differences were found only in Panel 4, which discussed medical-related issues. The characteristic message from the panel was a call for social system upgrading to trigger life innovation in Japan. The introduction of management concepts, or system operation, is also important, as shown by the similarity between the keywords (see section 2-3) from scenarios related to life innovation and topics related to management (Panel 11).

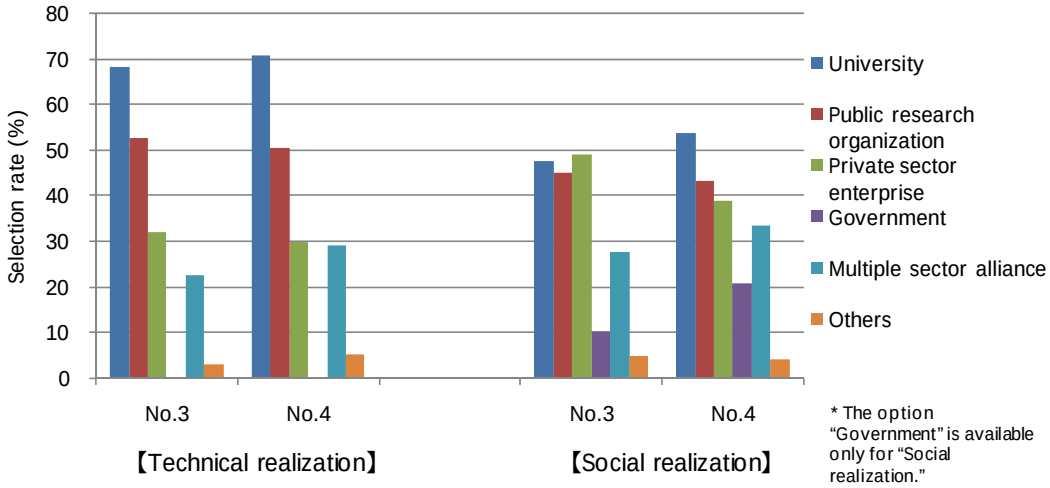
Figure 1-19: Importance assigned to the areas in Panel 4



(3) Promotion system

As a whole, it is strongly expected that universities will lead life innovation. A glance over the sectors assigned the role of an engine for realizing life-related topics in Panel 3 (biotechnology) and Panel 4 (medical)—reveals that the experts' view is that universities and public research organizations will take the lead in the efforts for technical realization, and in addition, that the private sector enterprises will assume the role of engines for social realization (Figure 1-20).

Figure 1-20: Sectors that serve as an engine for realization (multiple answers allowed)



Group scenarios point out the importance of collaboration connecting various areas, and mention the need for researchers and engineers from dissimilar areas to participate in the field of medical care. Typically, the need for collaborations between non-medical engineering and sciences, and collaboration with social science and humanities (including psychology, behavior science, and business science) are mentioned.

ICT is ranked as the essential basis technology, and scenarios mention a method for efficient promotion of life innovation on a short-term basis: the researchers and engineers in ICT area gain knowledge on preventive medicine and healthcare management, or those in the medicine and

healthcare area gain knowledge on ICT. In conjunction with this approach, the establishment of a system that allows non-medical experts to gain technical knowledge in preventive medicine, or medical experts to gain expertise in different disciplines will be highly desirable.

Solving such challenges as those due to the effects of environmental pollution and global warming on human health and infectious diseases requires an approach involving global commitment, and the enrichment of bio-resources of human diseases requires cross-border coalition and cooperation. As will be described later, international deployment of businesses, as well as international cooperation, is considered an indispensable element of future Japan. This will require the development of human resources with international mindset who are capable of activities overseas.

(4) Improved environment to accelerate innovation

Group scenarios mention, as an essential item, the need to review and improve laws and regulations in conjunction with changes in social and economic situations, and in coordination with technological advances and their widespread application. Typically, these institutional issues include: the improvement of medical, pharmaceutical and health care regulations, the establishment of a system that guarantees safe public use of personal health information, the preparation of ethical guidelines, and a system that supports healthcare management on a personal basis. Especially, in view of the development of healthcare industries (body and mind) and services on a regional basis, a full-fledged deliberation on the application of health cost insurance on preventive medicine will be required, as well as the tax benefit for self-help efforts and services to maintain healthy conditions.

Table 1-9: Delphi topics regarding systems related to medical service

Topic	Forecasted year of social realization	Important to Japan (%) *
Regional medical care system that can take prompt actions and correct regional disparities in regard to emergency medical service.	2021	82
A medical community that allows optimal management of the quality and resources of medical treatment.	2019	88
Technology for the systemization of regional medical care based on the seamless cooperation between medical treatment and nursing care.	2022	79
An original Japan Medical Standard system.	2020	83
Establishing a safety standard for capsule material and dose amount in a drug delivery system (DDS).	2023	9
Management technique for genetic-related personal information.	2022	32
Establishment of ethical guidelines for the clinical application of regenerative medicine.	2018	34
Implementation of a multiphase national debate in which many citizens participate, for the harmonization of bioethics and research activities.	2019	66
Health education for the public about personalized medicine using genome data.	2020	59
Family medicine education for preventing and dealing with lifestyle diseases and aging issues.	2018	62
In Japan, the medical records containing motion video will be converted into electronic form and entrusted to patients, and the medical information, including the results of examination, will be shared among all medical institutions. Based on this environment, a health care agent business will be formed between patients and medical institutions.	2024	56

*The experts had four options to select from: “important for Japan and the rest of the world,” “Especially important for the world,” “Especially important for Japan”, and “Low importance/priority,” The table above shows the ratios of the “Especially important for Japan” selection.

The Delphi survey included such a wide variety of topics as those directly related to institutional improvement of medical care (medical and nursing care on a regional basis, standardization of medical care, and creation of safety standard), those related to social acceptance (e.g. life ethics), and those related to education and information systems that facilitate healthcare on a personal basis (Table 1-9).

(5) Deployment for the benefit of society

Promotion of deployment

The topics in Panels 3 and 4 are generally closely linked to life innovation, and many are forecasted to take a relatively long period before technological realization than others, and are also expected to take a long period before social realization. By the same token, the past Delphi surveys also predicted that it would take a long time before topics related to life innovation gave impact to society. This led to the tendency for the same topics to be adopted repeatedly in the successive rounds of Delphi surveys.

However, a look into the actual realization status of the past Delphi topics reveals that, after more than twenty years from each survey, life-science and medical-related topics have generally shown higher than average in ratio of realized topics (Figure 1-21). In fact, the general tendency is that the topics viewed as taking a long time to come into reality have, by and large, a lower rate of actual implementation. Nevertheless, many topics in life science that were predicted to take more than twenty years to be realized, were actually brought into realization earlier than expected (Table 1-10) (see also Appendix C).

Figure 1-21: Ration of realization in life science and medical care filed

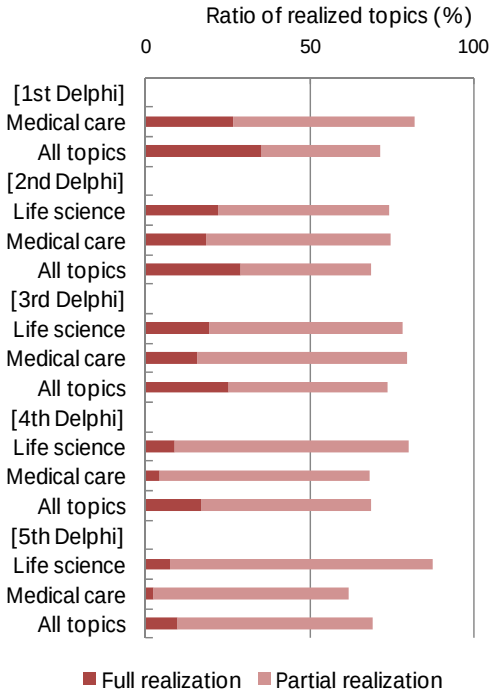


Table 1-10: The number of topics realized (or partially realized) earlier than expected in areas related to life innovation

Delphi	Published yr.	Evaluated yr.	The number of topics realized earlier than expected	
			All areas	Life innovation related areas
1st	1971	1992	19	13 (healthcare service: 13)
2nd	1977	1997	26	7 (life science: 3, healthcare service: 4)
3rd	1982	2000	64	30 (life science: 17, healthcare service: 13)
4th	1987	2004	70	24 (life science: 10, healthcare service: 14)
5th	1992	2009	73	38 (life science: 29, healthcare service: 9)

Note: Reviewed after twenty years from the survey. Because some of the topics appear more than once in the series of surveys, they may have been counted in multiple surveys.

Topics related to life innovation, even though they may take a long period of time before realization, generally have a longstanding and consistent research and development objective, and the fruits of their development efforts are handed over to society with relatively high certainty. The results indicate that there is a relatively high probability that the fruits of development efforts may be passed on to society earlier than the average expert predictions.

This implies that the objectives of research and development in this area are defined clearly, inside and outside Japan, indicating the possibility of forthcoming scientific and technological breakthroughs in the countries and regions that survived fierce intellectual competition. However, the fruits of research will not necessarily be passed on to the country or region where they originated. This is a different issue. The application of the results of research and development for the benefit of society requires a well-prepared social institutional system. It depends on the country or region itself, that is, on whether the society is prepared to accept the results.

Business prospect

Group scenarios present the possible evolution of new businesses related to medical and nursing care. In conjunction with medical care, they point out several items, including the reduction of healthcare cost through the development of new, cost-effective techniques and enhancing the recognition of awareness thereof, as well as the accelerated introduction of new medical care techniques to eliminate drug/device lag and vaccine gap. In conjunction with health management and preventive medicine, it mentioned such items as the development of safe food products for enhanced health, the construction of barrier-free households, and living environments equipped with a variety of sensors.

It also proposed a plan whereby local regions would consider their natural environment as not only providing tourism resources but also resources enabling the local population to maintain healthy bodies and minds, using them to create new industries and services. In the discussions among ICT engineers and entrepreneurs in younger generations, various new services assisted by telecommunication technology were mentioned (Figure 1-11).

Group scenarios point out the necessity of business deployment into Asian countries that will together form a colossal market in the future. The approach aiming at this objective must proceed with an eye toward the ever changing global situations. The specific proposals include the implementation of projects such as the analysis of the gene polymorphism characteristic to the Asian population and of the adoption of English as a standard language in Japan to facilitate the sharing of international approval processes for drugs and medicine. The promotion of medical tourism falls in this category. The view toward global deployment should always be incorporated into research and development projects and system improvement plans.

Table 1-11: New life-innovation-related services: ideas from younger generation ICT experts

Service	Description
ICT medicine concierge	◆ Streamlining of medical diagnosis services using remote communication. This enables clinical consultation by an overseas doctor at midnight. ◆ Self-examination by the patient using a simple test kit, log-hour monitoring. ◆ Purchasing a drug prescribed by a doctor from an overseas supplier using the network service.
Medical tourism	◆ Provision of advanced medical services and oriental medicine services.
Medical logistics	◆ Remote medical care using ICT. Elimination of queuing time through scheduling. ◆ Optimization of logistics: from ambulance conveyance to organ transportation.
Long-term life-long medicine	◆ Utilization of such personal records for personalized medicine as: diet history, biomonitoring, genome information, and response to drug administration.
Intelligent plateware, lavatory basin	◆ Incorporation of sensors in plateware, enabling nutrition data monitoring. ◆ Health monitoring using a lavatory basin.
Efficiency upgrade in nursing care and nursery care	◆ Selection of optimum service using network search. ◆ Overseas deployment of nursing care beds and wheelchairs that contain a biomonitoring function and brain-machine interface.

3-3. Common issues for promoting innovation

Looking at the entire results, the following viewpoints have emerged as a basis for bringing forth innovation. They were not considered to be urgent issues in science and technology policies in the past, but they have become an integral part of consideration when we aim at applying the fruits of scientific and technological progress for the benefit of society.

(1) Review from the viewpoint of systematization

A summary of the results from the preliminary discussion and scenarios written up by expert groups emphasizes two important aspects for incorporating the outcome of science and technology in a manner compatible to society and conducive to the resolution of global and national challenges: one is to regard the relevant element technologies as a component of a system for total optimization, and the other is to view a system in perspective of its application to society, including the service management and institutional design. This approach necessarily requires interdisciplinary thinking, removing the boundaries of the existing disciplines. The results from the Delphi survey point out the special importance of ICT utilization as the basis for a society-compatible systematization of scientific and technological outcomes.

Another aspect to be considered for well-managed system with science and technology incorporated as important elements, is how well the potential of local communities can be brought into play in the context of total system structure. Especially in terms of the safe society (i.e. prevention and tolerance against disasters), it is necessary to construct a system that can take full advantage of the power of local communities. The communities must autonomously construct the basis for addressing a disaster and enhance social tolerance against it. As the birthrate further declines and the population further ages while internationalization progresses, the diversification of communities in terms of generation and cultural background is sure to proceed. It is clear that there is a need to consider how to systemize the power of new communities in combination with the fruits of science and technology.

Systematization in the real world requires discussions on multifaceted issues, including the relationship between people's lifestyle and their sense of values, and the optimum method to convey information to the population. The clarification of responsibility allocation—who should be accountable for what—is another important issue in the real world. The need for discussions on many aspects of innovation policies, from the viewpoint of social science and humanities, has become apparent through the results of the investigative studies.

(2) Enhanced management

The importance of management—as a means to connect science and technology with innovation—is pointed out in many contexts of the Delphi survey and scenarios. In Figure 1-11, management is shown as one of the elements of common infrastructure. Special emphasis is placed on such aspects of management concerning human resources, internationalization, and the creation of social innovation.

The discussions on the management of human resources and internationalization come to the same conclusion. The essence of human resources management represents compatibility with diversification and internationalization. Amid the trend toward the falling birthrate and aging population, effective utilization of various human resources, irrespective of gender and nationality, is the only way to move forward. The recruitment and use of host country workers is inevitable at overseas sites. Thus, optimized management of diversified human resources is essential, including diversified employment status and domestic and international mobility of human resources.

The key to management in our globalized world is prompt and urgent attention to the

progressively intensifying global competition. As symbolized by the fierce competition for securing resources, many talent workers who can make extensive use of an international person-to-person network constitutes an essential asset to address international issues. With the increased opportunities of offshore production, the human resources with a true international mindset are required. Human-resource education in this context should go beyond the framework of conventional schooling systems and should include reeducation of adult members of society. In addition to the management in research and development, enhanced business management capability is also essential to increase international competitiveness in manufacturing and services.

An essential part of social innovation management lies in the creation of social values. An important viewpoint in this context is to construct a social framework that enables creation of social values: this idea should step ahead beyond the corporate social responsibility (CSR) and encompass the creation of a service-system that aims for sustainable society; a creation of social enterprise, and so on.

The enhanced management capability assumes a decisive role in promoting innovation: it is essential to go beyond the mere pursuit of a single element in science and technology.

(3) Acquisition, accumulation, and sharing of basic data

An accurate understanding of the current situation is a prerequisite for stepping forward to resolve the challenges. Three studies point out that it is necessary to acquire, accumulate, and share basic data to provide an accurate understanding of the current situation. The basic data covers such a wide variety as: global observation information regarding the environment and disasters; precision exploration information on weather, hydrology and crustal structure; infrastructure management information from urban sensor networks; geological and spatial information concerning victims and objects at the time of a disaster; information on infectious diseases (outbreak and propagation); personal life-long health information, and ultra-deep resource exploration information.

The acquired and accumulated data, however, has no meaning in itself. The implementation of data integration and breaking down from multiple information sources as needed for widespread applications—forecasting, simulation, and new research and development— gives meaning to the data. ICT assumes a decisive role underpinning these processes.

Many classes of data have no meaning, typically the global observation data, without the construction of an international data acquisition and sharing system under global cooperation. Thus, proactive participation in the international data network is also desired.

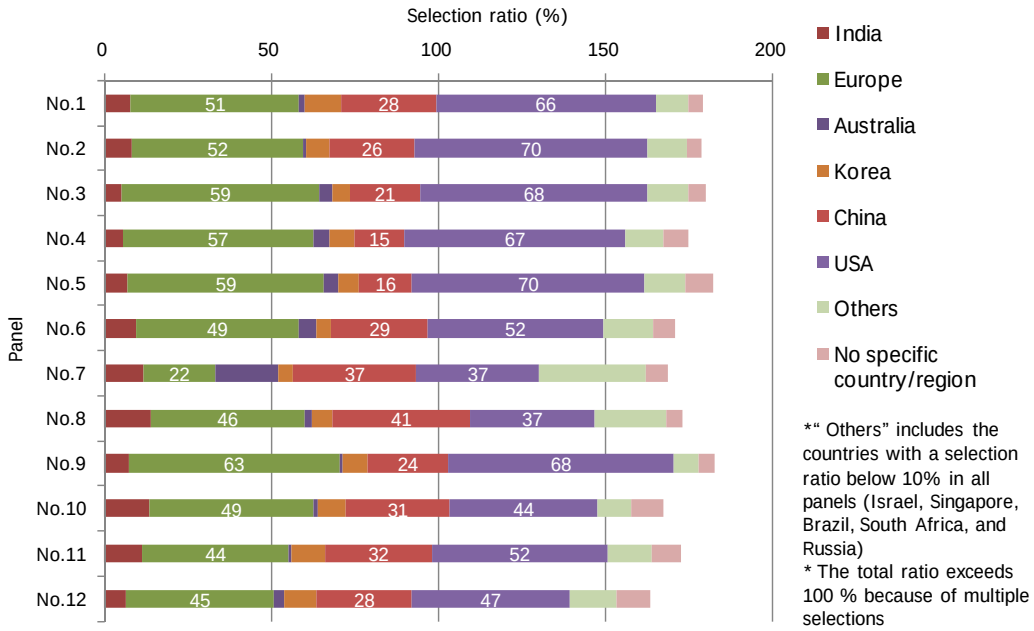
3-4. International strategy

As mentioned in the sections from 3-1 to 3-3, internationalization should always be kept in mind when stepping forward to resolve the challenges.

In the Delphi survey, many areas were recognized as being "important for Japan and the rest of the world," indicating the need to develop science and technology not only from the viewpoint of Japan, but also from a global standpoint. Some of the areas, on the other hand, were ranked as having "especially important to Japan": these involve social and geological conditions peculiar to Japan and include such areas as medical system, prevention and tolerance against disasters, regional environment (urban and agricultural communities), human resource cultivation, and the securing of resources.

Many respondents point out that the "attainment and maintenance of the global leading role in research, development and commercialization" is the most important aspect in Japan's international strategy, and "playing the leading role as well as participating in international collaboration projects" was also ranked high in the areas related to environment and preventive medicine. In conjunction with the "Countries and regions with which Japan should hold strong relationships in the future," Japan used to look toward USA and European countries. This situation has changed, and Japan's attention is now directed toward three regions: USA, Europe, and China. In terms of natural resources, the emphasis is placed on relationships with resource powers, such as Australia (Figure 1-22).

Figure 1-22: Countries and regions with which Japan should hold stronger relationships in the future



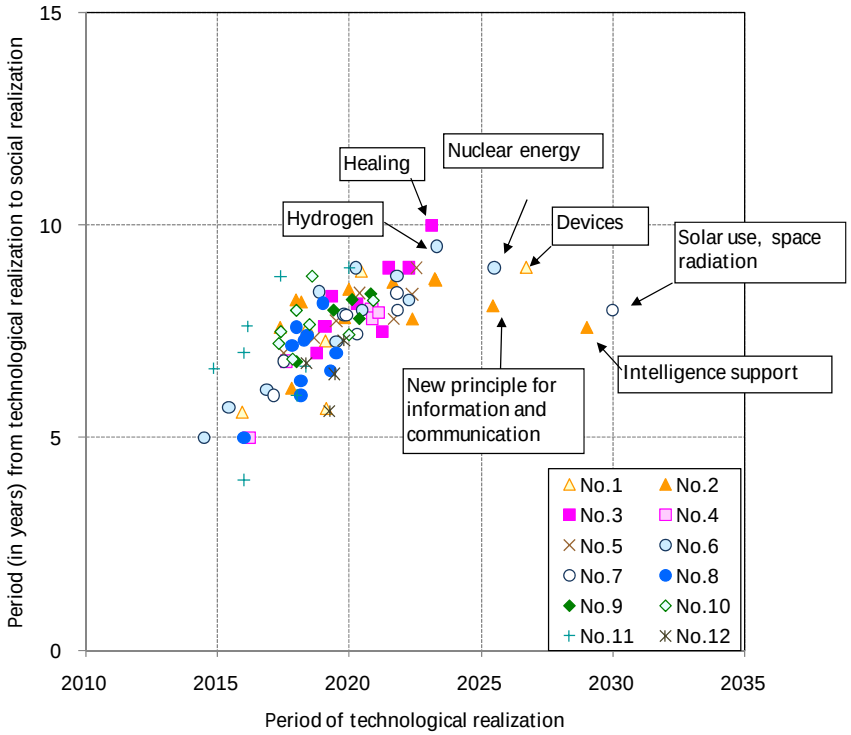
3-5. Accelerated development of science and technology

The sense of speed in the development of science and technology are undergoing a change. With the advent of the era of global intellectual competition, it is even more likely that a breakthrough solution (invention and discovery) will be discovered in any place in the world. The dramatic speed of information exchange has made the status of the forerunners rather shaky; countries and regions that have achieved technological realization are not necessarily guaranteed of its superiority when it comes to the competition toward its social realization. When solving social issues by linking the fruits of scientific and technological development efforts to innovation, a society that allows a shorter period from technological to social realization has the definite advantage.

Results of innovation gap—the period required for the transition from technological realization to social realization—indicate that it takes a total of five to ten years, or about seven years on average. The areas expected to be realized within ten years from now include those related to evaluation and management: a medical care system and energy management, and environmental economy. Those related to medical care technology and energy are expected to take a longer period of more than ten years before becoming practically applicable to society (Figure 1-23). Note, however, that some areas and fields have a tendency to be realized earlier than expected, even if the initial forecast predicted a long period.

These results show a general tendency similar to those of the past survey conducted five years ago, but the period required for the transition from technological to social realization has in general become shorter, especially for the areas that were predicted to take more than ten years. In fact, areas rarely have a prediction longer than ten years. On the whole, we can see the demand for more rapid realization in society. A factor behind this demand may have something to do with the interdisciplinary nature sought after throughout this round of the investigative study. In other words, interdisciplinary commitment may accelerate social realization in the areas where the application of scientific and technological results in society poses difficulties.

Figure 1-23: Periods from technological to social realization



3-6. Addressing diversification

Japanese society will progress toward a diversified assembly of communities with a variety of social value concepts depending on their location (urban area or local region) and population composition (aged or younger). The requirements on science and technology may differ for each community, and people in each community have to draw up the vision themselves as to what advancement they hope based on their own philosophy.

Although the interdisciplinary nature was considered, the collective opinions from experts were not free from bias in terms of regional characteristics and generational composition. Due to the inherent nature of the expert groups, their way of thinking is urban-centric and their age composition is centered on middle to senior ages. Therefore, a measure is considered necessary to compensate for these regional and generational biases. In foreign countries, there has been much activity on foresight on a subnational basis (states and prefectures) and a supranational basis (assembly of several countries). Such region-based foresight activities are also highly desirable here in Japan too.

Discussions were made in the eight selected local regions in Japan on their future visions with an emphasis on sustainable development, and the industries and services conducive to realizing them. Through these discussions, many original future visions that take advantage of their social and geological features, and the prospects of enabling technologies were mentioned (Figure 1-12). The results also indicated the need for discussions from a variety of viewpoints.

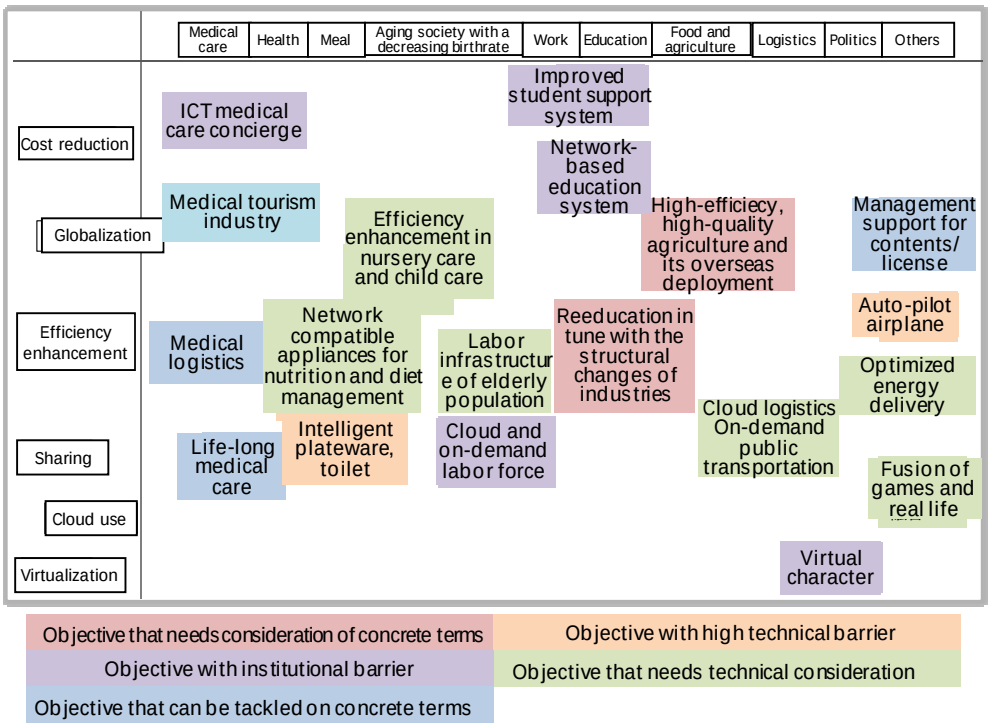
Table 1-12: Industries and services conducive to the realization of an ideal regional society model

	Key words	Related S&T	Institutional requirements
Effective utilization of energy	LCA, agricultural produce, logistics, food factory, ICT, compact city, etc.	◆Full use of regional characteristics (industry, climate, geological features) ◆Development of power grid networks and telecommunication networks. Advanced utilization of them	◆Fund support, and preferential taxation ◆Subsidies for forest fixation of CO_2, self-contained systems of new energy and energy-saving. System building for inter-regional cap & trade.
Regional model and social infrastructure	Traffic, tourism, agriculture, family, local time, new “3K” (dirty, dangerous, difficult jobs), lifestyle, etc.	◆Transport system for the elderly, system for road accident prevention, high-speed transport network, advanced use of GPS, and public transport system with low environmental load. ◆Urban planning, housing technology compatible with heavy snow. ◆Energy utilization of rivers and snow in residential areas	◆Regional investment in public transport ◆Car Sharing – electric vehicles ◆Improvement of public transport system: consolidation and integration.
Health maintenance of body and mind	Health, Onsen (hot spring), sports, ICT, life style, etc.	◆Health management technology utilizing ICT (e.g. Web doctor) ◆Medical care system based on health data: elimination of the need for hospitals ◆Wellness medicine, sports medicine ◆Rehabilitation technology	◆Self-reliant effort for maintaining the health of body and mind, including the application of the insurance system to preventive medicine. ◆Tax benefits for the businesses that provide health care services
New industrial service	High-value added agriculture, farmstay, health maintenance, educational hub, etc.	◆Enhancement of added values in agricultural products ◆Element technologies for utilization of natural-resources (snow, deep-sea water…), small electric vehicles for agricultural use, environmentally- friendly logistics, and plant factories.	◆Communication from the regions for the widespread knowledge of ecological health services and local tourism ◆One-stop service for production, logistics, and sales ◆Cultivation of human resources capable of communicating with the customers ◆Regional development of vehicles, and the measures to support endeavors such as public purchase and tax benefits.

Many of the region-based discussions this time focused only on inside Japan, but some arguments were propounded toward international deployment. International deployment originating from a domestic region may be a necessary addition to the set of viewpoints. With the local population looking overseas, this will have a beneficial effect on the progress of all-Japan globalization.

In the discussions among younger generation ICT engineers and entrepreneurs, many youthful and international ideas were put forward in regard to such familiar subjects as medical care, nursing care, and job opportunities (Figure 1-24). However, when it came to environmental issues, their discussion became somewhat lackluster and uninspiring, indicating the strong need for the improvement of environmental education. To create an image of future evolution of science and technology, an exercise to think about the future is required on a routine basis. More occasions for discussion should be provided to the younger generation, which will forge the future of our society. It is also necessary to provide an environment in which the members of the younger generation can develop their ideas actively.

Figure 1-24: Vision of future life services as conceived by younger generations



<Reference C> Requirements for promotion of science and technology conducive to social contributions

In section 2-3, the areas that would be of importance toward resolving global and national challenges, as well as having greatest potential to contribute to society were mentioned, namely, energy, resources, environment, and health and medical care. In addition, it was argued that some other areas— ICT, urban infrastructure, and culture and life style—should be promoted at the same time. Specific issues in these areas that the government should address are listed below.

○ CO_2 emission reduction, resources, and water resources

- ◆ Network construction and effective utilization (including institutional design)
  - ➢ Advanced utilization of power grid network (the smart grid and others)
    - ✧ Lowering of power consumption at data centers, the power usage of which is anticipated to increase rapidly in the future. Reduction of power usage at factories and households by effectively utilizing the information available from the smart grid.
    - ✧ Technology developments required for efficient collection, transmission, and reduction of data, and the institutional design for enabling them.
  - ➢ Construction of information networks that provide space for new technology, such as Ipv6 communication.
- ◆ Construction of regional social infrastructure
  - ➢ Implementation of transportation system that boosts convenience
    - ✧ Compacting urban areas and thereby enabling the optimized arrangement of public transportation systems and car sharing with electric vehicles
- ◆ Enhanced management
  - ➢ Implementation of municipality-based management for regional utilization of energy and resource utilization. What is required for the implementation includes the cultivation of human resources capable of looking at the grand picture, as well as system construction, the enhancement of management capabilities, and collaboration between multiple sectors.
- ◆ Establishment of strategy and measures under the initiative of the government
- ◆ Institutional support
  - ➢ Continuation of existing institutions (e.g. subsidy system) for production, utilization, and widespread application of renewable energy.
  - ➢ Establishment of an inter-regional cap and trade system (subsidy for CO_2 forest absorption, and self-contained renewable energy usage)

○ Support for food production

- ◆ Integration of agriculture, forestry, and fishery industry into a unified entity
  - ➢ Promotion of so-called sixth industrialization: integration of primary, secondary and tertiary industry into a unified entity, and the creation of new business and production bringing new added value to foodstuff
- ◆ Efficiency upgrade of primary industry production
  - ➢ Development of robotics, and enhanced genome and post-genome research on useful plants and livestock
  - ➢ Enhanced management awareness based on agro-economics and business science
  - ➢ Technical development to enhance production per unit area of farmland: micro farm and plant factory
- ◆ Proactive application of ICT in agriculture, forestry and fishing industry
  - ➢ Promotion of simulation technology research for all-inclusive upgrading of the agriculture, forestry, and fishery industry: the scope of the research ranges from environmental observation and weather forecast to logistics and delivery. The establishment of sophisticated, ICT-assisted traceability technology to ensure the safety of food products.
- ◆ Satellite assisted monitoring system used for the agriculture, forestry, and fishery industry
- ◆ Addressing GM products
  - ➢ For increased production and the stable supply of food, the production of genetically engineered

animals and plants will take on increasing importance. To address this issue, a two-sided approach should be driven forward, namely the development of cutting-edge bio-molecular technology and safety evaluation methods. In addition to the scientific and engineering aspects, a support effort toward social consensus building with regard to genetically engineered food products will be essential.

- ◆ Human resource cultivation
  - ➢ To attract the interest of competent members of the younger generation in the primary industry, projects to promote an understanding of agriculture should be implemented. It is necessary to construct an educational system that will enhance a correct understanding of today's primary industries, such as the production in mechanized facilities and post harvest processes, while removing the old, clichéd image of agriculture.

○ Medical care, nano- and biotechnology

- ◆ Introduction of a health insurance system for preventive medicine
  - ➢ A health insurance system should be implemented not only for disease treatment but also for prevention
- ◆ Technical development of consolidation, management, and delivery of health and medical information aiming at the implementation of personalized health management and medical care.
  - ➢ Well-balanced promotion of the two approaches: technology development of prognostic and preventive medicine that helps control diseases, and the advanced diagnostic and treatment techniques to cure them.
- ◆ Improvement of institution and system, and environmental arrangement for enhancing public awareness
  - ➢ Along with the improvement of medical-related institutions and systems, the following aspects of medical environments should be implemented: building of a sense of ethics among the researchers and personnel engaged in medicine as well as the general public, national consensus building toward the cutting edge medical care (e.g. regenerative medicine), and the enhancement of health-information literacy among the people.
- ◆ Career path construction for the persons with cross-disciplinary capacity
  - ➢ Development of a career path program to provide permanent jobs to multidisciplinary personnel such as: researchers with cross-cutting ability (for example, medicine and information technology), and those capable of leading research and development strategically, always striving to bring the fruits of the effort to the market.
- ◆ Implementation of an open database
  - ➢ Implementation of an open database for the promotion of genome cohort research, which translates into the provision of an environment for researchers in different fields to start research. In concrete terms, disclosure of a clinical record database, under strict protection of personal information, for unrestricted use in the research of mining text data. Interdisciplinary research in areas other than medicine should also be promoted by providing an environment that allows open access, for research purposes, to the databases in agriculture, forestry and fishery.

○ ICT

- ◆ Effective utilization of ICT toward realizing a low-carbon society, enhancing the convenience and wealth of life, and establishing a new lifestyle
  - ➢ Enrichment of ICT contents including: electric clinical records, the traceability of commercial goods, electric textbooks, e-learning (school education, higher education, and lifelong education), and e-museums (including e-theaters).
  - ➢ Promotion of ICT use in day-to-day life, such as health management using a Web doctor and remote nursing care
  - ➢ Promotion of robotics that support elderly people and perform work in dangerous environments

○ Urban infrastructure

- ◆ Promotion of effective use of existing infrastructure that is not actively used now
  - ➢ Provision of open access to institutional facilities (e.g. optical fiber network and super-computers) to private sector enterprises and individuals for a higher level of effective use

- ◆ Upgrading services for effective logistics
  - ➢ One-stop service provided by official bodies and business associations to promote efficiency in production, distribution, and selling
- ◆ Study on the application of science and technology for crime prevention
  - ➢ Study on the untapped applications of science and technology effective to prevent crime, including biometrics and sensor networks, as well as the application of ICT infrastructure. Along with the scientific and technological aspects, the viewpoints of crime from the perspectives of sociological science and humanities should also be investigated.

○ Culture and lifestyle

- ◆ Evolution of new region-based industries
  - ➢ Cultivation of coordinators—people who are knowledgeable in marketing and can communicate with consumers—under the initiative of organic organizations for deploying new service businesses closely linked to the regional industries
  - ➢ Construction of a system, under a close commitment of the local public authorities, that carries out activities publicizing the merits of the region
  - ➢ Financial support that facilitates the launching and development of new businesses in the region (funding, taxation incentive, public procurement)
- ◆ Education and cultivation of human resources that assumes changes in the industrial structure
  - ➢ The globalization and penetration of ICT enhance the growth of some industries and trigger the decline of others. To address these changes in industrial structure, improvement of the system for developing skilled human resources and to reeducate people in the working world is required. A review of the scale of the education system will also be needed in view of the future industrial structure and labor market.

Part II: Summary of the 9th Science and Technology Foresight

Chapter 1: Survey Design

The National Institute of Science and Technology Policy — an organization affiliated with MEXT (Ministry of Education, Culture, Sports, Science and Technology) — conducted a survey titled "The 9th Science and Technology Foresight" under grants-in-aid from the Special Coordination Funds for Promoting Science and Technology (FY2009). The objective of the survey was to clarify the policies to be taken in the fields of science, technology, and innovation in view of coping with future challenges. For this purpose, extensive discussions were held on an out-of-the-box basis while considering the direction to take for the future, whereby the focus is placed on the sciences and technologies that contribute to solving the projected global and national challenges. The mission-oriented approach (specifically aiming at solving the global and national challenges) and the interdisciplinary approach (out-of-the-box discussion crossing the boundaries of existing disciplines) characterize the methodology employed in this survey.

Considering the current global trends and situation in Japan, the survey narrowed down the course of actions, in terms of scientific and technological challenges, into the following four directions (grand challenges).

- ✧ Central player in the scientific and technological arena
- ✧ Sustainable growth through green innovation.
- ✧ Successful model for healthy-aging society.
- ✧ Secure life.

Subsequently, an interdisciplinary, out-of-the-box discussion was held from the viewpoint of constructing the framework for knowledge integration and paths to be taken, aiming at providing solutions to the grand challenges. In specific terms, the survey consisted of a combination of the following methods: Delphi survey based on interdisciplinary considerations with the targets in the future society clearly in mind; scenario writing using several methods in view of paths to be taken toward the desired future; region-based discussions for the realization of sustainable regional societies (Figure 2-1).

The results of the discussions are summarized in the following three reports:

[Delphi survey]

The 9th Delphi Survey（NISTEP REPORT No. 140）
http://www.nistep.go.jp/achiev/ftx/jpn/rep140j/idx140j.html

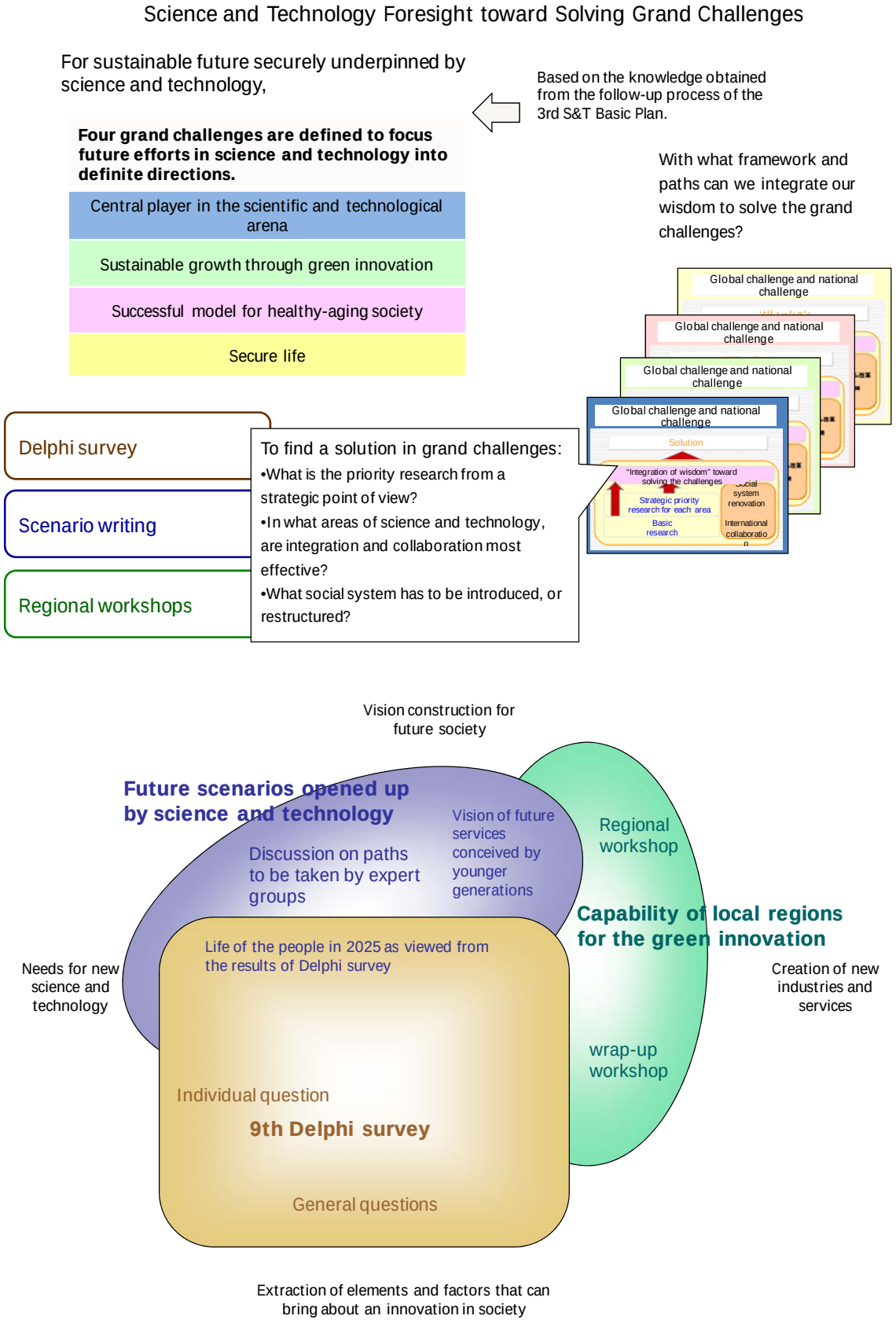
[Scenario writing]

Future Scenarios Opened up by Science and Technology (NISTEP REPORT No. 141)
http://www.nistep.go.jp/achiev/ftx/jpn/rep141j/idx141j.html

[Regional Green Innovation]

Capability of Local Regions for the Green Innovation (NISTEP REPORT No. 142)
http://www.nistep.go.jp/achiev/ftx/jpn/rep142j/idx142j.html

Figure 2-1: General overview of the survey



Chapter 2: The 9th Delphi Survey

Japan has a 40-year history of foresight activities in science and technology. This is the 9th round of the series of successive Delphi[*1] surveys since the first survey conducted in 1971.

In the survey this time, an attempt was made to outline the future prospect of evolutions in major areas of science and technology, whereby the relevant areas were extracted irrespective of the existing disciplines. The guiding viewpoint here was to define "what we should do from now onward" to attain future goals and resolve the global and national challenges. For this reason, cross-sectional panels were established across scientific and technological frontiers — in contrast to those organized on a section-by-section basis in the previous surveys — and they were designated by numbers. Through interdisciplinary discussions, the panels defined the survey topics and question items, and analyzed the results.

*1: The Delphi method iterates two or more rounds of the same questionnaire to the same respondents, until the answers converge to some specific way of thinking. In the second and subsequent questionnaire, the respondents are allowed to change their answers based on the summarized information (i.e. general trend of thinking) of the previous round. Some of the respondents change their opinions, allowing the overall opinions to converge.

2-1. Flow of the survey

Four preliminary panels were established and designated as "Security," "Safety," "International Collaboration," and "International Competitiveness." They involved the experts from the humanities and social sciences, as well as natural sciences, in discussion on future targets that science and technology can contribute to attain, and on global and national challenges to be resolved. Through extensive discussions, the targets and challenges were clarified and summarized into 24 "critical issues".

Twelve interdisciplinary panels (see Table 2-1), consisting of 135 experts in total from the humanities, social sciences and natural sciences (from universities, industrial sectors, and research organizations), held discussions to finally configure the topics[*2] and areas[*3] for the survey. Through the discussions, a selection was made with primary focus on the sciences and technologies that can contribute to resolving the global and national challenges, and with due consideration given to relationships with the critical issues. To avoid discussion limited by existing disciplines, names of disciplines or technological fields are intentionally left out of the panel designations. The scope and central theme of the discussion was determined by each panel.

A general deliberation was conducted on setting up the framework of subsequent discussions, and it pointed out the importance of paths through which future science and technology will be assimilated into society as a "system compatible with society," and thus the need for the following: a) systematic research and development involving the inter-related areas of science and technology, b) a point of view that grasps multiple areas of inter-related areas of science and technology as a unified system, c) research into the methodology for implementation in a society, and d) an overhead view that perceives the social system as a inseparable part of science and technology.

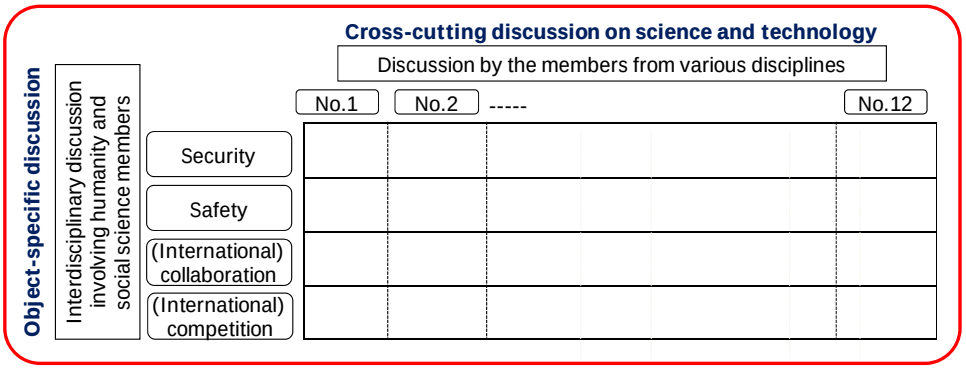
*2: A topic represents a description of such entities as future science, technology, and social system.
*3: An area represents a group of inter-related topics.

Table 2-1: Panel structure

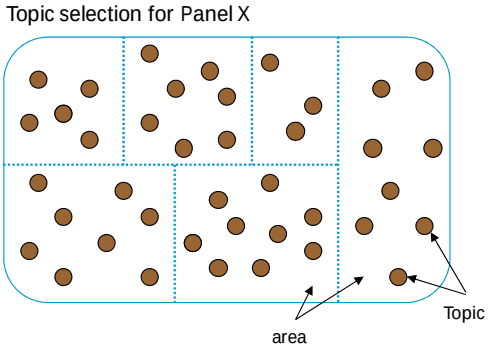
Panel	Viewpoint (defined by each panel)	Number of areas	Number of topics
No. 1	Utilization of electronics, communication, and nanotechnology in a ubiquitous society	6	70
No. 2	Information technology including media and contents	12	76
No. 3	Biotechnology and nanotechnology to contribute to humankind	8	58
No. 4	Medical technology to contribute to healthy lifestyles of the nation's people using IT, etc.	5	85
No. 5	Understanding of dynamics of space, earth, and life, and science and technology which expand the region of human activity	7	64
No. 6	Promotion of diverse energy technology innovations	13	72
No. 7	Necessary resources, including water, food, minerals	7	59
No. 8	Technologies for protecting environment and forming sustainable society	10	68
No. 9	Fundamental technologies, including substances, materials, nanosystems, processing, measurement, etc.	5	84
No. 10	Manufacturing technologies which totally support development of industry, society, and science and technology	8	76
No. 11	Strengthening of management led/required by advancement of science and technology	8	58
No. 12	Infrastructure technologies supporting daily life base and industrial base	5	62
Total		94	832

Figure 2-2: Method of setting topics

Relationship with twelve interdisciplinary panels and four object-specific panels



Method of setting topics



Setting topics:
1) Selection of keywords that most typically represent issues to be focused.
2) Definition of areas by grouping relevant keywords (the area definition was reviewed after the topics were set)
3) Definition of topics for each area
* More than one conceptually similar topic exists within an area.

Two rounds of the questionnaire were conducted — the first in November 2009 and the second in February 2010 — about the future perspective of the topics (832 in all) from the viewpoint of a time span of 30 years until 2040, and a total of 2900 experts responded (Figure

2-3). An analysis was carried out based on the final results from the second round (Table 2-2, Figure 2-4). Note that, in the first round, additional questions were designed by each panel to inquire about Japan's desirable approach to resolving global and national challenges.

Figure 2-3: Classification of respondents

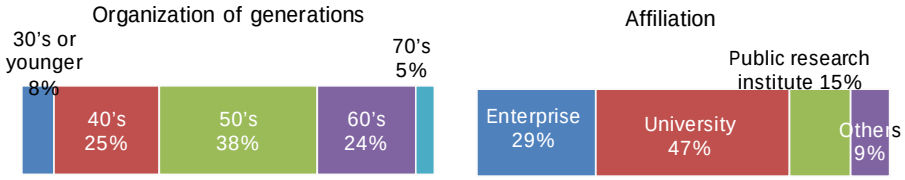
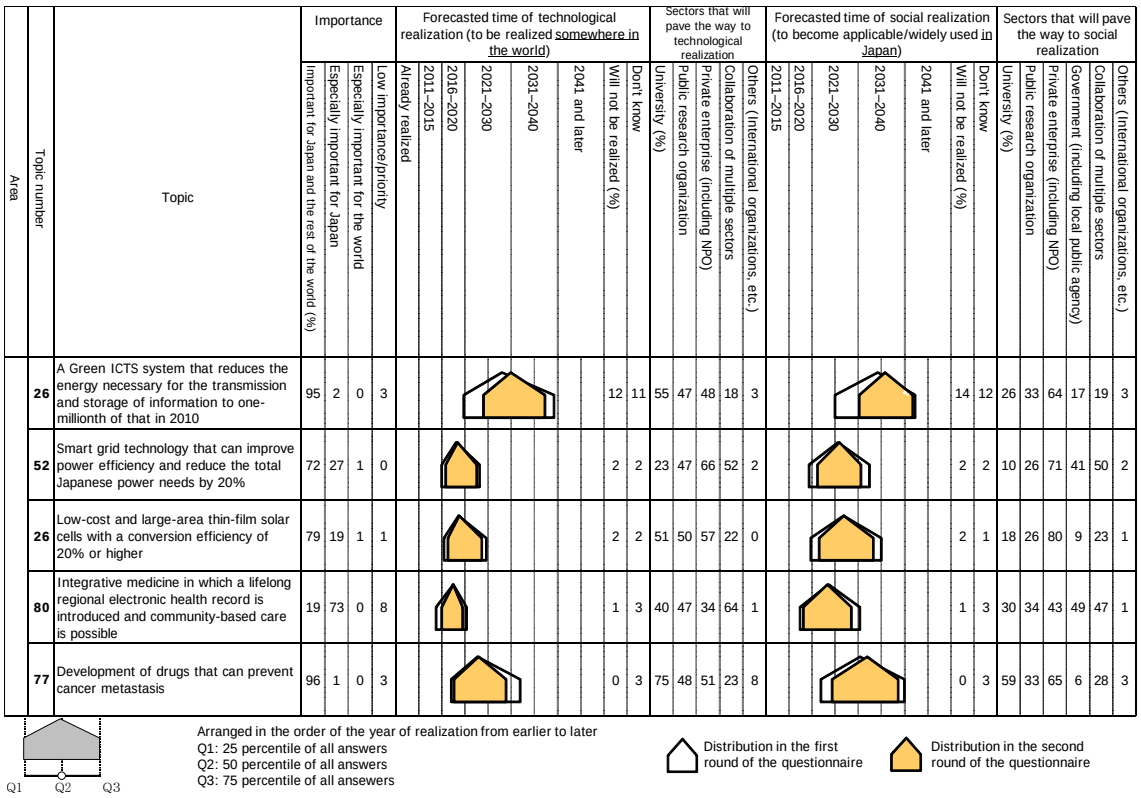


Table 2-2: Question items

Question items regarding each topic	Question items regarding Japan's approach for solving global / national challenges
◆ Importance ◆ Forecasted time of technological/social realization ◆ Sectors that will pave the way to tecchnological/ social realization Technological realization: Sufficient implementation of technological environment Social realization: Availability as tangible commodities and services	◆ Items of key importance for the resolution of global and national challenges ◆ R&D required for the resolution of the challenges ◆ International strategy in R&D ◆ Priority items that the government should address ◆ R&D needed for simultaneous pursuit of environmental preservation and sustainable development.

Figure 2-4: An example of a questionnaire summary



2-2. Major Survey Results

(1) Items that need a focused approach for the resolution of global and national challenges

◊ Many items that are directly or indirectly related to energy, resources and the environment have been cited as having key importance for the resolution of global/national challenges (Table 2-3). In the health and medical areas, prognosis and preventive medicine gathered attention, and so did therapy. Other items that received attention included ICT infrastructure, human resource development and management, and fundamental technology.

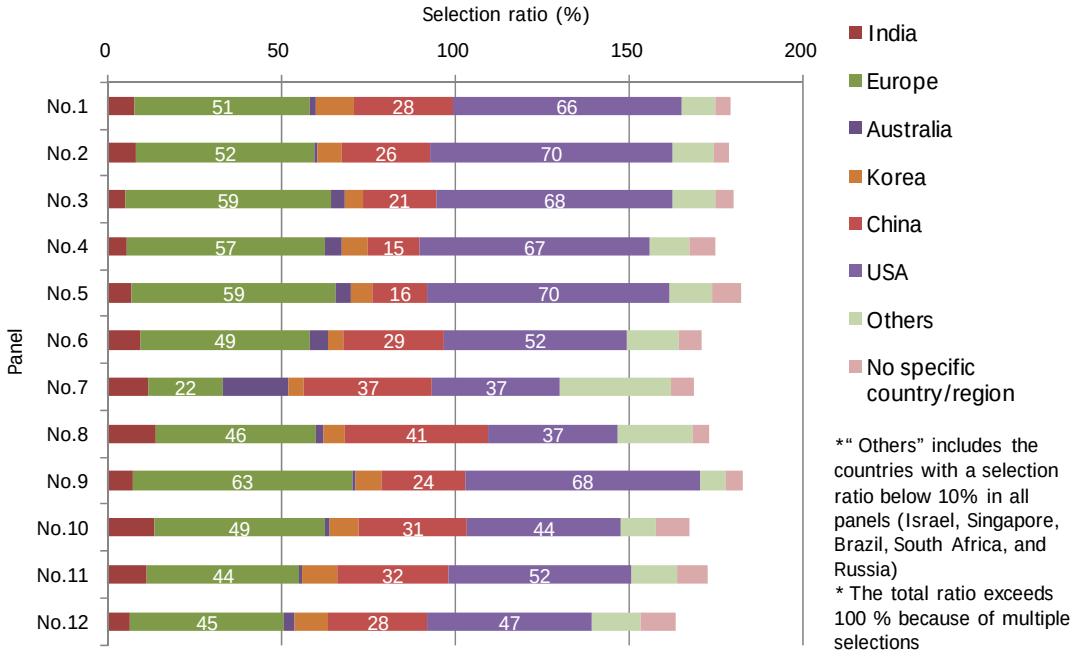
Table 2-3: Items of key importance for the resolution of global and national challenges

	Panel	Key item (selected from the areas defined by panels)
Energy, resources, and environment	No. 1	Energy-related
	No. 3	Industrial bio-nanotechnology related to energy and environment
	No. 5	Geo-diagnosis technology
	No. 5	Space and ocean management technology (including observations)
	No. 6	Nuclear energy
	No. 6	Renewable energy
	No. 6	Fossil energy
	No. 6	Efficient power storage system
	No. 6	Energy saving
	No. 7	Agriculture, forestry, and fisheries resources (including forest conservation, and biohazards)
	No. 7	Water resources
	No. 7	Environment, recyclable resources, recycling, LCA
	No. 7	Hydrocarbon resources, mineral resources, and CCS
	No. 8	Life style and environment (including environment ethics)
	No. 8	Evaluation of and countermeasures to global warming
	No. 8	Technology for urban waste minimization / material circulation for environmental conservation / resource- and energy- saving products
	No .8	Pollution prevention for atmosphere, water and soil / circulative use technology for water resources
	No. 10	Energy, resources, and environment
Medical	No. 3	Applied bio-nanotechnology
	No. 3	Healing (exogenous factor, metabolic disease, and psychiatric disease)
	No. 4	Medical treatment aiming at safety and security
	No. 4	Creation of new medical technology
	No. 4	Development of predictive and preventive medicine
Others	No. 2	Socialization of information
	No. 2	Cloud computing
	No. 2	New principle for information and communication
	No. 5	Space technologies (including space medicine)
	No. 9	Base materials for Nano-technology
	No. 9	Output (device, systemization and applied technology)
	No. 10	Globalization, value-adding and market creation
	No. 10	Unpopularity of science and engineering, human resource problem, the declining birth rate and aging population
	No. 11	Management (Global management) to prevent the decrease of competitiveness in the international market (international management), human resource development to compete with foreign workers, and cross-cultural cooperative management.
	No. 11	Service management, management in the education and research field, environment business management, governmental institution management
	No. 11	Framework for facilitation of social innovation and network building
	No. 11	Management of humans (e.g., to cope with disparity and diversity), creation, management, and transfer of knowledge, education, and maintenance of education level by standardization
	No. 12	Strategy toward sustainable infrastructure system

◊ As the sciences and technologies on which Japan has to focus on for the promotion of the key items, and, as the items Japan has to grapple with for addressing global environmental problems, the following topics were given: 90 topics related to energy, resources, and environment; 7 topics related to health and medical treatment; and other 23 topics (see Appendix A).

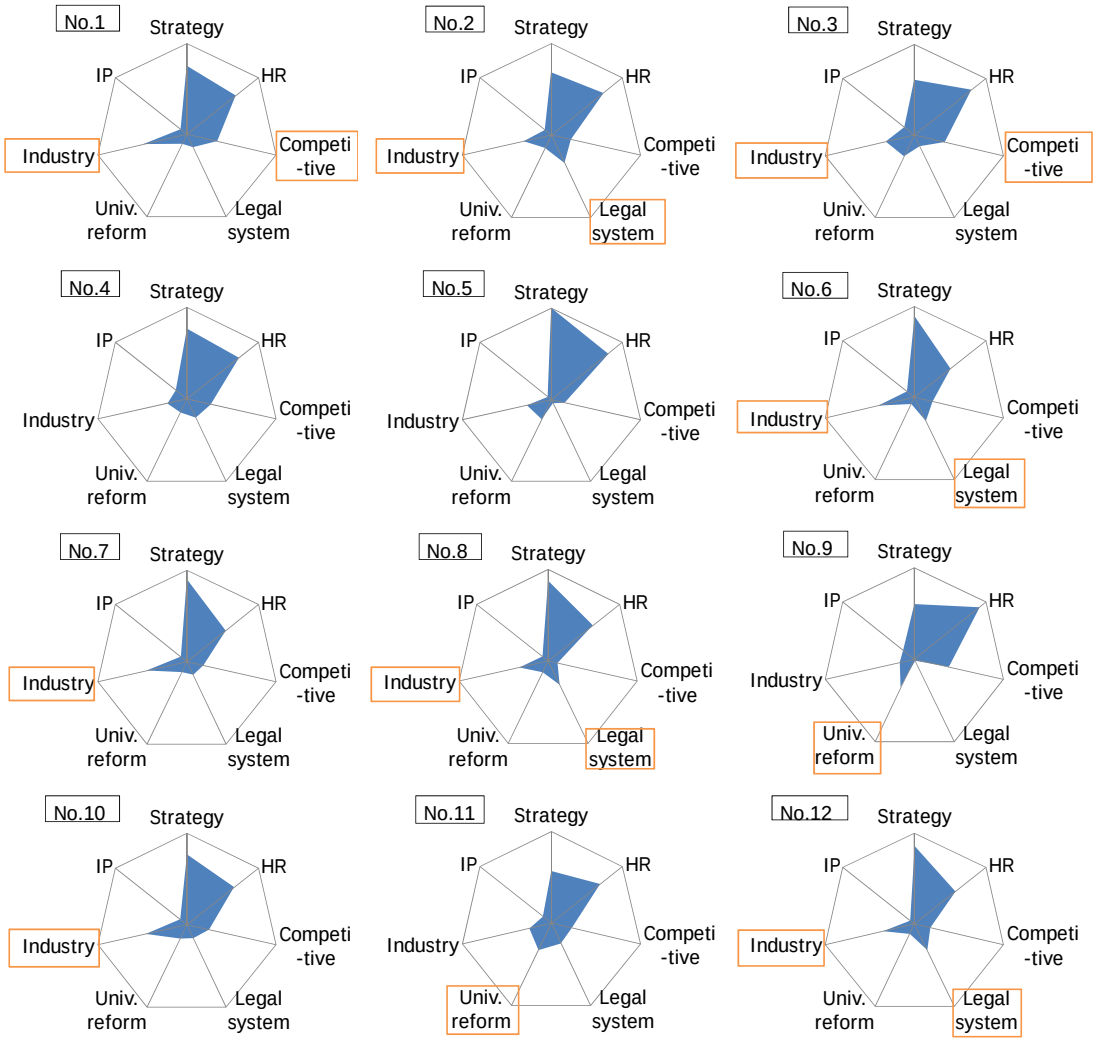
◊ In conjunction with "Japan's international strategy," the largest number of topics is related to the attainment and maintenance of the global leading role in research, development and commercialization. In the areas of global environment observation and prognosis/preventive medicine, participation in international collaboration projects gained much support. In conjunction with the "Countries/regions with which Japan should have strong relationships" in the future, China took precedence after USA and European countries (Figure 2-5). In particular, in the panels relating to environment and resources (Panel 7 and 8), interest was almost equally divided into three regions of USA, Europe, and China.

Figure 2-5: Countries/regions with which Japan should have close ties by panel



◊ In conjunction with the "priority items that the government should address," the respondents from all panels placed the "establishment of strategy and vision" and "human resource cultivation for the next generation" in the top two positions. The panels relating to information, energy, environment, and infrastructure technology (i.e. Panel 2, 6, 8, and 12) placed "legal system reform" in the third position, and those relating to electronics, biotechnology, and nanotechnology (Panel 1, 3, and 9) placed "streamlining of competitive environment" in the third position. The panels that require the overall context of the national policy, such as infrastructure improvement, and the securing of resources and energy, tend to call for the establishment of strategy and vision on a nation-wide basis, and those closely related to underlying elemental technologies tend to call for the cultivation of human resources for the next generation and the streamlining of a competitive environment. Those panels concerned with basic infrastructure as a social system call for legal system reform for further steps ahead.

Figure 2-6: Priority items that the government should address by panel



Items with a higher score (>20%) are shown in a box (except "Strategy (strategy formulation")) and "HR (human resource cultivation)")

Stragegy: Strategy formulation HR: Human resource cultivation Competitive: Competitive environment
Legal system: Legal system reform Univ. reform: University and public research institution reform
Industry: Support for industry IP: Intelledtrual property strategy

(2) Topic by topic considerations on future trend of evolution

◊ Most of the topics are considered to have common relevance across the world. Among these, the following were assessed to have special importance to Japan: the topics relating to social system creation (social infrastructure, medical system, prevention/ alleviation of disasters, and the regional environment), those relating to securing resources, and those relating to securing human resources (Figure 2-7).

◊ The following areas were mentioned as likely to be realized in Japanese society within the next ten years: medical system, energy management, cloud computing, and service management. On the other hand, regarding some technologies, such as medical treatment, and hydrogen and atomic energy, it is assessed that rendering their technical realization into social implementation will take nearly ten years (Figure 2-8).

Figure 2-7: The areas evaluated as "Especially important for Japan" (selection ratio >40%)

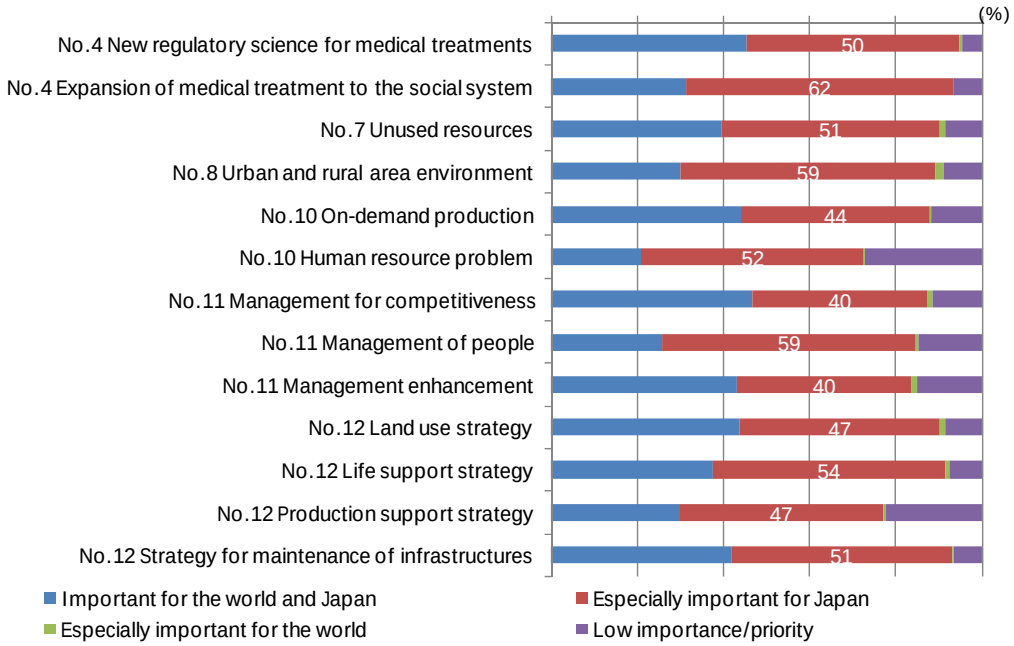
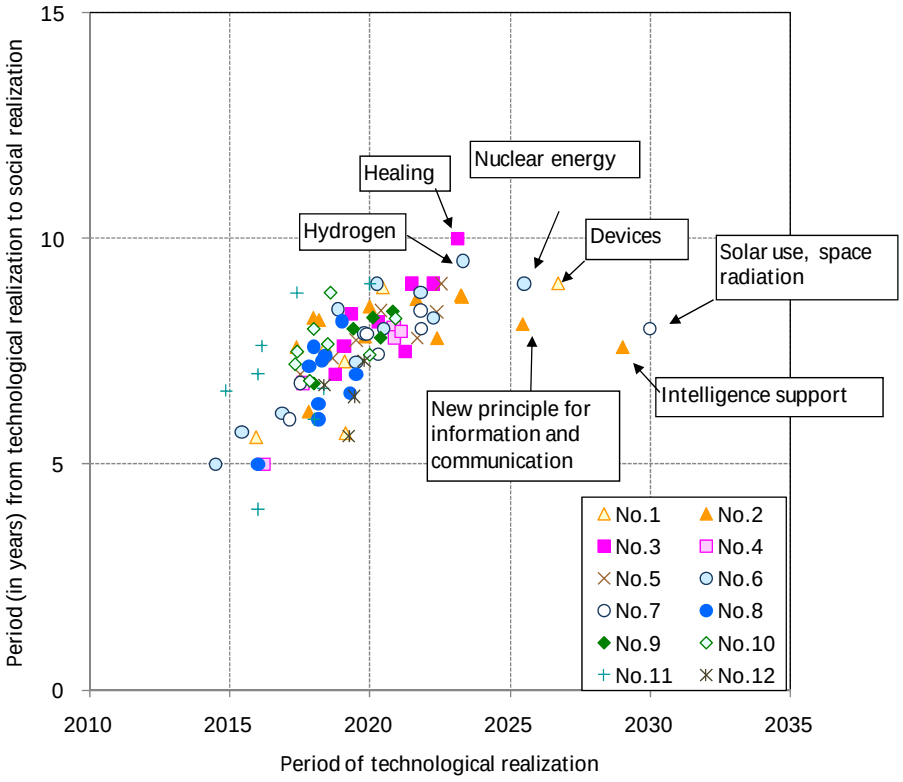
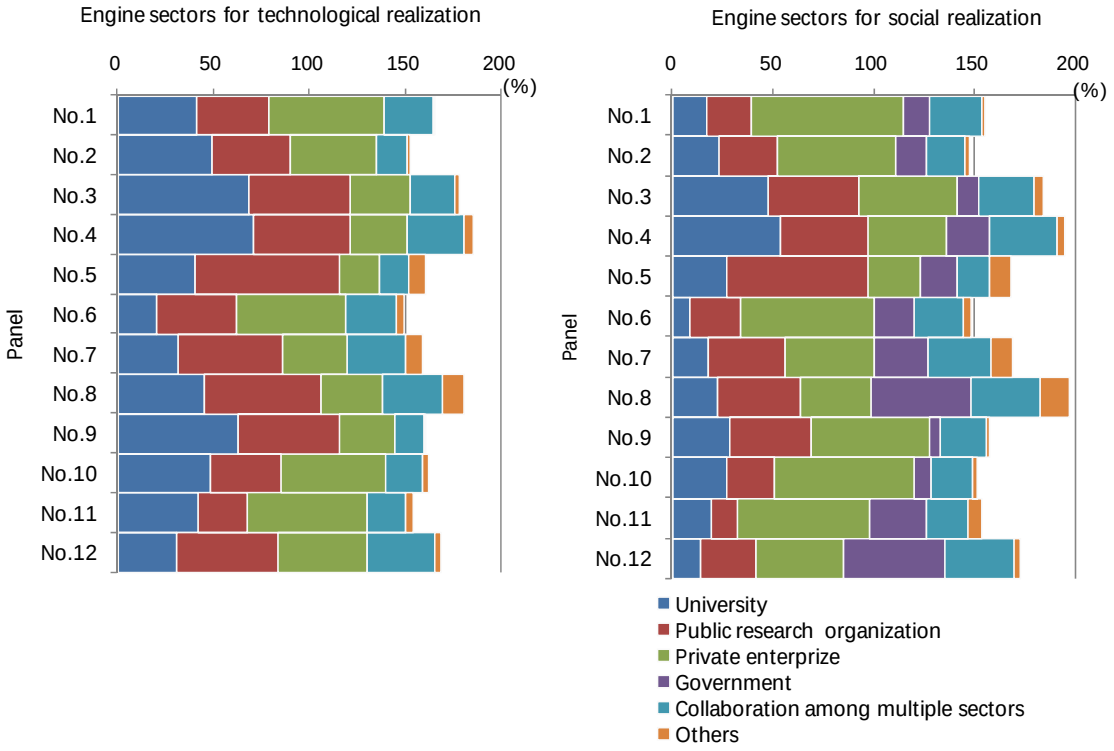


Figure 2-8: The period from technological realization to social realization



◊ The sector that serves as an engine toward the topic's realization depends on the type of science and technology. For the topics relating to biotechnology and medical care (Panel 3 and 4), universities are considered to play a leading role both in the establishment of technology and application in society. For the topics relating to energy (Panel 6), enterprises in the private sector are considered to serve as the engine both in the establishment of technology and application in society. Meanwhile, the government is expected to play a key role in social implementation of the topics relating to the environment (Panel 8) and social infrastructure (Panel 12).

Figure 2-9: Sectors that will pave the way to realization



Chapter 3: Future Scenarios Opened up by Science and Technology

The objective of this investigative research is to shed light on the future toward which the forthcoming science and technology are geared, and also to identify science and technology required in overcoming global and national challenges that lie ahead of us.

The research tried to ascertain the challenges that Japan's science and technology should take, wherein the paths for attaining the objectives and the framework in future society that will come into being as a result of social changes and integration of knowledge were investigated through the following three approaches: scenario writing by group work, future scenarios derived from results of Delphi survey, and discussion by younger generation on future society.

3-1. Scenario writing by group work

（1）Implementation overview

Groups consisting of experts held extensive interdisciplinary discussions about the state of society 15 to 30 years from now, in view of identifying science and technology that will be conducive to the realization of such future. Each scenario was supposed to be centered on drawing up paths to the future, whereby an extensive coverage and description of related elements was requested, including priority research and development, human resources development, social systems to be improved, and international deployment (Figure 2-10).

The experts, 54 in all, examined 12 scenarios (Table 2-4) and came up with illustrative ideas for the framework and paths to be implemented toward a solution of global and national challenges, whereby collaborative accomplishment through interdisciplinary effort involving a variety of fields in science and technology, and the improvement of social systems were counted for.

Figure 2-10: Structure of a scenario

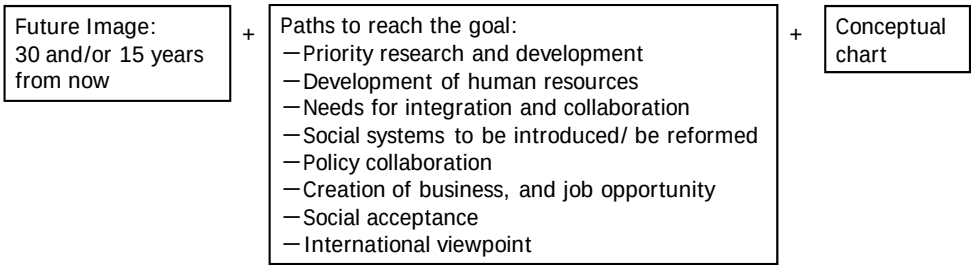


Table 2-4: Scenario themes

Grand challenges	Scenario theme
Sustainable growth through green innovation.	Realization of a low-carbon society through the active use of the Smart-grid
	Water supply system with global reach
	Green ICT business
	Integration of the agriculture, forestry, and fishery industries into a unified entity
	Measures against environmental changes
Successful model for healty-aging society	Maintenance and promotion of health in an aging society with fewer children
	World's highest level medical environment underlying the healthy society with longevity
	Health information infrastructure for eliminating disparities
Secure life	Stable supply of food
	Safely securing fossil and mineral resources
	World's highest level life security: realization of a society oriented toward disaster reduction
	Reliable social infrastructure

* "Central player in the scientific and technological arena" is also mentioned as a grand challenge. But it is set aside from the scenario writing themes, as it is an objective common to all areas of science and technology.

(2) Future scenarios

Scenario 1: Realization of low-carbon society through the active use of the Smart-grid

Leader: Dr. Hiroshi ASANO, Central Research Institute of Electric Power Industry and Tokyo University

Key issues:

- Technical development and international diffusion of the smart grid
- Japan should lead the construction of the low-carbon energy supply/demand system, thereby contributing to the reduction of green house gas (GHG) emissions, promotion of new breeds of industry, job creation, and local activity.

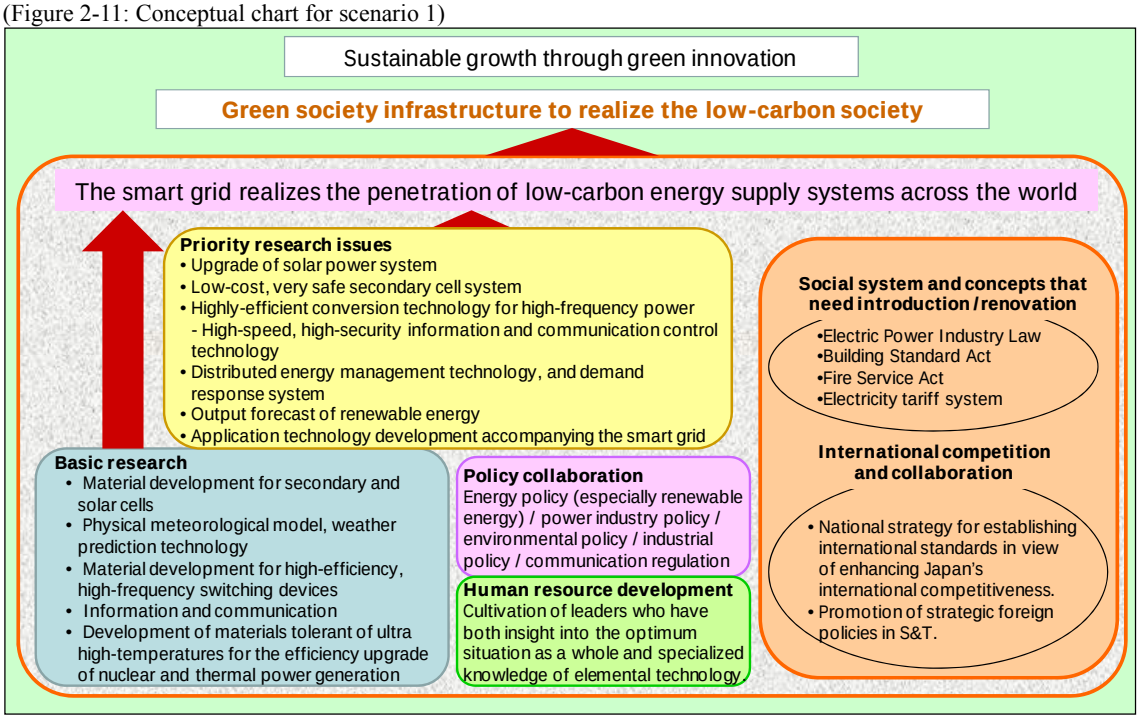
Future image in 2040:

- Due to integrated operation of the demand-side resources and supply-side large-scale power generation and transmission/distribution networks, energy/power supply system with high-efficiency, high-reliability, and high-quality will be realized.
- Expanded market size of power demand-supply chains in developing countries: from the trunk system to the demand system.

Path to realization:

- Development of elemental/communication/control technologies required to streamline the path to full-fledged application of solar and wind power generation.
  - Solar generation system, secondary battery cells, highly-efficient, high-frequency power conversion technology, high-speed and high-capacity information and communication and control technology, distributed energy management system, etc.
- Breakthrough in basic research
  - Secondary battery cell materials, new materials for highly-efficient next generation solar cells, weather forecast technology to facilitate output prediction of renewable energy sources, highly-efficient switching devices, security technology for information and telecommunications.
- Integrated research that includes institutional design, aiming at the provision of a total life solution.
- The securing of human resources that lead to system integration.
- Review of regulations to comply with the changes in the socio-economic environment and advancement and diffusion of technologies: the Electric Power Industry Law, regulations on connecting distributed power systems, the Building Standard Act, the Fire Service Act, and the consumer protection law.
- International collaboration to formulate international standards, and conclusion of strategic alliance.

(Figure 2-11: Conceptual chart for scenario 1)



Scenario 2: Water supply system with global reach

Leader: Prof. Kaoru TAKARA, Kyoto University

Key issues:Global deployment of water supply system technologies compatible with regional conditions (e.g. weather, climate, and social conditions), contributing to the construction of a society with access to a safe and secure water supply.

Future image in 2040:Low-cost, low environmental load water is supplied, but the scarcity of water continues. The securing of new water resources in inland areas has become an issue, due to reduced sizes of lakes, contamination, and the depletion of surface water and fossil water.

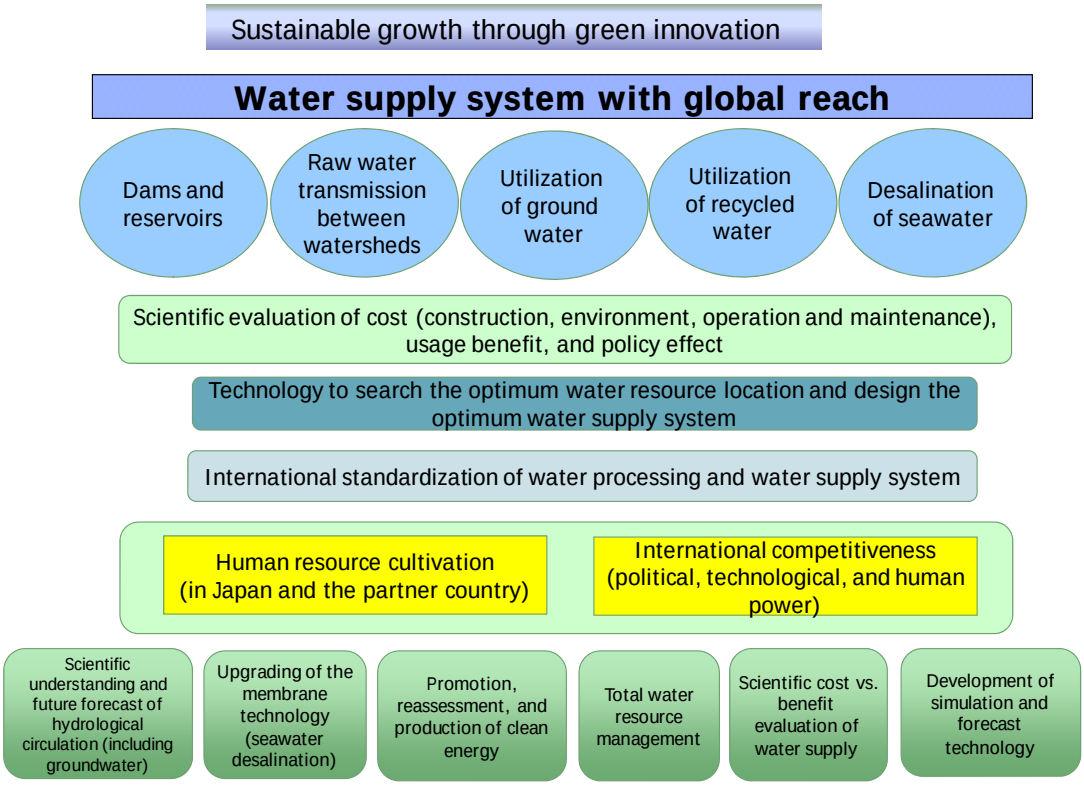
- Japan's water supply system and weather-water forecast system gain global acceptance, and receive large business opportunities from many countries.

Path to realization:Realizing a global deployment of water supply systems that are oriented towards a low-carbon society and provide Japan with a wider business opportunity.

- Scientific understanding of water and groundwater circulation systems in global, continental, and watershed scales as a prerequisite to shed light on the optimum water supply system.
- Further upgrading of engineering technologies for desalinating seawater.
- Utilization of solar, wind, and geothermal energies.
- Total water resource management within a watershed, and in an aggregate of watersheds.
- Evaluation of costs and benefits of obtaining water.
- Sophistication of simulation/forecast technology conducive to the development of an enhanced water supply system.

- Collaborations among hydrology, meteorology, civil engineering, energy science, public economics, international law, and policy studies.
- Cultivation of human resources capable of global thinking with a sense of ethics and mission: specialists with general understanding, and generalists with the viewpoint of a specialist.

(Figure 2-12: Conceptual chart for scenario 2)



Scenario 3: Green ICT business

Leader: Dr. Shinji NAKADAI, NEC Corporation

Key issues:

- Realization of the infrastructure that distributes thermal energy evolved in ICT to household demand using the water supply network.

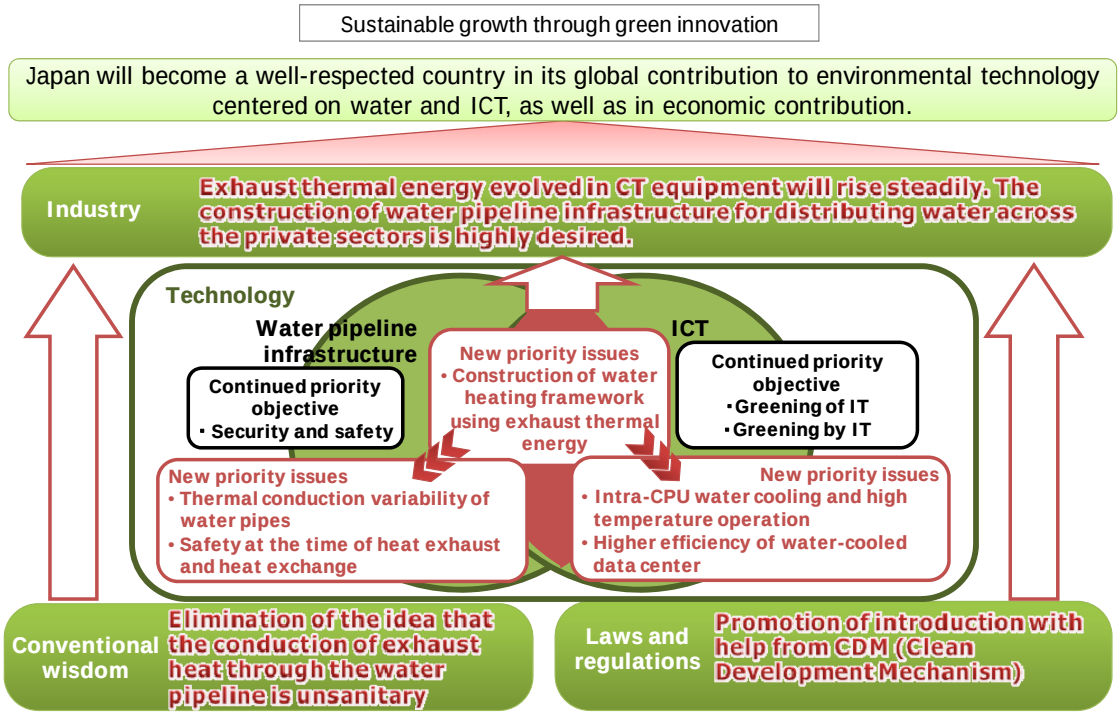
Future image in 2040:

- A water supply system that uses exhaust heat is in operation
- A water treatment facility and a data center are located adjacent to each other, enabling the cooling down of server-cooling water using the low temperature water of the water treatment facility.
- Overseas presence is gained by taking advantage of the operational know-how developed in Japan on water heating (utilization of exhaust heat)

Path to realization

- The thermal energy evolved in ICT can be viewed as a supplementary heat source useable in the private sector. The energy consumption in the ICT domain is recaptured in conjunction with the water infrastructure, leading to a symbiotic utilization of ICT and water networks.
- Priority objectives
  - Optimum arrangement of geothermal sources and IT exhaust heat sources in a water supply network
  - Provision of variable thermal conductivity to water channels
  - Stable heat exchange requires a complete exclusion of foreign objects from the water channels.
  - Development of water-cooling technology inside a CPU chip.
  - Efficiency upgrade in the water-cooling system of the data center.
  - Search for untapped exhaust heat sources other than the data center.
- Collaborations among hitherto unrelated areas for the construction of a general framework, under which a set of individual research projects is organized.
- Institutional reform: relaxation of responsibility boundaries in water business, and promotion of introduction through the green development mechanism.
- Harmonization among government policies
- Understanding of water quality needed by citizens, and awareness on the side of the water business as a “cool energy provider”

(Figure 2-13: Conceptual chart for scenario 3)



Scenario 4: Integration of the agriculture, forestry, and fishery industries into a unified entity

Leader: Prof. Kei-ichiro MAEDA, Nagoya University

Key issues:

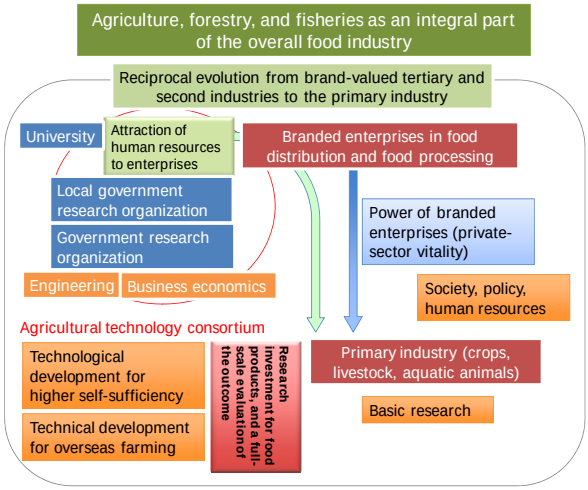
- Agriculture, forestry, and fishery industries as integral elements of total industry.
- Reciprocal evolution from brand-valued third and second industries to the primary industry

Future image in 2040:

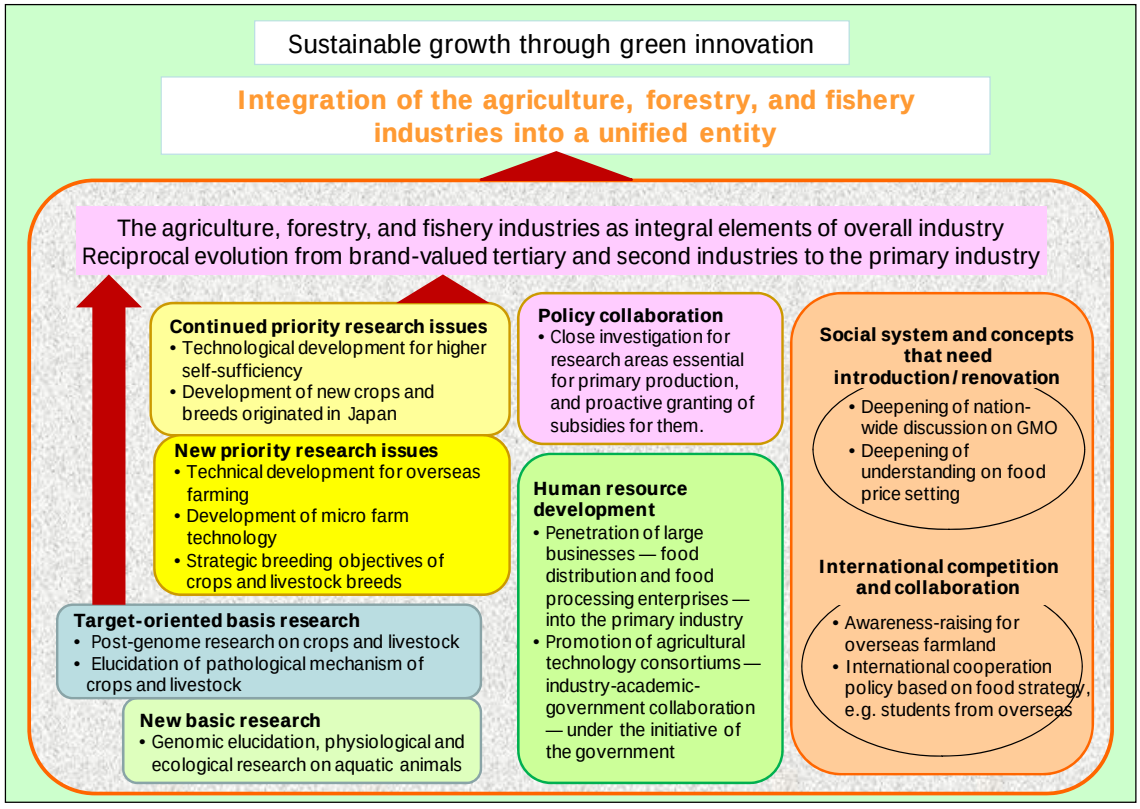
- "6th industrialization": backward evolution from the third industry to the second, and then to the primary industry. The primary industry as a total entity embracing the secondary and third industries. Production of brand-valued crops
- Collaborative technical development by private sector enterprises (second and third industries) and the government, aiming at global deployment (fostering of multinational enterprises that engage in primary industry). Agricultural production overseas under the control of Japanese companies (i.e. farmland ownership outside Japan).

Path to realization:

- Establishment of a technology consortium centered on private sector enterprises, and involving the government and universities.
- Close investigation for research areas essential for primary production, and proactive granting of subsidies for them.



(Figure 2-14: Conceptual chart for scenario 4)



Scenario 5: Measures against environmental changes

Leader: Prof. Satoshi TAKIZAWA, Tokyo University

Key issues:

- Enhanced adaptability to environmental changes — caused by climate change and socio-economical activities — that supports social innovation for safe and secure life.

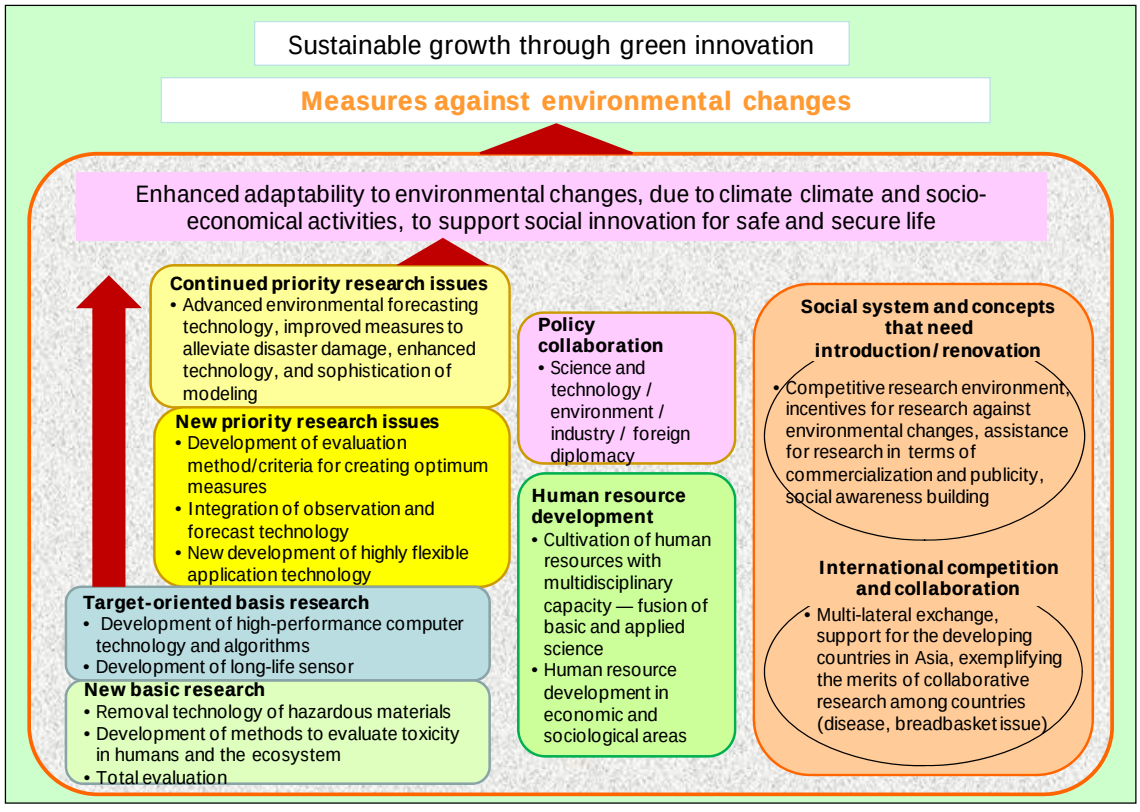
Future image in 2040:

- Significant contribution to solving the urban environmental problems that evolve in line with explosive urbanization in developing countries. Development of life-oriented technologies based on natural energy. Transfer of these technologies to Africa, where rampant regional conflicts are triggered by burgeoning environmental refugees, and thereby contributing to solving regional issues.
- In Japan, a drastic review of urban structure to alleviate the heat-island effect. Reduction of CO_2 emissions through the introduction of electric vehicles and other methods into the public transport system. Production of unconventional crops in high-latitude and high-altitude regions.
- Development of advanced disaster forecasting system, which will function as the core of the system operation to distribute real-time disaster forecast information to the countries of the Asia-Pacific regions.

Path to realization:

- Construction of advanced environmental forecast technologies that relate to all aspects of human life — water resources, eco-system, agriculture, forestry and fishing industry, coastal protection, disaster prevention, and health — and thereby provide a way to prevent environmental degradation in the future.
- International cooperation from a global perspective is an integral part of science and technology for effectively addressing the changing environment. Bilateral and multilateral exchange and mutual support of technology enable coordinated research in several countries, and result in effective sharing of the technology.
- Cross-cutting efforts involving economics and sociology from the viewpoints of synthesis, integration, and combination.

(Figure 2-15: Conceptual chart for scenario 5)



Scenario 6: Maintenance and promotion of health in an aging society with fewer children

Leader: Dr. Norihiro KATO, Research Institute National Center for Global Health and Medicine

Key issues:

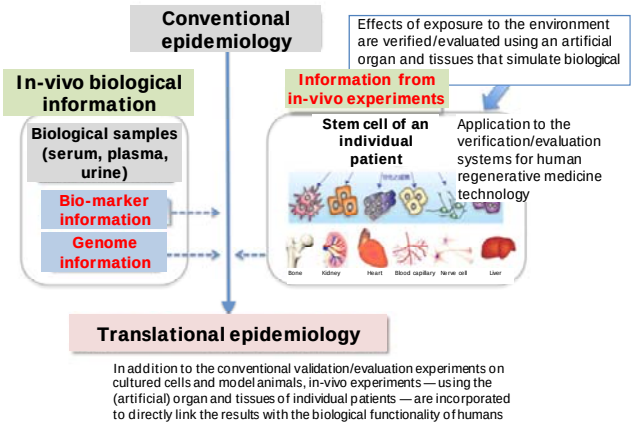
- "Tailor-made" management of mental and physical health with special emphasis on preventive medicine, based on the life-long clinical record.

Future image in 2040:

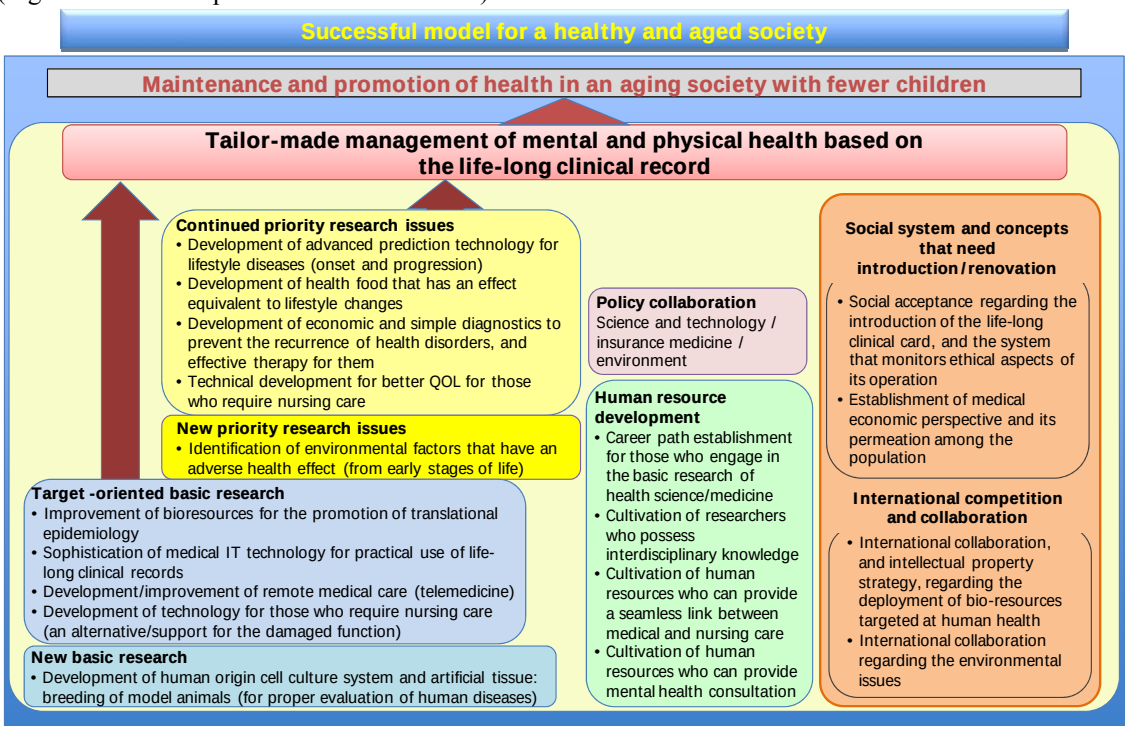
- Proactive promotion of dietary education to prevent the three major diseases, enabling meticulous dietary life management based on the genetic make-up of each individual.
- Tailor-made health management, prognosis, and preventive medicine based on life-long electronic clinical records, which also include information on the interaction between the environment and genetic make-up of the individual.

Path to realization

- Development and promotion of translational epidemiology.
- Development of health food, prevention of disease aggravation, and identification of environmental factors affecting the occurrence of a disease.
- Enhanced collaboration between medical and nursing care, and better QOL of those who require nursing care (e.g. provision of alternative physical functions), as well as mental health and enhanced awareness of achieving health through self-reliance efforts.
- Collaboration among such disciplines as physics, chemistry, architectonics, urban engineering, humanities, and behavior science.
- Deliberation from a medical-economics viewpoint and formulation of ethical guidelines, in order to put the life-long clinical record into practice



(Figure 2-16: Conceptual chart for scenario 6)



Scenario 7: World's highest level medical environment underlying a healthy society with longevity

Leader: Prof. Koichi KAWABUCHI, Tokyo Medical and Dental University

Key issues:

- Secure healthcare setting embedded in ordinary life, and an international competition arena for breakthrough medicine and medical devices. Cross-fertilization of these two.

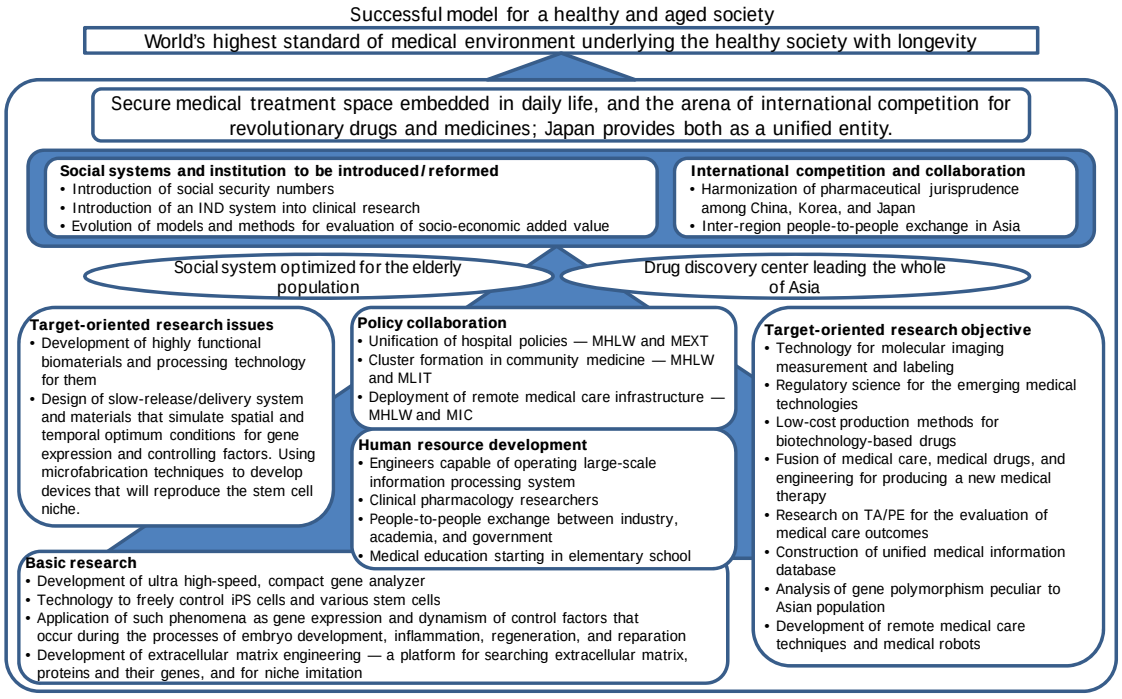
Future image in 2040:

- A health care resource giant that allows citizens to enjoy the world's top-level medical services, and to manage life-long health resources using a single card.
- The largest center of medical product researchers in Asia, and the largest exporter of advanced medical care products in Asia.
- The country where citizens can receive tailored medical care based on their lifestyle and philosophy, with minimum economic burden.

Path to realization

- Priority research and development
  - Technology development conducive to early exploratory clinical trials on humans
  - Computerized treatment information and construction of a variety of databases
  - Medical devices based on the principle of in-vivo regenerative medicine, eliminating the need for cell introduction from outside.
  - Development of an ultra high-speed gene analyzer that provides personal gene information for tailored medicine.
  - Evolution of extra-cellular matrix engineering.
  - Regenerative medicine research for the regeneration of organ functions utilizing human stem cells (e.g. iPs), etc.
- Collaboration with information and communication technology and urban renovation planning. Advanced management linking research development with clinical applications.
- Review and renovation of medical and pharmaceutical regulations: introduction of IND that allows explorative human clinical trials at an early stage, and review of health insurance plans.
- Establishment of a "special medical zone" and other measures to boost the industrialization of medicine for the creation of new business and job opportunities.
- Creation of a social system coping with the rapidly aging population. Japan, Korea, and China should play a central role in this system, which will be capable of global deployment.

(Figure 2-17: Conceptual chart for scenario 7)



Scenario 8: Health information infrastructure for eliminating disparities

Leader: Prof. Hiroshi OYAMA, Tokyo University

Key issues:

- Expansion of domestic demand and the realization of a healthy nation through the improvement of health information infrastructure.

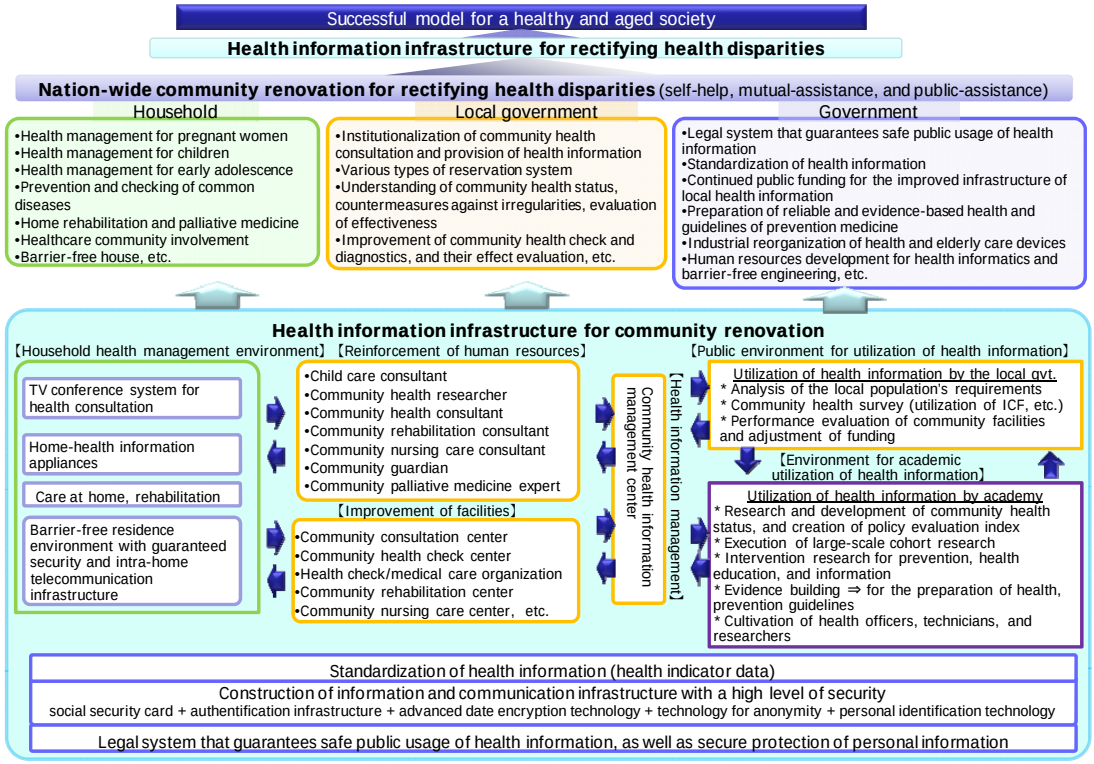
Future image in 2040:

- A complete set of constituent elements for the mutual life assistance social model is in place, including the local nursing care point system and citizen guardian system.
- Local government health facilities for strengthening electronic health checkup, disease surveillance and monitoring real-time emergency health hazards are in operation. The protected health information accumulated at the center is used for disease prevention, health care, health policy and health assurance purposes.
- The electronic clinical guidelines for national health and preventive medicine come into effect, and they function as the infrastructure to eliminate disparities in health management.
- The timing and content of the next health check up and immunization are personalized owing to the development of a person-to-person adaptive health prediction algorithm based on clinical guidelines.
- A personal health information management unit and/or intelligent health monitoring bed are in place in household as needed (leased from the local government).

Path to realization:

- Increase of public investment in healthcare IT: the scale expansion has the effect of inducing human resources into this field.
- Institutional renovation in the public sector systems including: the introduction of a guarantee promotion system of health information; a review of the medical equipment screening system; a review of the community healthcare system.
- Implementation of the following measures to eliminate disparities in national health care: 1) an accurate collection and analysis of anonymous personal health information, 2) improved environment for the full use of reliable health information, 3) deployment of self-help, mutual-assistance, and a public-assistance system in each region.

(Figure 2-18: Conceptual chart of scenario 8)



Scenario 9: Stable supply of food

Leader: Prof. Akira YAMAUCHI, Nagoya University

Key issues:

- Stable supply of food to the Japanese population.
- Development of innovative technology to boost food production in farmland in Japan and abroad.

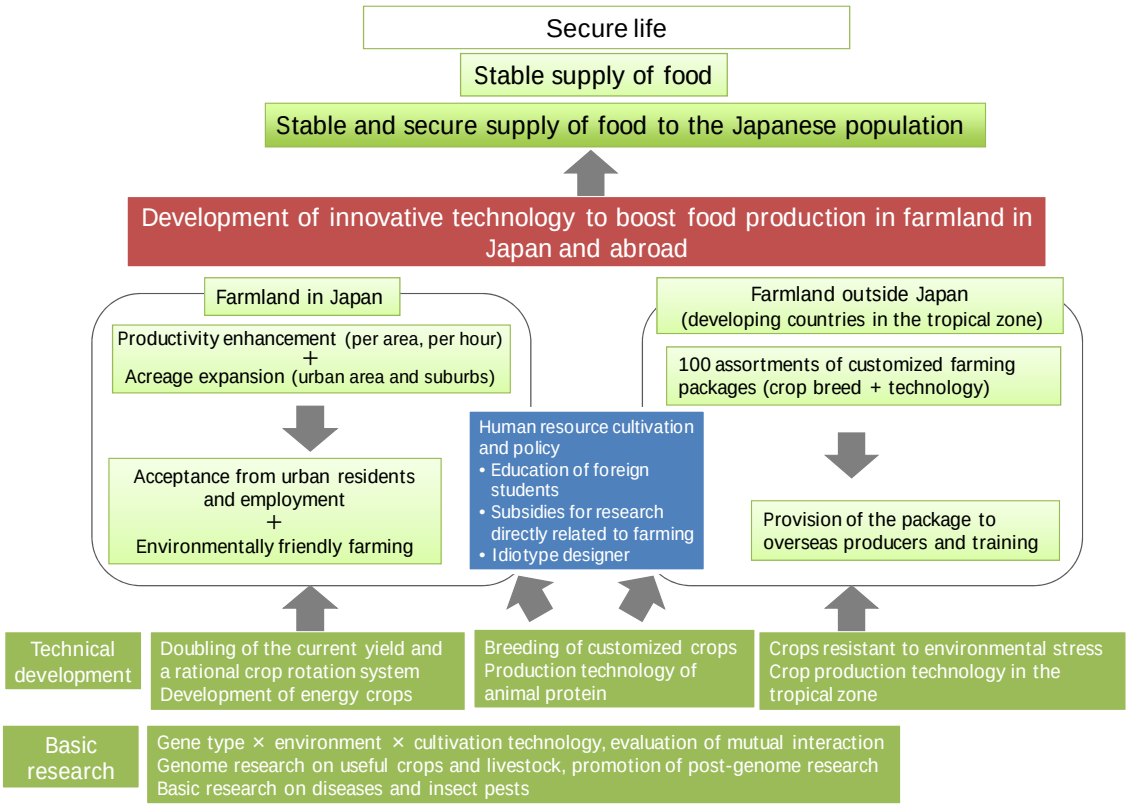
Future image in 2040:

- Establishment of the system that guarantees a stable supply of food: enhanced yield and increase of cultivated acreage at home, the securing of farmland overseas, and the implementation of Japanese technology to boost productivity.
  - Enhancement of unit yield and technology level
  - Conversion of idle land into farmland: vast area of land becomes redundant as a result of the changes in industrial structure and due to decreasing population.
  - Agricultural production overseas under the guidance of Japanese technology.

Path to realization:

- Technical development
  - Creation of new crops customized with consideration given to biological, environmental, and social factors.
  - Improved production technology of crops and livestock
  - Establishment of crop production and control technology specifically applied in overseas farmland.
- Human resource cultivation
  - Ability to propose the optimum combination of breed and cultivation techniques, whereby the genetic heredity of crops/animals and their interaction with environmental factors must be considered, as well as socio-economical factors.
  - Ability to tackle farming on site, and carry out research for boosting agricultural production abroad.

(Figure 2-19: Conceptual diagram for scenario 9)



Scenario 10 <Safely securing fossil and mineral resources>

Leader: Dr. Kazunori TANIGUCHI, Idemitsu Kosan Co., Ltd.

Key issues:

- Development of world leading technologies, and fostering of industry for actual application of them, in such areas as the securing of resources in quantity, replenishment by recycling, higher usage efficiency, and reduction of environmental load.

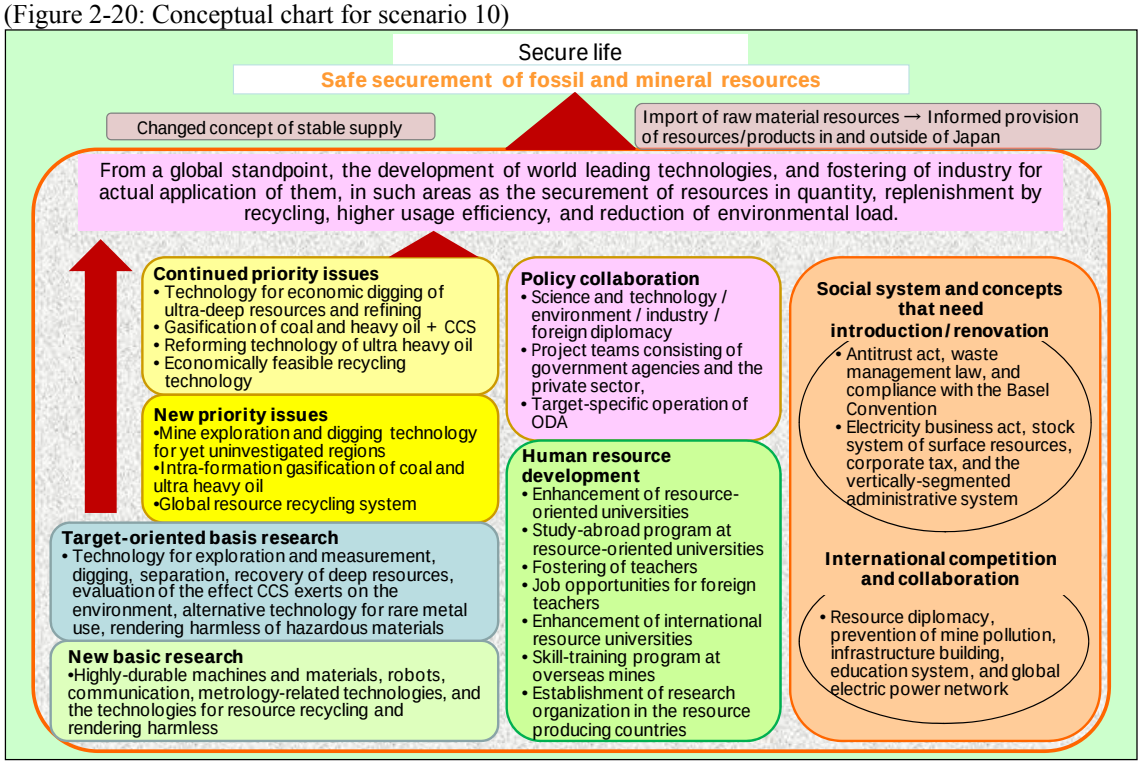
Future image in 2040:

- The minimum required resources are available. But the trend toward higher pricing continues, and the risks in terms of geopolitical situations and the inflow of speculative funds persist.
- Fund procurement consortiums consisting of enterprises with global competitiveness have huge power.
- Construction of interdependent, multi-strata relationships with resource producing countries, e.g. establishing full-scale production facilities on site — from raw materials to the final product — in cooperation with resource-producing countries.

Path to realization:

- The essential theme is to maintain the balance of supply and demand in view of the rapid economic growth in developing countries, and to address properly the increasing restrictions on the environment. Japan should lead the world through the development of science and technology that provide solutions in terms of commercialization, engineering, and industrial production.
- Technology development for untapped, unconventional resources, such as ultra-deep and seabed resources, cyclic use of metal resources, and upgrading the utilization efficiency of fossil resources.
- Suppression of CO_2 emissions in production and utilization processes. Elimination of hazardous materials or rendering them harmless.
- Resource exploitation in uninvestigated regions, and method of development for obtaining resources using techniques other than digging. Unconventional approaches that change our mind-set will become important, e.g. a resource recycling system crossing national borders.
- The need for the integrated production approach, from upstream to downstream, located in resource-producing countries. Therefore, the cultivation of human resources capable of overseas assignment is urgently needed.
- National policy based overseas investment in the areas relating to mines and refining, and ODA funding for resource development purposes.

(Figure 2-20: Conceptual chart for scenario 10)



Scenario 11: World's highest level life security: realization of a society oriented toward disaster reduction

Leader: Prof. Hirokazu TATANO. Kyoto University

Key issues:

- Promotion of visualization of urban security, and introduction of community safety diagnostics and concrete measures.

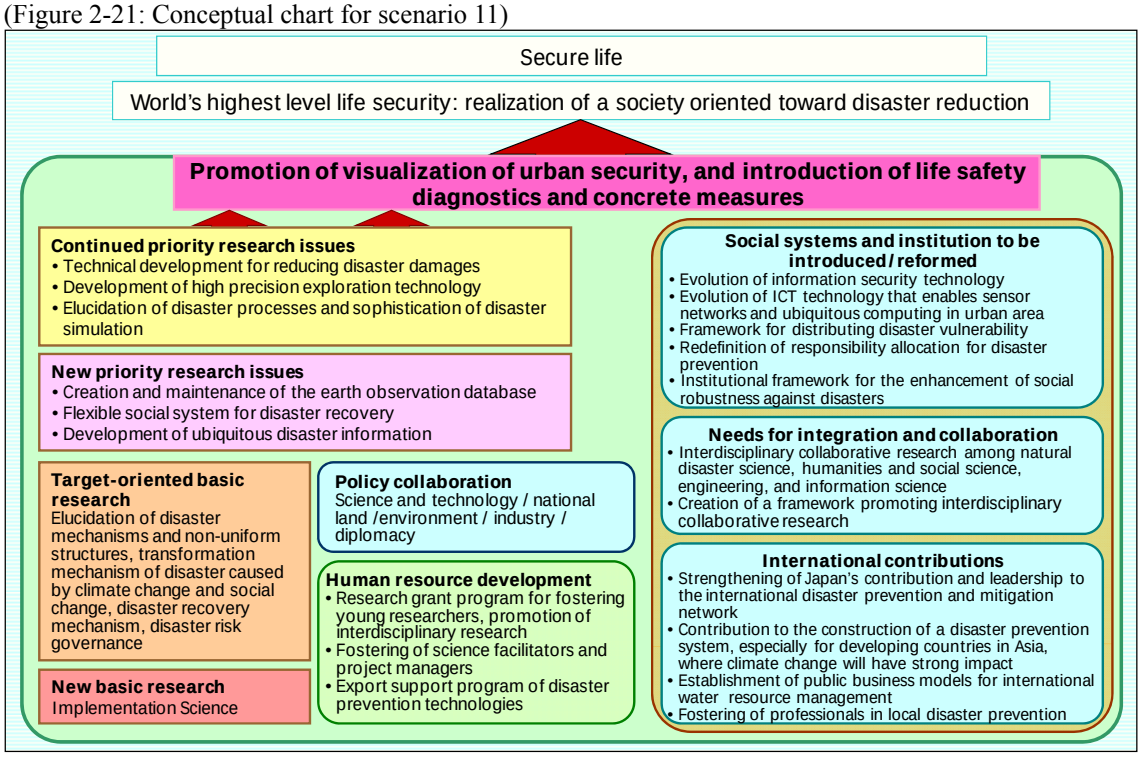
Future image in 2040:

- Sensor networks are ubiquitously deployed across the urban environment. The sensor nodes directly provide citizens with useful information regarding ordinary infrastructure management and human actions to be taken when a disaster takes place.
- Although the frequency of extreme climatic phenomena increases, citizens act appropriately under the guidance of advanced forecast technology.
- Implementation of a real-time disaster-stricken information and communication system enables quick first response at the time of disaster.

Path to realization:

- Technological development for reducing damage:
  - Sophistication of simulation technology (large structure, disaster phenomena, precipitation)
  - Development of high-precision probing technology (situation inside a structure, crustal architecture, ground)
  - Flood control within a river basin and provision of information, regulations and guidance on land utilization.
- Technology research and development useful to enhance the recovery of the social system (i.e. a flexible social system considering disaster recovery)
- Disaster prevention information and communication through the ubiquitously deployed information network (ubiquitous disaster prevention information system).
- Creation and maintenance of earth observation database (unified control and interoperability of various observation data in such areas as earth crust, geology, soil, terrestrial objects, and hydrology)
- Object specific (solution oriented) basic research, in which a discovery contributes to the realization of disaster reduction society.

(Figure 2-21: Conceptual chart for scenario 11)



Scenario 12: Reliable social infrastructure

Leader: Prof. Yasuyuki IIDA, Komazawa University

Key issues:

- Construction of a safe and secure society through an organic collaboration of law enforcement, community, and media.

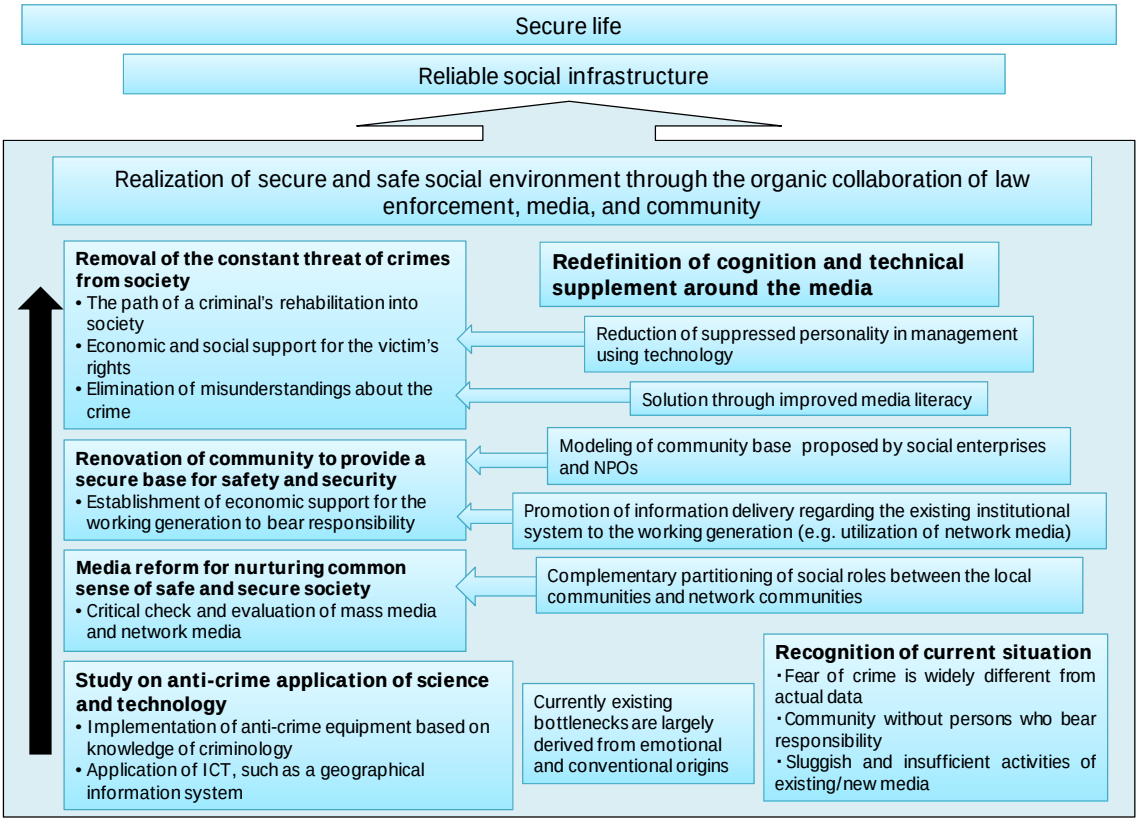
Future image in 2040:

- The three elements (law enforcement, community, and media) play complementary roles, and the citizens have a real feeling of safety and security.

Path to realization:

- Removal of the constant threat of crime from society.
- Renovation of community to provide the base underpinning safety and security.
- Media reform for nurturing common sense regarding crime.
- Study anti-crime application of science and technology

(Figure 2-22: Conceptual chart for scenario 12)



3-2. Future scenario based on the results of the Delphi survey

Based on the results of the Delphi survey (see Chapter 2 of Part II), contributions from science and technology to the society as of 2025 were coordinated, from the viewpoint of citizens' daily life, into the three images of society described below. Attempts were made to draw up the images as objectively and as neutrally as possible based on the forecasted maturity of technologies and their diffusion: citizens are likely to enjoy healthy daily life and take environmentally-friendly infrastructures for granted.

* For descriptions of all the scenarios, see Appendix B.
* The applicable Delphi topic is shown in each illustration. The number in front of the topic statement indicates the topic ID (Panel-topic number), and the trailing number in parentheses indicates the forecasted year of social realization.

A society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail
A society where individuals can use various types of energy selectively based on their comprehensive evaluation of value and can feel that they proactively contribute to global warming prevention and environmental preservation
A society in the early stage of coping with the various disasters caused by environmental changes

(1) A society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail

Primary subject:

- Availability of gene information and medical monitor greatly enhances the level of health promotion and preventive medicine. Excellent public health education enables all citizens to self-manage the way of life for maintenance of health. Even upon falling ill, they are still able to avoid going into decline and hence, albeit with certain compromises, lead a healthy life.
- Expectations are high for the potentials of novel therapies, as the availability of a group of new medical methods, e.g. regenerative medicine, is coming into sight (in terms of technical feasibility).

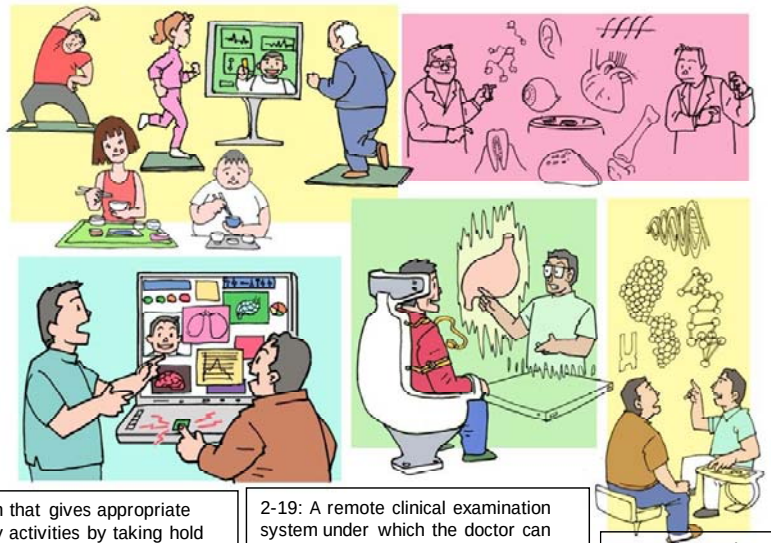
Subordinate subject:

- Pressing problems, such as regional differences in medical care and emergency medical services, have already reached a partial solution.
- An appropriate assessment system for medical practices, including the standardization of medical care and the overhaul of the medical fee scheme, has been established, contributing to the equalization of medical care, and the alleviation of medical manpower shortage and overwork.
- Public trust in doctors and medical facilities has been enhanced owing to the improvements in medical education

Figure 2-23: Scenes in daily life (a society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail)

1-16: Ubiquitous computing technology supporting health control to maintain and to improve one's health in daily life using computer software (2018)

3-33: Artificial organs which include human cells or tissues derived from iPS cells (2033)
3-34: Technology for regenerative medicine using iPS cells (2032)
3-35: Therapeutic technology using functional cells induced from stem cells, including iPS cells, without risks of carcinogenesis (2030)
4-10: Technology for the regeneration of muscles and organs using stem cells (2031)



2-05: A system that gives appropriate advice for daily activities by taking hold of information on the lifestyle, health conditions and working situation of each individual, in a continuous and comprehensive manner (2022)

2-19: A remote clinical examination system under which the doctor can use a stethoscope and palpate the patient or smell the patient's breath from a distance, as if they were face to face (2029)

4-51: Diagnostic methods for the risks of acquiring diseases through genome data (2023)

4-80: Integrative medicine in which a lifelong regional electronic health record is introduced and community-based care is possible (2023)

11-17: In Japan, the medical records containing motion video will be converted into electronic form and entrusted to patients, and the medical information, including the results of examination, will be shared among all medical institutions. Based on this environment, a health care agent business will be formed between patients and medical institutions (2024)

12-20: Diffusion of logistics services that deliver medicine and food for medical treatment, without requiring a hospital visit, to support the lives of elderly persons and patients of lifestyle diseases living in inconveniently located areas, such as mountainous regions, by establishing a remote consultation system and health care system using IT technologies (2020)

4-83: Medical ethics education for healthcare professionals (2017)

4-84: Medical safety education for healthcare professionals in which simulation technology is introduced (2018)

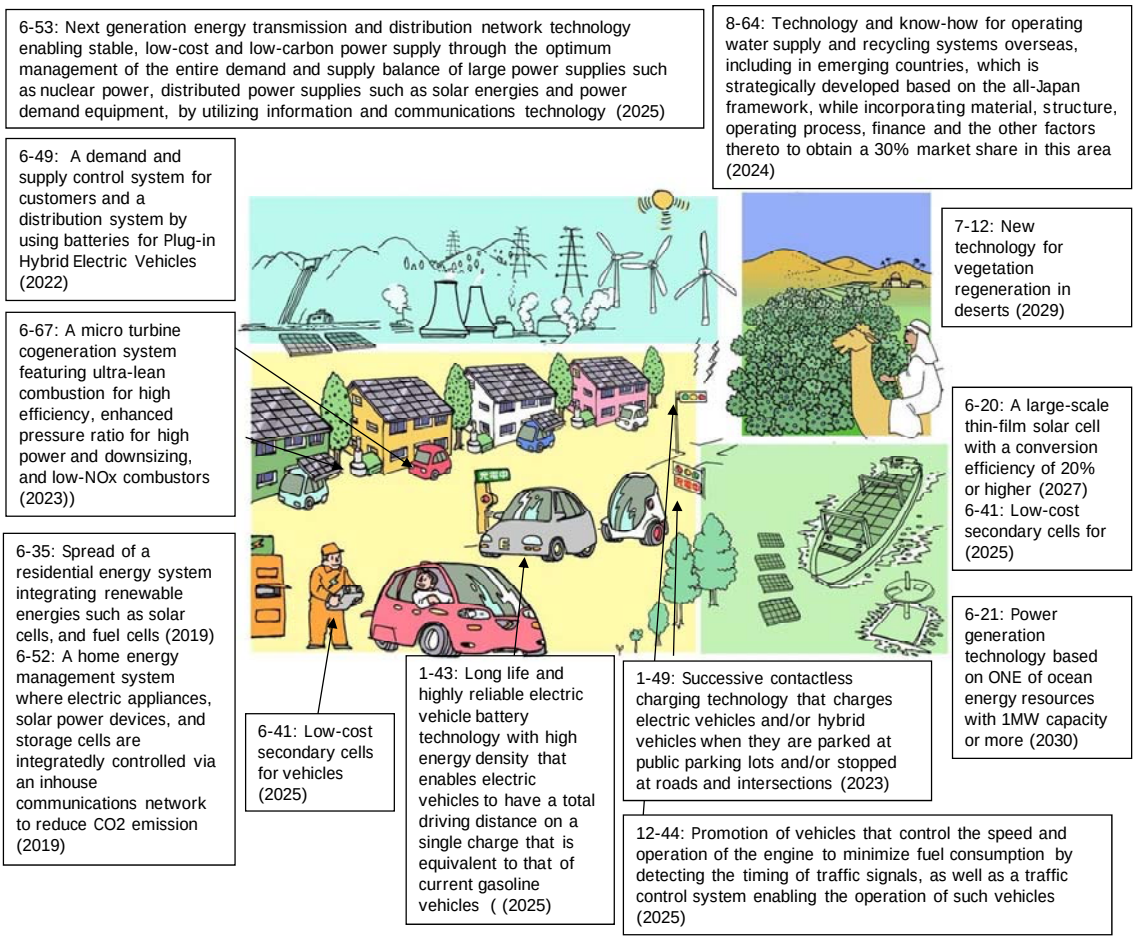
4-66: Regional medical care system that can take prompt actions and correct regional disparities in regard to emergency medical service (2021)

(2) A society where individuals can use various types of energy selectively based on their comprehensive evaluation of value and can feel that they proactively contribute to global warming prevention and environmental preservation

Primary subject:

- A greater number of houses are capable of utilizing non-fossil energy.
- Untapped energy sources, such as garbage and rainwater, are going to be efficiently utilized by each household and local community.
- Electric vehicles have come into wide use with the help of improved performance and infrastructure.
- The collective management of essential utilities (i.e. electricity, gas, and water) allows citizens to make selective use of the energy sources according to personal preference, or based on the overall ecological considerations. In terms of electricity, for example, users are free to choose non-fossil power that is remotely generated using natural energies. The benefit points, obtained from the activities with environmental consideration, can be used for further ecological society by donating them for the forest conservation or by using them as discount tickets for electric vehicle rental, etc.

Figure 2-24: Scenes in daily life (a society where individuals proactively contribute to global warming prevention and environmental preservation)

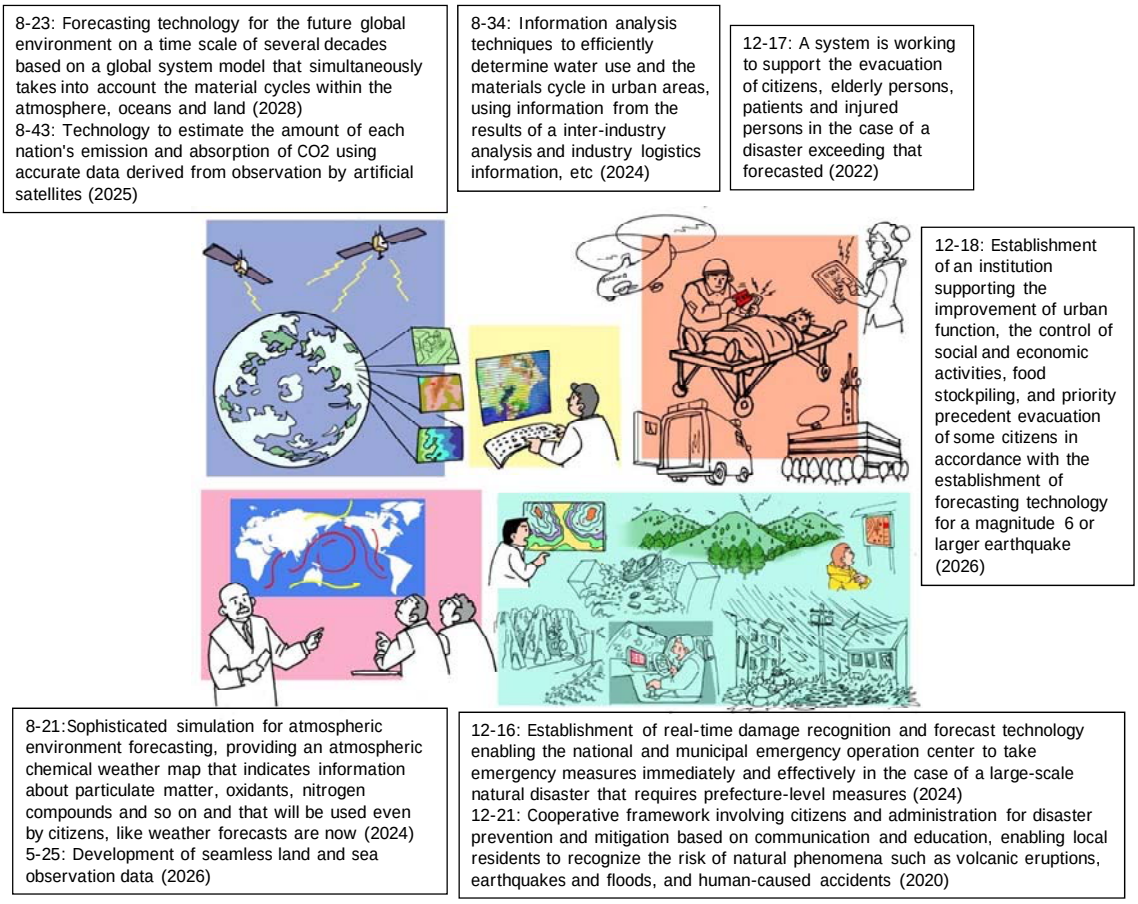


(3) A society where people have begun to cope with various disasters caused by the environmental change

Primary subject:

- Upgrading of global observation networks enables us to obtain manifold environmental data on a global scale. The data are used in various forecasts and simulations, resulting in much better accuracy.
- Global environmental information is accessible to the public on a real-time basis and is used for environmental education and for raising people's awareness of environmental issues.
- Such global information, however, has not produced substantial effect on local societies. For instance, it is not effectively used in a disaster-prevention system
- Local environmental data also become available as necessary. Local forecast and simulation of sudden incidences, such as outbreak of infectious diseases, concentrated heavy rains, flash floods, and so on, comes into practical use to a certain degree, which enables the local government to take quick action against such sudden incidences.

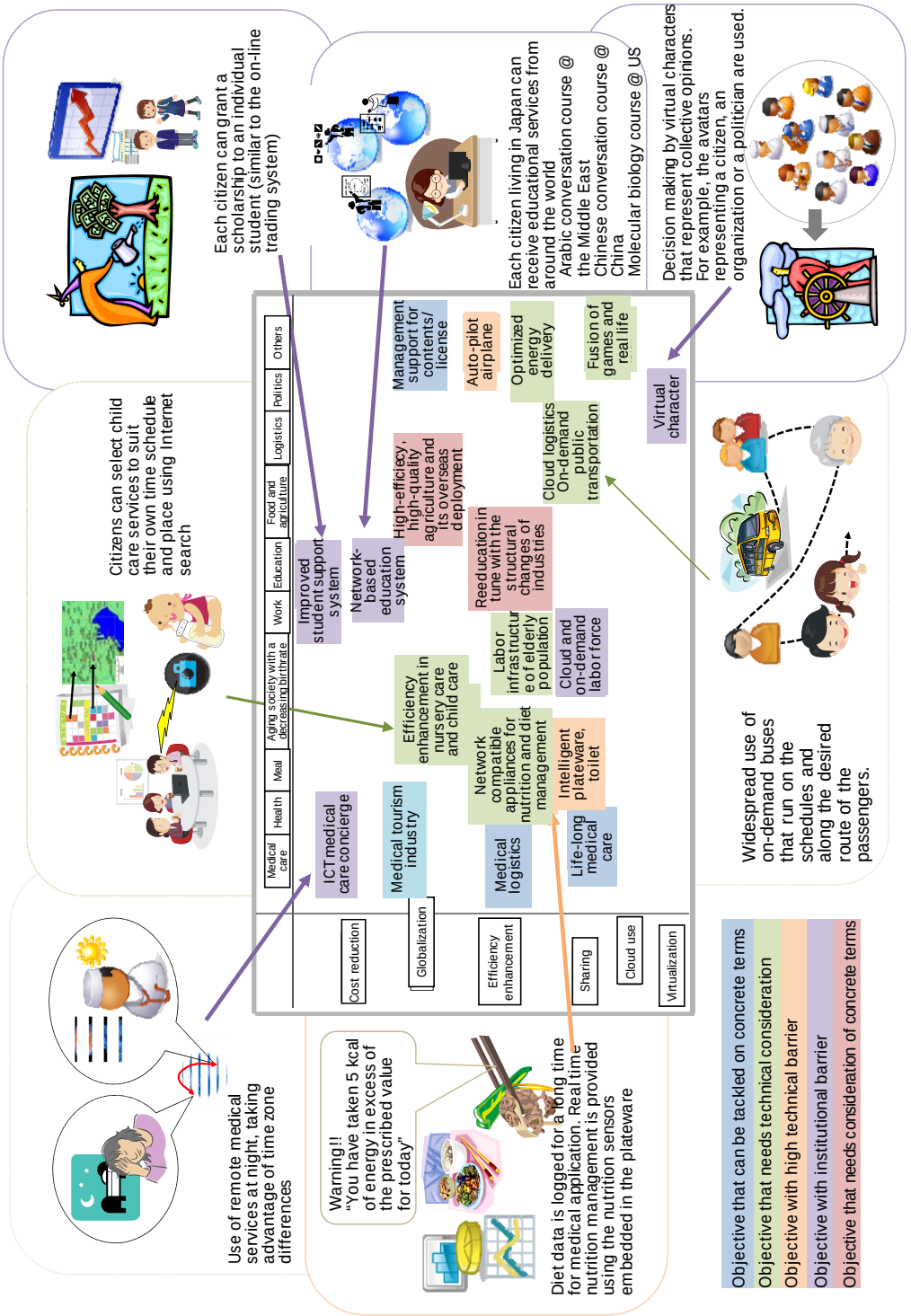
Figure 2-25: Scenes in dairy life (a society where people have begun to cope with various disasters)



3-3. Future society as discussed by younger generation

To complement the argument in 3-1 and 3-2, a discussion was held by a group consisting solely of members of younger generation (aged from 20 to 30). The discussion was focused on the service case studies of ICT applications, i.e. the potential contribution of ICT to such areas as medical care, nursing care, education, labor, and environment.

Figure 2-26: Future innovation envisaged by younger generations



Chapter 4: Capability of Local Regions for the Green Innovation

This investigative research placed focus on green innovation, one of the global challenges that we have to address most urgently. Green innovation embraces all aspects of new industry and job creation accompanying the process of constructing a low-carbon society, rather than the simple idea of forming a low-carbon society. Considering this concept, deliberations were made on the ideal social model of each region to be realized in the future (Figure 2-27). As a concrete procedure, workshops were held in eight regions across Japan, where the representatives of the region — researchers, business people, civil servants, and general citizens — discussed a wide range of issues from the viewpoint of realizing the ideal future society (Figure 2-28, 2-29). In the concluding workshop that was set up based on the results of the regional workshops, the focus of the discussion was placed on the industries and services, as well as the science and technology relating thereto, conducive to the realization of the ideal social models.

Figure 2-27: Flow of the survey

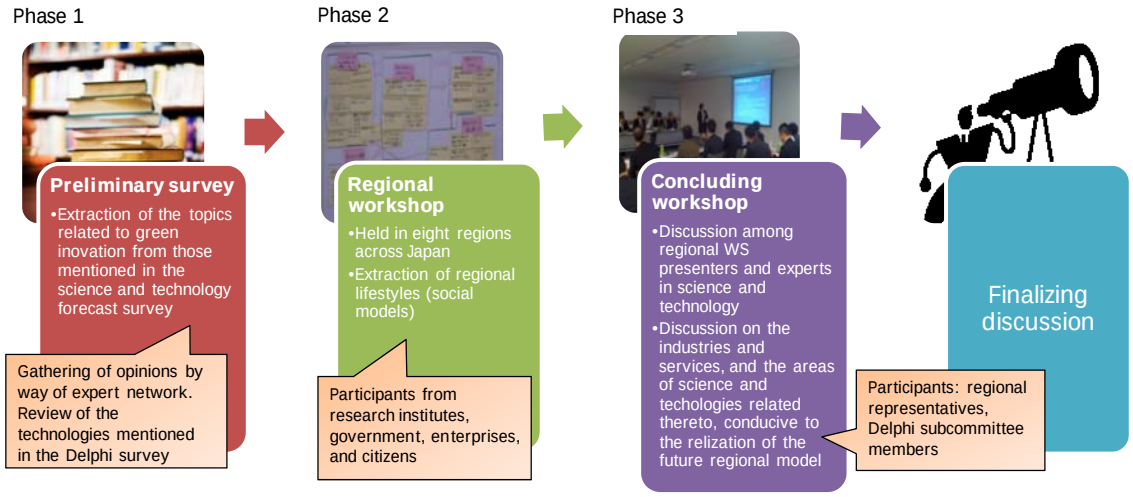
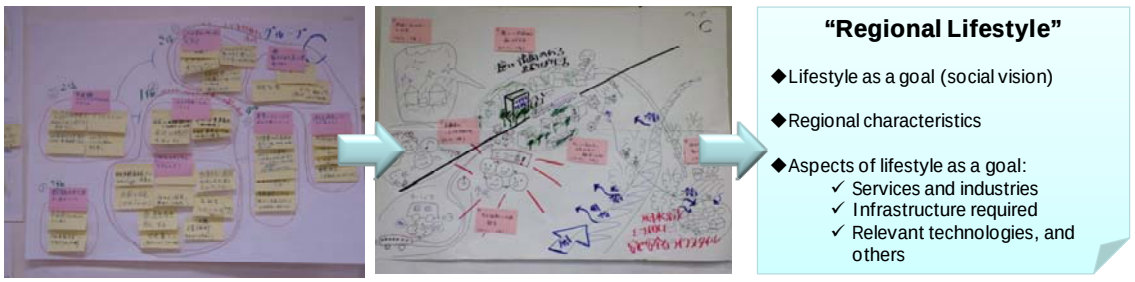


Figure 2-28: The discussion process in regional workshops



All participants imagined scenes of life in their regions 20 years and 40 years from now (living, shopping, working, child raising, healing, playing, learning, and social interactions), and described them on a card.
These cards were classified and compiled based on their inherent associations, and then labeled.

Based on the results of discussion, the group made a picture, "Regional lifestyle" (see above).
AHP (Analytic Hierarchy Process) was performed on the extracted items to arrange them in order of priority in view of attaining the targeted lifestyle.

Based on the outcomes from the group discussions, a plenary session was held to discuss the ideal lifestyle in the region.

Figure 2-29: The host regions of the regional workshops

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Shichinohe town (Aomori pref.; population: approximately 18,000)
"A convivial town that is in harmony with nature and attracts people"

Kazumaki town (Iwate pref.; population: approximately 8,000)
"Community renovation: turning deficiencies into strengths"

Kaminoyama city (Yamagata pref.; population: approximately 34,000)
"Japan's No. 1 life-long lively community"

Tsukuba city (Ibaraki pref.; population: approximately 210,000)
* Reference: Number of foreign residents: approximately 73,000
"Global-minded research and university town with an established low-carbon lifestyle"

Nagoya city (Aichi pref.; population: approximately 2,258,000)
"Urban life compatible with nature (wind, water, and greenery)"

Tsuruga city (Fukui pref.; population: approximately 68,000)
"Town full of vigor with affluent electric power"

Miyazaki pref. (population: approximately 1,132,000)
*Miyazaki city (approximately 370,000)
"A society letting you live in affluence, with mutual independence and coexistence"

Okinawa pref. (population: approximately 1,380,000)
*Naha city (approximately 318,000)
"An affluent society blessed with bright sunshine, the wide open sea, and an assortment of new energy sources"

4-1. The vision of the ideal future society

The following ideal social models were developed through the discussion in the workshops held in eight regions.

1) Shichinohe town (Aomori pref.)

Desired society in 2050
"Harmony with nature. Convivial town that attracts people"

- Located on the foot of Mt. Hakkoda and surrounded by rich nature, Shichinohe city is gaining popularity as a sightseeing destination utilizing a castle ruin and ruins from the Jomon period.
- It has a station on the Tohoku Shinkansen line (Shichinohe-Towada), which provides the population with easy access to nearby cities, as well as a convenient intra-city transport system. It attracts citizens and visitors alike owing to the convenient infrastructure.
- It utilizes such nuisances as snow and garbage wisely as the untapped energy resources for positive use.
- Active cultivation of human resources that think wisely of nature and ecology.
- A city where you can live safely and comfortably with spiritual richness, and with a rich supply of water and food.

Results of group discussions (ordering of priority; AHP scores are shown in [ ])

	Group A	Group B	Group C	Group D
1	Production/utilization of regional energy [11.0]	Most advanced morning sightseeing services in Japan [16.0]	Good environment for both working and living, contributing to more of the population living comfortably [13.0]	Well preserved Water of Life (clear water) [14.0]

	Group A	Group B	Group C	Group D
2	Education in general [9.0]	A compact city with well-developed public transportation, providing citizens and visitors with an easy means of transport [8.5]	Enhanced amenities attract people to Shichinohe [12.3]	Local production for local consumption [9.3]
		Sightseeing services utilizing historical heritage and horses [8.5]	Easier access to nearby and remote regions [12.3]	
3	Population increase through the well-developed transportation modes [7.0]	High value-added food product utilizing nature (snow) [3.9]	Making agriculture a more exciting job [11.7]	Life with a rich flow of communication [4.6]
4	Nature-friendly living/environment [6.3]	Potential establishment of an agriculture and nature learning system, embracing a range of participants from children to university students (from large cities) [3.7]	Turn the nuisances into benefits: effective use of snow and garbage [1.6]	Means of high-speed transportation (migration, conveyance) [1.7]
5	Establishment of a sightseeing route activated the city [2.9]			

2) Kazumaki town (Iwate pref.)

Desired society in 2050

"Community renovation: turning deficiencies into strengths"

- Energy sources from the blessings of nature (solar energy, wind, river, forest, livestock, energy-conservation, systems).
- Education, welfare, a place for people to gather (educational collaboration, place for gaining experience, ICT, medical care, community, housing, jobs, high value-added agricultural products, settlement-type nature school).
- Infrastructure and value creation (public transport infrastructure, information infrastructure, new affluence, safety and security in the Kazumaki brand)

Results of group discussions (ordering of priority; AHP scores are shown in [ ])

	Group A	Group B	Group C	Group D
1	Efficient use of energy [26.0]	Environment in general [21.0]	Value creation that money can't buy [12.0]	Housing and regions in harmony with nature in Kazumaki [21.0]
2	Realization of high value-added agricultural products [24.0]	High-profit industry based on the locally available resources [17.0]	Affluent living in the province [12.0]	Availability of houses elderly people can live in safely [12.2]
3	Charming town that attracts people [14.1]	Self-sufficiency ratio of locally available renewable energy to other energy is much larger than 100 : 1 [12.6]	Utilization of resources available in Kazumaki [2.4]	Availability of means of transportation elderly people can use comfortably [7.5]
4	Improved job opportunities [5.5]	Medical care, community renovation, education [13.0]	Making money (jobs) [2.4]	Japan's top agricultural and welfare university [4.7]
5	Learn ecology within nature [3.8]	Optical fiber network [12.3]		Increasing job opportunities in the welfare sector [2.1]
6	Safety and security infrastructure is in place [3.8]	Affluent living environ-ment utilizing the local resource (timber) [11.4]		
7		Recreational opportunities [1.9]		

3) Kaminoyama city (Yamagata pref.)

Desired society in 2050

"Japan's No. 1 life-long lively community"

Kaminoyama-onsen "Kurort" project takes root firmly, and:

- the local population enjoys a lifestyle that helps them be healthy both in body and mind (fostering of lively "bodies and minds")
- the local population inherits and learns the merits of the region across the generations (lively "local links" are fostered)
- many visitors from all across Japan come in search of "health in body and mind" (lively local economy)

Results of group discussions (ordering of priority; AHP scores are shown in [ ])

	Group A	Group B	Group C	Group D
1	Kaminoyama "Kurort" is realized (including institutional design) [17.0]	Pervasion of facilities and institutions that make life easier [19.0]	Education that cherishes local values. [19.0]	Local production for local consumption [23.0]
2	Local vitality is pervasive and centered on the hot spring [12.6]	Living without anxiety in body and mind (reliable and comfortable town) [14.2]	Healthy way of community renovation based on local merits (the hot spring, agricultural produce) [12.2]	Establishment of individual lifestyles backed up by Kaminoyama resources [17.0]
3	The local population makes full use of local products [10.3]	Various lifestyle conveniences [9.4]	Comfortable town that attracts people [11.0]	Ecological infrastructure encouraging people to settle down for child-raising [15.2]
4	Learning opportunities are in place for receiving foreign visitors (enhanced local style) [4.6]	The local population enjoys life-long learning (various learning opportunities) [7.5]	Ecological town (energy, 3R) [4.8]	Education on the recycling environment [9.2]
5	Established transport infrastructure making Bodaira (Zao) accessible [2.0]	Lively town teeming with sightseers [2.5]	A bridge between regions [1.7]	Effective utilization of hot springs and snow [1.4]

4) Tsukuba city (Ibaraki pref.)

Desired society in 2050

"Global-minded research and university town with an established low-carbon lifestyle"

- The citizens are living in a compact and smart town in well-organized collaboration among a variety of sectors (green house gas emissions will be reduced by 80% compared to today)
- An established lifestyle that supports the regional environment and cultural evolution based on scientific of thinking.
- Various occupations, in addition to researcher, are available for the next generation.
- Internationally compatible education is pervasive, and citizens are leading healthy and stress-free lives with ease of communication.

Results of group discussions (ordering of priority; AHP scores are shown in [ ])

	Group A	Group B	Group C	Group D
1	Social health policy [17.0]	Compact city plan [19.3]	Communities, education, work [10.0]	Scientific lifestyle make it stylish [15.0]
2	Energy [14.3]	Healthy and stress-free social life [16.2]	The environment [9.3]	The city makes collaborative efforts to reduce CO2, CFCs, CO [14.3]
3	Lifestyle Education Communication [7.5]	Clean energy and high efficiency [15.3]	Smart city [8.0]	Work-life balance [10.2]

	Group A	Group B	Group C	Group D
4	Eco-friendly food recycling and waste [4.6]	Eco-friendly public transportation and bicycles: “Give up my car” [6.3]	Sport and health [1.5]	Education (more efficient and flexible) [6.8]
5	Transportation Infrastructure [2.8]	International communication and education [1.7]		Local, natural, and organic food [1.8]

5) Nagoya city (Aichi pref.)

Desired society in 2050

“Urban life compatible with nature (wind, water, and greenery)”

- Realization of a disaster-tolerant and environmentally-friendly lifestyle, with effective use of wind, water, and greenery, inside and outside the urban area.
- Realization of internationally compatible education and cultural life — with a sophisticated taste for cultural assets and art — making Nagoya a well known metropolis around the world.
- Well-established cooperation between the local government and citizens enables the provision of energy, a recycling system, food, and water (including clean rivers).
- The public transport system, with wise use of automobiles, enables citizens to move to their work sites within 30 minutes, and move anywhere in the urban area within 15 minutes.
- Wide diffusion of welfare and medical services provides citizens with the environment for secure child-raising and centenarian longevity.

Results of group discussions (ordering of priority; AHP scores are shown in [ ])

	Group A	Group B	Group C	Group D
1	Disaster resistant city [21.0]	Solid basis of medical care [23.0]	Lifestyle in harmony with nature (wind, water, greenery) [22.0]	Substantial array of public transportation [19.0]
2	Rich array of public services [12.3]	Substantial level of education [17.0]	City where citizens lead eco-friendly lifestyles through collaboration [21.3]	Education and child raising [10.3] Science and technology, environment, and energy [10.3]
3	Charming city that attracts people from around Japan and abroad [8.2]	Improvement of energy, transportation, and infrastructure [7.3]	Comfortable urban life with healing [12.5]	Living, life, nursing care [4.9]
4	A model city for saving and creating energy, recycling, and reuse [4.7]	Conversion of lifestyle [4.6]	Wise car usage compatible with public transportation [7.6]	Recreational opportunities [1.8]
5	Beautiful Nagoya [2.0]		Comfortable, low-energy life [3.0]	

6) Tsuruga city (Fukui pref.)

Desired society in 2050

“Town full of vigor with affluent electric power”

- Industries related to nuclear power and research organizations are operating actively, and there is a positive job environment in terms of both quality and quantity.
- Tsuruga, as a town of electricity, is aiming at becoming an attractive town utilizing its affluent supply of electricity.
- A downsized town that is oriented toward safety and security and allows spiritually affluent lives across three generations. This compact town attracts people by its own merits.
- A substantial range of infrastructures (public transport, hospitals, education), backed up by the affluent supply of electricity, enables citizens to lead lives that value nature and historical heritage.

Results of group discussions (ordering of priority; AHP scores are shown in [ ])

	Group A	Group B	Group C
1	Town of electricity [19.0]	A town that cultivates diverse human resources [23.1]	Industry: based on nuclear power (employment) [6.0]
2	Improved job opportunities [10.0]	A town with well-established security [22.0]	Safety: security and safety [3.3]
3	A compact town where three generations live together comfortably [7.5]	Infrastructure building [16.5]	Living: urban planning/town [0.6]
4	A town where you can live with nature [6.3]	Busy and lively town [8.3]	
5	A town with a rich array of infrastructures [2.5]	Nuclear power related industries [1.9]	

7) Miyazaki prefecture

Desired society in 2050

"A society where you can live in affluence, with mutual independence and coexistence"

- Comfortable life, with a well-ordered environment for both working and staying healthy
- Seamless symbiosis between humans and nature, while maintaining independence.
- Well-organized separate areas (forest, farmland, residential area) are bustling with a variety of people leading various lifestyles.
- Ecological society that allows cooperation both within and beyond the region, conducive to eliminating alienation.

Results of group discussions (ordering of priority; AHP score is shown in [ ])

	Group A	Group B	Group C	Group D
1	Healthy and economical life [13.0]	Food [23.0]	Reinvention of rural energy [19.0]	Comfortable society both in terms of working and maintaining health [12.0]
2	Independent individuals support each other [11.0]	Area design [17.0]	Miyazaki as a health farm [10.3]	Society that allows independent but symbiotic existence of humans and nature [9.3]
3	Utilization and stable supply of local energy sources [5.7] Realization of zero-emission agriculture [5.7]	Human resource cultivation [16.3]	Town teeming with a variety of people (visiting sports enthusiasts, etc.) [9.6]	Ecological society conducive to eliminating feelings of alienation [8.0]
4	Construction of environmentally-friendly public transportation system [2.2]	New energy resources [11.0]	Green-region renovation (elimination of concrete buildings) [4.8]	Society that has attained such a level of ecology that ordinary ways of living automatically translate into further enhancement of ecology [1.5]
5		ICT [6.1]	Elimination of dependence on automobiles [1.9]	
6		Migration [3.9]		
7		Natural environment [3.7]		

8) Okinawa prefecture

Desired society in 2050

"An affluent society blessed with bright sunshine, the wide open sea, and an assortment of new energy sources"

- The lifestyle, tourism, and work aspects of Okinawa are all in harmony with its environment and gain the spotlight.

- An educational system that fosters independence and has a strong international flavor is established, and it produces material results.
- With full work and education options, and with traditional spirits maintained, Okinawa provides an environment in which you can lead an active life.
- Okinawa receives attention for its characteristic production and utilization of natural energy resources, such as deep-sea water, solar power, and solar heat.

Results of group discussions (ordering of priority; AHP scores are shown in [ ])

	Group A	Group B	Group C	Group D
1	A society in which citizens feel happy [17.0]	Community [15.0]	Work to link cities with agricultural communities (links between medicine, diet, and tourism) [18.0]	Utilization of deep sea water as an alternative to petroleum energy [25.0]
2	Preservation of the natural environment [15.0]	Energy [8.3]	International education, Okinawan style (increasing motivation) [14.0]	Utilization of a variety of natural energy in Okinawa receives widespread attention [16.2]
3	Energy-saving, safe living [7.0]	Health [7.6]	High technology, region-specific food products [9.9]	Steady conservation of native ecosystem has boosted tourism, and lifestyles became affluent [7.3]
4	Work-education cycle [6.4]	Education [7.4]	Fuel-free transport network covering a wide area [7.9]	Traditional spirit everywhere in Okinawa has gained recognition [4.6]
5	Energy utilization, Okinawan style [1.9]	Industry, tourism, employment [2.8]	Okinawa as an environmental theme park that gathers the world' s attention (tourism) [7.7]	Variety of lifestyles that allow family and friends to work together [2.1]
6			Realization of sustainable living and life, Okinawan style [2.3]	

4-2. Essential industries and services to make the future social model into reality

In the concluding workshop, many views were put forward, in terms of industries and services, aiming at the realization of regional ideal models of future society. The views are listed in Table 2-5, and graphically summarized in Table 2-6. The industries and services essential for the purpose described above are broadly classified into four categories: "Effective utilization of energy," "Regional model and social infrastructure," "Health care of body and mind," and "Emerging industries and services."

Table 2-5: The points that received recognition from other regions

1) Effective utilization of energy:

Region	Points mentioned
Shichinohe	[High diffusion ratio of new energy] ● Realization of new energy industry → EV town ● Subsidy to promote the introduction of new energy and energy saving.
Kazumaki	[High self-sufficiency ratio of food and energy] ● Self-sufficiency ratio for food: 180%; for energy: 160% ● High self-sufficiency ratios for energy and food ● Wind-power generation ● Biomass ⇔ manure ⇔ live stock – meadow, forest, dairy farming, alcohol (wine) ● Respectable achievements in introduction and development of various types of clean energy ● Local people's understanding of clean energy

Region	Points mentioned
Tsukuba	[A society with fewer cars] ● Promotion of bicycle use over automobiles ● “Give up my car”
Tsuruga	[Energy-source town: understanding of nuclear power generation] ● Citizen’s viewpoint toward the town embracing an energy-generation facility ● Community renovation focusing on the characteristics of the “electric energy town” ● Affluent town with the supply of nuclear power. Does the large number of out-migrants threaten the establishment of research facilities? ● Very high local understanding and expectations of the nuclear power plant ● Dependency on the electric industry is similar to Nagoya’s dependency on the automobile industry ● Self-contained town: local city that does not rely on other cities.
Miyazaki	[Utilization of new energy] ● Solar power, small-scale hydropower
Okinawa	[Energy farm] ● Energy farm ● Energy industry that considers the sea as a energy source ● Solar, wind, deep seawater, wave, and tidal power. CO2 fixation by marine biomass ● Approached leveraging the wealth of the natural environment ● Independence in terms of energy

2) Regional model and social infrastructure:

Region	Points mentioned
Shichinohe	[Rendering historical and natural heritage into tourism/service resources] ● Emphasis on the link with neighboring areas (e.g. Sannai-Maruyama) ● Route connecting Jomon ruins ● Highly attractive, magnificent nature ⇒ great tourist attraction ● Attentive preservation of nature ● Tsutsuji road aims to be Japan’s No. 1 attraction ● Approached nature conservation and consolidation of population [High value-added food industry and agriculture] ● High value-added food industry that takes advantage of the local specialty (i.e. snow) ● Secure and safe food supply ● “Agriculture with motivation”
Kazumaki	[High value-added agricultural product] ● Heightening of added value during the production process: shiitake mushroom production utilizing electricity ● Heightening of added value in agriculture by application of new technology
Kaminoyama	[Formation of regional community] ● Emphasis on kizuna (emotional ties) [Professionalization of guides] ● Professionalization of guides ● Professionalization of guides for regional development and cyclical form of education
Tsukuba	[Creation of internationally compatible town: acceptance of foreigners] ● Internationally compatible town ● A town highly responsive to changes ● A town that embraces foreigners as community members ● Foreigner’s stay
Nagoya	[Well balanced city design between urban functionality and natural environment] ● Emphasis on nature in the large city: city keywords include “wind, water, and greenery”. ● Well balanced link between urban functionalities and the natural environment ● Affinity to the river (water) ● Easy access to promotion locations (e.g. nature) ● Public relations approach for industries and local culture
Tsuruga	[Compact town: zoning] ● Safety and security in a compact town ● Zoning concept within the town ● A compact city where three generations can live comfortably. An approach to area zoning.
Miyazaki	[Invigoration of primary industry and collaboration with NPO] ● New “3K” (smart, profitable, and exciting) ● Primary industry: the approach of the local government to link each area to enhance the whole prefecture activities, and linkage strategy with NOPs. ● Self-sufficiency ratio of food: 246% (ranked top in Japan) ● Agricultural power, self-sufficiency ratio of food
Okinawa	[Design of town and community] ● Community oriented zoning: miniaturized version of a compact city

Region	Points mentioned
	● Car traffic is banned within the community ● ARUKU (walking) community ● Light-rail train ● Fuel-free transportation network ● New approach for community formation

3) Health care of body and mind:

Region	Points mentioned
Shichinohe	[Energy-saving oriented lifestyle] ● Morning-type sightseeing service
Kaminoyama	[Kurort: a stay-in-nature approach for health care and preventive medicine] ● An idea of rendering nature into an exercise course ● Preventive medicine by field-trekking approach (Terrainkur) and health food ● Geological environment and local resources (i.e. hot spring) serve to promote health and create local attraction. ● “Terrainkur” course ● A health promotion approach utilizing local resource (i.e. hot spring) ● Health resort therapy ● Medical care system without a hospital ● Spa therapy — a viewpoint toward longevity [Health related technology] ● New technologies inspired by the processes toward health promotion
Tsukuba	[Social evolution through the acceptance of overseas wisdom] ● Analysis form an international viewpoint ● Tsukuba is in the process of creating an international region through proactive acceptance of wisdom from overseas. ● Contact with citizens and students in the open laboratories ● Internationally compatible (common) education ● Opportunities to be exposed to science and technology [Creation of internationally-minded civic society] ● Courteous greetings, and respectful attitudes ● Permeation of “Tsukuba people” concept ● Local-people concept of “Tsukuba people” ● Preserved countryside environment --- Rich in spirit, and courteous attitude
Nagoya	[Sense of balance] ● Regional renovation balancing various aspects of the region ● Region with a sense of balance [Securement of comfortable life for citizens in a large city] ● Realization of a comfortable life for citizens in a metropolis ● Renewed attention to the magnitude of difference in regional characteristics between big cities and rural areas.
Tsuruga	[Town renovation toward intercommunication across three generations] ● Town renovation toward intercommunication across three generations ● A town that enables spiritually rich lives across three generations
Miyazaki	[Stabilization of intermediate and mountainous area] ● The group activities of volunteers (“Chu-sankanchi Moriage-Tai”) have the effect of preventing suicides, and promoting regional activation. ● Disaster-tolerant region — enlivenment of intermediate and mountainous areas ● The problem of the high suicide rate can not be resolved only by symbiosis with nature
Okinawa	[Community formation around large families: inheritance of culture and natural features] ● Community formation based on large families ● Inheritance of Ryukyu culture, and cooperation within the community

4) Emerging industries and services:

Region	Points mentioned
Shichinohe	[Subsidies according to the amount of CO2 absorption] ● Subsidy system for emission reduction ● Subsidy for CO2 absorption by the forest [Cutting-edge technology] ● Interesting concepts such as portable nuclear power, and agricultural robots.
Kazumaki	● Joint public-private ventures turned a profit
Kaminoyama	[Various purchasing benefits (Eco-points)] ● Introduction of various types “Eco-points” ● Insurance for preventive medicine ● “Agricultural product eco-points” to promote local production for local consumption ● “Health eco-points” system

Table 2-6: Industries and services conducive to the realization of the ideal regional social model

Industries and services conducive to the realization of the ideal social model	**Effective utilization of energy**	**Regional model and social infrastructure**	**Health maintenance of body and mind**	**New industrial service**
Related keywords	LCA, agricultural produce, logistics, food factory, ICT, compact city, etc.	Traffic, tourism, agriculture, family, local time, new "3K" (dirty, dangerous, difficult jobs), lifestyle, etc.	Health, Onsen (hot spring), sports, ICT, life style, etc.	High-value added agriculture, farmstay, health maintenance, educational hub, etc.
Shichinohe town (Aomori pref.)	□●	●	□	
Kazumaki town (Iwate pref.)	□●		□●	
Kaminoyama city (Yamagata pref.)	□		□●	□●
Tsukuba city (Ibaraki pref.)	□●	●	□●	
Nagoya city (Aichi pref.)			□●	□
Tsuruga city (Fukui pref.)	□●	□●		
Miyazaki pref.	□●		●	□
Okinawa pref.	□●	●	□●	

□: Industries and services mentioned as having priority in the regional WS, from the viewpoint of "regional life style."
●: Industries and services highly evaluated by the experts in science and technology from the viewpoint of having "potential for future evolution (industry)."

4-3. General discussion

The science and technology that are instrumental for the realization of each region's future social model, as well as the schemes for promoting them, are shown in Figure 2-30.

In all the target regions of this survey, the need for technical development for energy with zero CO_2 emissions was commonly mentioned. Also mentioned was the importance of integration with conventional technologies, as well as the development of technology management schemes and business models. To facilitate actual realization of these technologies, a detailed discussion is necessary on the institutional bottleneck that will impede the diffusion and utilization of them.

Who will take the lead in the processes toward realizing the ideal models in society? This is the most important issue to be discussed. To build a society wherein citizens live comfortably, an essential step of the processes consists of drawing up a regional model fully compatible with the environmental conditions of the region. For this purpose, a platform for consensus building must be set up involving the general public, and social infrastructure improvements will have to proceed. The improvement of environmental conditions according to the needs of many citizens requires a continued investment from public resources, and this, in turn, will necessitate the securing of financial resources by such measures as the creation of new industries and services to expand job opportunities, and the enhancement of value added products of the region.

The establishment of new industries and services requires, first of all, self-reliant effort on the part of the enterprising body, and a large-scale investment may be unfeasible for some regions. To construct a society with low environmental load, it is necessary to consider the introduction of a system that allows inter-regional CO_2 cap & trade to secure financial resources, as well as support, through investment and financing, for self-sustaining growth of new industries and services. Along with the continued regional effort to establish a self-reliant social infrastructure, in terms of both energy and food, collaborations between distant regions (for example, Tohoku and Kyushu), as well as between neighboring regions, should be considered proactively in the future. In the course toward the construction of a low carbon society, yet another challenge lies in providing the social foundation that embraces an aging society.

Figure 2-30: Science and technology relating to the emerging industries and services, and promotion measures to be taken

"Effective utilization of energy"

Related science and technology

- Full use of regional characteristics (industry, climate, geological features):
  — Biomass power generation (manure, forest)
  —Snow, cool energy, geothermal heat, underground geothermal energy
  —Ocean thermal energy conversion, tidal power generation, cool energy of deep sea water, algae utilization (fuel production, CO_2 fixation)
- Development of power grid networks and telecommunication networks. Advanced utilization of them.

etc.

Institutional requirements for promotion

1. Fund support, and preferential taxation
2. Subsidies for forest fixation of CO_2, self-contained systems of new energy and energy-saving. System building for inter-regional cap & trade.

etc.

	Relevant topics in the 9th Delphi survey (Forecasted years of social realization)
Industries and services that utilize waste (from forestry and stockbreeding) for the generation and selling of electric power.	A co-production process for bio fuels and hydrogen through biomass fermentation and gasification (2025)
	A co-production system of chemicals and energies under biorefinery (2028)
Plant factories that utilize water and new energy	(a proposal that was not covered by the Delphi survey)
Utilization of snow and cool energy for the cool storage of vegetables.	(a proposal that was not covered by the Delphi survey)

"Regional model and social infrastructure"

Related science and technology

- Transport system for the elderly population, system for road accident prevention, high-speed transport network, advanced use of GPS, and public transport system with low environmental load.
- Urban planning, housing technology compatible with heavy snow.
- Energy utilization of rivers and snow in residential areas

etc.

Institutional requirements for promotion

1. Regional investment in public transport
2. Car sharing — electric vehicles
3. Improvement of public transport system: consolidation and integration.

etc.

	Relevant topics in the 9th Delphi survey (Forecasted years of social realization)
Transportation and related areas	Promotion of a driver assistance system not only to prevent rear-end crashes and collisions due to sudden encounters but also to forecast any trouble with the engine and/or tires by using various sensors installed in the car (2023)
Electric power and related areas	Distributed energy system including garbage processing technology that effectively uses household waste while promoting resident participation (2020)
Infrastructure and related areas	In the case of downsizing the urban area because of population decline, a compact infrastructure plan will be constructed in view toward a natural symbiotic urban area with due consideratio to sustainability of the water cycle, ecosystem and lifestyles (2027)
Management	Technology and a legal system for making the most of natural and renewable energy by region or district and realizing, for goods and material circulation, local production for local consumption will be developed (2027)

“Health maintenance of body and mind”

Related science and technology

- Health management technology utilizing ICT (e.g. Web doctor)
- Medical care system based on health data: elimination of the need for hospitals
- Wellness medicine, sports medicine
- Rehabilitation technology

etc.

Institutional requirements for promotion technology

1. Self-reliant effort for maintaining the health of body and mind, including the application of the insurance system to preventive medicine.
2. Tax benefits for the businesses that provide health care (body and mind) services

etc.

	Relevant topics in the 9th Delphi survey (Forecasted years of social realization)
Web doctor	(a proposal that was not covered by the Delphi survey)
Urban renovation technology (normalization of urban area)	Promotion of high-quality and long-life block planning in urban and rural areas, for the formation of a community in which people from various generations can interact, and for the improvement of quality of life (QoL) within the block and cluster as a result (2025)
Utilization of thermal energy from hot springs	(a proposal that was not covered by the Delphi survey)
Wellness medicine, sports medicine	(a proposal that was not covered by the Delphi survey)
Rehabilitation technology	(a proposal that was not covered by the Delphi survey)
ICT supported health management technology	(a proposal that was not covered by the Delphi survey)
Medical care system based on health data: elimination of the need for hospitals	(a proposal that was not covered by the Delphi survey)

“New industries and services”

Related science and technology

•Enhancement of added values in agricultural products
•Element technologies for utilization of natural-resources (snow, deep-sea water…), small electric vehicles for agricultural use, environmentally-friendly logistics, and plant factories.
etc.

Institutional requirements for promotion

1. Communication from the regions for the widespread knowledge of ecological health services and local tourism
2. One-stop service for production, logistics, and sales
3. Cultivation of human resources capable of communicating with the customers
4. Regional development of vehicles (e.g. a lightweight truck), and the measures to support endeavors such as public purchase and tax benefits.

etc.

	Relevant topics in the 9th Delphi survey (Forecasted years of social realization)
Life, education, and culture	An evaluation method for local environment preservation activities, including traditional festival and cultural behavior, which is impossible to evaluated with economical indicators (2025)
Management	Market economy methods including mitigation banking (biodiversity offset banking) that offsets the environmental load on urban areas by the rehabilitation and maintenance of natural resources in rural areas (2026)
	Promotion of a support framework for such matters as U-/I-/J-turn and multi-habitation among urban and rural areas to maintain conservation of farmland and other lands (2022)
	The citizen-driven "New Public" leads the regional strategy and carries out the regional management for the maintenance of security, safety and vitality of the region (2024)

Appendix A: Priority items in science and technology for Japan

- Year: “Tech”: forecasted time of technological realization (somewhere in the world); “Social”: forecasted time of social realization (in Japan)
- Importance: “W/J”: important for Japan and the rest of the world; “J”: important especially for Japan; “Important for the world” and “Low importance/priority” columns are omitted because of a low selection rate (<40% in all topics)
- Leading sectors (tech/social) (Sectors that will pave the way to technological/social realization): “Uni”: University; “PRO”: public research organization; “Ent”: Enterprise in the private sector (including NPO); “Govt”: Government; “Coll”: collaboration among multiple sectors.
- Level of “Importance” and “Leading sectors”: “++”: indicates a selection rate over 70%, and “+”: indicates a selection rate over 40% but less than 70%.
- For each category, the topics are arranged in the order of the year of social realization (from earlier to later).

< Energy, environment, and resources >

Utilization of non-fossil energy

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Leading sectors (tech)					Leading to sectoris (social)					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
5-11: Technology for the utilization of ocean energies such as the wind, waves and tides on a commercial basis.	2016	2024	++			+	+					+			
8-62: Gasification techniques for power generation or synthetic fuel production technology using unused biomass and waste that reduces dependence on fossil fuels.	2016	2024	++		+	+	++					++	+		
1-42: Home-use electric power storage cell technology, with a price tag of one million yen or less, that can stably cover approximately 90% of the necessary electric energy by integrating photovoltaic generation and secondary cells for All-DENKA house (a house in which electricity fully covers home-use energy).	2019	2026	++				++					++			
6-20: A large-scale thin-film solar cell with a conversion efficiency of 20% or higher.	2019	2027	++				++					++			
9-26: Low-cost and large-area thin-film solar cells with a conversion efficiency of 20% or higher.	2019	2027	++		+	+	+					++			
6-04: Technology to reduce waste dramatically through the nuclear transformation of radionuclides in high level waste.	2020	2028	++			+	+					+			
6-19: New material technology for solar cells leading to higher efficiency than silicon or GaAs.	2021	2029	++		+	+	+					++			
1-44: Solar cells with energy conversion efficiency of 60% or more.	2023	2030	++		+	+	+					++			
9-45: Materials with high energy conversion efficiency, high energy capacity, and low environmental load to utilize renewable energy sources.	2021	2030	++		+	+						+			
7-48: Implementation of utilization of solar energy at optimal places on a global basis, and energy interchange between the place of production and place of use.	2022	2031	++					+				+			

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Leading sectors (tech)					Leading to sectoris (social)					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
9-34: Technology to produce hydrogen from water and sunlight with an energy conversion efficiency of 5% or more.	2024	2031	++		+	+					+	+			
6-01: Next generation light water reactor standard technology with such merits as the capability for enriched fuel over 5%, 80-year durability, and no location restrictions thanks to the adoption of seismic technology.	2026	2034	+				+					+			
7-53: Innovative technology that enables the diffusion of the use of non-fossil primary energy such as solar energy on a global basis.	2025	2034	++			+	+					+		+	
6-06: Geological disposal technology for high level radioactive waste.	2022	2034	++			++					+		+		
5-44: Solar photoelectric power generation plants in space that transmit electricity to the ground via microwaves or lasers.	2027	2037	+			++					+				
6-02: Fast breeder reactor cycle technology.	2029	2038	+			++					+				

Effective conversion/utilization of energy

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
11-15: Various incentive systems to reduce the peak electric power demand facilitate the leveling of electric power demand and the effective utilization of resources.	-	2019	++		-	-	-	-	-			++	+	+	
2-61: More than half of the white goods (refrigerators, washing machines, microwave ovens, rice cookers, and air conditioners, etc.) are connected to home networks in 30% or more of the households in Japan.	2015	2022					++					++			
7-03: Technology for the formation of a material cycle by utilizing natural and unused energies by a community unit.	2018	2024	++					++					+	+	
1-52: Smart grid technology that can improve power efficiency and reduce the total Japanese power needs by 20%	2019	2026	++			+	+	+				++	+	+	
1-51: Component devices using novel materials such as SiC or GaN that allow a power density of 100 W/cc or more.	2019	2026	++				++					++			
12-58: Technology and a legal system for making the most of natural and renewable energy by region or district and realizing, for goods and material circulation, local production for local consumption will be developed.	2020	2027		+		+		++					+	+	
1-18: Network nodes for which power consumption will be 1,000 times as little as present consumption through nanophotonic technology.	2020	2027	++		+	+	+					++			
12-59: A material and energy circulation system will be constructed on a prefectural or larger administrative bloc levels, based on material correlation of biomass energy from forest resources, animal excrement, and unused material from cereal, as well as on that of by-products and functional materials.	2020	2028	+	+		+		+					+	+	

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
8-57: Building of a recycling society using materials, energy and water efficiently within the community unit.	2021	2030	++			+		+					+	+	
9-22: A thermoelectric power generation module with a conversion efficiency of 10% or higher.	2022	2031	++		++	+						+			
3-55: Development of a nanoscale voltage separating device for an enzyme reaction fuel cell using bio organic substances, and expanding the scale of such fuel cells through integrating them.	2025	2032	+		++	+				+		+			
3-54: Highly efficient energy conversion technology that utilizes motor proteins (molecular motors) that convert chemical energy to mechanical energy.	2028	2035	+		++	+				+					
2-26: A Green ICTS system that reduces the energy necessary for the transmission and storage of information to one-millionth of that in 2010 (normalized by the amount of information handled).	2030	2036	++		+	+	+					+			

Industries in a recycle-based society

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
4-85: Industrialization of a consistent medical waste treatment system including recycling.	2016	2020	+	+		+	+	+				+	+	+	
10-62: Solar cell system that is developed considering recycling and reuse with a low environmental load upon disposal.	2017	2024	+				+					++			
9-19: Technology for mass-producing fuel and bio-plastics from non-petroleum materials by using the function of plants or microorganisms	2018	2025	++		+	+	+					++			
10-63: A recycling production system unifying the processes of the "input of resource → design and production → use → disposition" and the "collection → separation → resource recycling."	2018	2025	++				+					++			
10-19: Comprehensive design methodology for total optimization, from the overall picture of the life cycle, from design and production to disposal and recycling, the overview of the global supply chain, and a product series that can flexibly correspond to the variety of customers' needs.	2017	2025	+		+		+					++			
3-52: A biocatalyst showing productivity equivalent to or greater than that of a chemical catalyst useable in industrial production.	2019	2026	++		++	+	+			+	+	+			
7-16: Technology for production of fuels and bio-chemicals on a commercial base by using plants and microorganisms as biomass cascading.	2019	2028	++			+	+					+		+	
3-51: More than half of the chemical polymers made from petroleum become renewable biomass resource-based products.	2022	2030	++		+	+	+			+	+	+			
8-58: Promotion of eco-factory and low-entropy technology that reduces the environmental load by 50% while considering the life cycle of products from production to disposition and the ecological influence of each industry.	2021	2030	++		+	+	+					++	+	+	

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
10-02: Product and material manufacturing technology for safe, clean and energy-efficient mass production using knowledge of the mechanism of nature and organisms.	2021	2030	++		+							++			
12-50: A unified database (extending over business units such as railways, roads, electric power, and local public entities) of infrastructure investment history and deterioration data will be constructed to allow management of infrastructure assets at entire city and regional levels.	2018	2025		+		+		+					+		
12-52: Semipermanent recessed sensor technology notifying the degree of deterioration, lifespan, and time for replacement of structures will be disseminated.	2019	2026	+		+	+	+					+			
12-56: A system for evaluation of design systems, structural performance, and asset value, allowing the functional extension, renewal, removal, and reuse of large-scale structures will be disseminated.	2019	2027	+	+	+	+	+					+			
12-51: High-precision modeling of deterioration environments based on design and construction technology for infrastructure deterioration prevention, repair, and establishment will become feasible, and sufficiently precise life-cycle management and asset management will come into practical use.	2019	2025	+	+	+	+					+		+		
3-38: Technology for crop production and green technology in deserts achieved by improving the crop's adaptability (salt tolerance, drought tolerance, cold tolerance) and controlling its growth.	2020	2028	+		+	+				+	+	+			
3-56: Achievement of low-cost agriculture/forestry and rural communities oriented towards zero emission by using local agricultural and forestry resources and organic wastes.	2019	2027	+	+		++					+		+		
3-57: Biological crop protection methods that reduce the use of synthetic chemical pesticides and fertilizers by 50%.	2018	2026	++		+	++					+	+			
3-49: Growth regulation of crops and trees based on the clarification of the mechanism of biosynthesis, transport, and receptor-mediated signaling by growth regulators in plants.	2020	2029	++		++	+				+	+				

CO_2 emission reduction, CCS

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
8-17: Introduction of environment education that has an effect of change in citizens' lifestyles through a specific behavior such as practical action to reduce household emissions of CO2.	-	2018	++		-	-	-	-	-				++	+	
10-65: Comprehensive and objective evaluation indices that replace CO2 as an indicator for the environmental load of energy and resource consumption, production processes (plants) and products, and measurement techniques for such indices.	2017	2023	++		+	+					+				

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
5-32: Establishment of technology capable of dissolving CO2 in water or fixing CO2 under the ocean floor.	2018	2026	++			++					+				
7-39: Technology that gives economic incentives to geologic sequestration of CO_2, such as the development of energy resources from oil layers, gas pools, and coal beds by CO_2 injection, and recycling of sequestrated CO_2.	2019	2027	++			+		+				+			
7-35: Practical use of power generation, hydrogen production, and synthetic fuel production by gasification incorporating CCS, with economic efficiency, which is applicable to hydrocarbon resources such as coal, heavy oils and biomass.	2020	2028	++			+	+	+				+		+	
7-36: Storage and management technology concerning the deep brine layer for the expansion of the potential of geologic sequestration of CO_2.	2020	2028	+			+		+						+	
9-46: Materials for carbon fixation so as to reduce CO_2	2021	2030	++		+	+					+	+			
9-33: Membrane separation techniques to produce hydrogen from coal without emitting CO_2 into the environment.	2023	2031	++		+	+						+			

Untapped resources, recycling

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
7-28: Financially viable selective separation and recovery of rare metals from Waste Electrical and Electronic Equipment (WEEE) and incineration ash.	2015	2020	+	+			+					++			
7-23: Establishment of a regional water reclamation system dealing with the uneven distribution of water by utilizing an economical and practical seawater desalination technology using reverse osmosis membrane, and purification and recycling technology for contaminated water.	2014	2020	+				++					++			
7-04: Technology utilizing medium and low temperature geothermal sources by binary power generation and heat pumps.	2015	2021	+	+			+					++			
10-59: Safe and low-cost storage system for general waste, such as home appliances including rare metals for which reuse and efficient disposal methods have not yet been developed, in a condition enabling future use.	2017	2023	+	+		+	+					+		+	
8-59: Technology to reasonably recover and use rare metals from urban mines, such as general and industrial waste, incinerated ash and fly ash, to supply more than 50% of the required amount of many kinds of rare metals.	2018	2024		+		+	++					++			
10-61: Efficient application technology for the unused thermal energy that is generated intermittently.	2018	2025	++		+	+	+					+			
10-60: Technology to efficiently convert low-grade thermal energy, which is hard to use from the viewpoint of exergy, to high exergy.	2019	2026	+		+	+	+					+			
5-12: Technology for mining ocean floor resources such as hydrothermal deposits on a commercial basis.	2020	2027		++		+	+				+	+			

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
8-60: Promotion of a design, production, collection and reuse system that recycles 90% or more of (thermal, chemical and material) products based on legislatively-defined product liability related to the collection and disposal of waste.	2019	2027	+	+			++					+	+		

Commuting, transport system

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
2-23: A system under which 80% of office work can be changed into distance work in Japan, that is, where a person can work together with his/her colleagues at different offices with the same communication as if they were at the same office all the time.	2017	2024	+				++					++			
4-59: Design techniques for medical communities and medical cities (such as the residential area for elderly persons)	2018	2024		+		+	+	+				+		+	
1-43: Long life and highly reliable electric vehicle battery technology with high energy density (approximately 3 times as dense as at present) that enables electric vehicles to have a total driving distance on a single charge that is equivalent to that of current gasoline vehicles (approximately 500km)	2018	2025	++				++					++			
2-24: A virtual office system that can halve the number of workers in Japan compared with the present real office.	2018	2025	+				++					++			
6-41: Low-cost secondary cells for vehicles (such as cars) (specific energy: 100 Wh/kg or more, specific power: 2000 W/kg, and specific cost: 30-thousand yen per 1kWh or less).	2019	2025	++				++					++			
11-16: Alternative technology for energy intensive transportation devices for humans to cope with global warming and the escalation of environmental problems.	2018	2026	++				+					+		+	
12-46: Development of a next-generation environmentally-friendly ship (green ship) with 50% less CO2 emissions and approx. 80% less NOx emissions than present ships.	2019	2026	++				++					++			
12-42: Development of a system to reduce by 50% the time, cost and environmental load at each node that links a railway and road, road and port/airport as well as a railway and port/airport so as to improve the efficiency of freight transportation between cities.	2020	2027	+	+		+	+	+				+	+	+	
9-32: High efficiency fuel cells for vehicles using no rare metals.	2020	2030	+		+	+	+					++			
2-53: Automatic driving technology for automobiles with a special lane that will enable the current usage efficiency of highways to triple.	2020	2031	+			+	+					+	+		

Observation, monitoring, simulation, and forecast

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
8-42: Analyses of the current status and the mechanism of the natural emission, absorption and fixation of greenhouse gas.	2018	-	++		++	++				-	-	-	-	-	-
4-61: Elucidation of biological effects of micro-pollutants in the environment.	2019	-	++		++	+				-	-	-	-	-	-
4-63: Prediction of the risk of infectious disease outbreaks, enabled by the progress in modeling and simulation technology for large-scale systems such as the ecosystem and environment.	2018	2025	++		+	+		+		+	+			+	
5-02: Global Earth Observation System that is capable of identifying greenhouse gasses and the density of air pollutants within a 5 × 5 × 1km frame over land, and a 20 × 20 × 4km frame over water.	2020	2027	++			++					++				
5-01: Future modeling over the next 50 to 100 years for the purpose of grasping the CO2 balance in the global atmospheric layer including the ecosystem and living environments of human beings as well as the changes of water circulation.	2020	2027	++		+	++					+				
12-10: Quantitative forecasting of the impact on nature (topography, geology, groundwater, plants and animals, etc.) caused by development becomes available, and the impact of certain development projects will be evaluated based on a simulation considering the scale of the project, alternative options, mitigation measures, and speed of nature restoration.	2019	2027	++		+	+					+		+		
5-03: Global Earth Observation System that is capable of identifying the vapor content of the atmosphere, the wind vector, and the amount of cloud cover arising thereby within a 5 × 5 × 1km frame over land, and a 20 × 20 × 4km frame over water.	2020	2027	++			++					++				
8-23: Forecasting technology for the future global environment on a time scale of several decades based on a global system model that simultaneously takes into account the material cycles within the atmosphere, oceans and land.	2020	2028	++		+	++				+	++				
5-22: Wide-area observation techniques for ocean floors to clarify the global balance of heat and CO2.	2022	2029	++		+	++					++				
2-30: A system to predict conditions of global weather, oceans, environment, ecosystems, epidemics, economics, and human activity through a total simulation based on real-time data can tackle unknown global crises.	2022	2030	++		+	+					+				

Evaluation, consensus building

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
7-57: Methodology for building international consensus on the cooperation in and transfer of technologies related to the environment, such as energy savings between developed countries, emerging countries and developing countries, so as to bring national interests, regional interests, and global interests to fruition.	2019	2025	++			+			+				+		+
11-37: A governance structure that monitors, manages, and coordinates within the world-wide framework beyond the framework of each national government's administration will be established to cope with such global issues as excessively speculative money, global warming and exploiting factories.	-	2025	++		-	-	-	-	-				+		+
8-20: Systems to support the relevant governments to make a rational political decision by enabling them to assemble and analyze various scientific knowledge, opinion and evaluation, and then recognize and understand the overview of the problem in cases of the global environmental issues such as climate change.	2020	2027	++			+			+				+		+
11-55: A coordinated decision-making system involving various stakeholders on the basis of use of a knowledge information platform, such as a database and a knowledge base related to the environment.	2019	2027	++		+		+					+			
11-57: In the context of risk management techniques, a scheme for long-term impact assessment to evaluate the influence of artificial and natural materials and systems on health and the environment will be established.	2019	2028	++		++	+				+	+				

<Topics related to health and medical care>

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
3-27: Elucidation of the pathophysiology of cancer metastasis.	2019	-	++		++	+				-	-	-	-	-	-
3-03: Technology for identification and functional analysis of the material interaction within a cell or between the inside and outside of the cell.	2018	2025	++		++	+				+		+			
3-02: Technology for molecular imaging in the body with the precision of a single molecule.	2019	2027	++		++	+				+		+			
3-09: Technology that predicts in a detailed manner biological activity, including the interaction between proteins, interaction between protein and DNA or RNA, and interaction between protein and synthetic compounds, from the higher order structure of protein.	2019	2028	++		++	+				+	+	+			
3-07: Technology that analyzes the conformation of protein, which is in a functional state in the body, in a dynamic and detailed manner.	2023	2032	++		++	+				+	+				

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
3-34: Technology for regenerative medicine using iPS cells.	2021	2032	++		++	+				+	+	+		+	
4-15: Systematic prevention and treatment methods for dementia that inhibits the decline in elderly people's brain functions.	2024	2033	++		++	+				+	+				

< Others >

Infrastructure management (including IT infrastructure)

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
2-01: In the system providing various services to various users by flexible connection of more than a hundred million computers, efficient and semi-automatic technology that builds stable services without any system failures is established.	2018	2023	++				++					++			
2-28: An information traceability system under which an electronic ID given to contents at time of the information source is maintained without being erased or altered, and thereby stolen or scattered information can be tracked easily.	2017	2024	++		+	+	+					+			
12-52: Semipermanent recessed sensor technology notifying the degree of deterioration, lifespan, and time for replacement of structures will be disseminated.	2019	2026	+		+	+	+					+			
2-02: In the system providing various services to various users by flexible connection of more than a hundred million computers, an advanced autonomous service creates new value-added information or new functional services from existing functions and services or from the group of data lying in such services.	2020	2027	++				+					++			

Crisis management, disaster control

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
12-16: Establishment of real-time damage recognition and forecast technology enabling the national and municipal emergency operation center to take emergency measures immediately and effectively in the case of a large-scale natural disaster that requires prefecture-level measures.	2018	2024		++		++		+					++		

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
12-13: Nation-wide high-precision observation systems for the atmosphere, hydrosphere and geosphere will be established to prevent harm to humans caused by large-scale natural disasters (floods, landslides, debris flow, avalanches, etc.) caused by some weather phenomena (precipitation, typhoon, heavy rain, snowfall, etc.) requiring prefecture-level measures, enabling the alarm, evacuation, and control based on the prediction of (approx. 1 hour in advance) the disaster.	2019	2027	+		+	++					+		+		
2-30: A system to predict conditions of global weather, oceans, environment, ecosystems, epidemics, economics, and human activity through a total simulation based on real-time data can tackle unknown global crises.	2022	2030	++		+	+					+				

Safety in life

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
4-42: An intelligent communication style living environment system including life support robots for elderly persons and disabled persons.	2019	2027	+		+		+	+				+		+	
2-29: A world wide traceability system covering most of the food products.	2019	2028	++				+					+			
2-31: Intelligent robotic technology that enables families and relatives to provide livelihood support to aged and handicapped people safely by remote control from a distance; the robots will be intelligent enough to avoid the risks that a teleoperator is unaware of.	2020	2028	+		+	+	+					+			

Human resource cultivation, mobility, diversification

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
11-32: A support system enabling staff to reuse and learn about the judgment process, skills and know-how of skilled staff, through the clear demonstration thereof.	2016	2021		+			++					++			
11-34: A social environment enabling women to balance marriage, birth and child care with work to promote their social involvement (for example, 30% of listed companies will have a day-care center for children) will be realized.	-	2021		++	-	-	-	-	-			++	+		
11-6: Along with the improvement of global management abilities premised on foreign cultures, faculty development programs will be carried out to understand the history, culture, language, legislation system, value system and so on of foreign countries.	-	2021	+	+	-	-	-	-	-			+			

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
11-31: Human resources will be mobilized according to changes in society and economics against the backdrop of the spread of the recurrent education for job training in graduate schools or later.	-	2022		++	-	-	-	-	-	+		+			+
10-68: Education system to train engineers who can rationally improve design in a more upper-stream phase than the conventional design process intends, and to continuously develop their ability.	-	2022		++	-	-	-	-	-	+		+			+
11-7: A globally networked human resource management system will be established, and it will help high-level experts to transfer freely beyond borders between countries.	-	2022	++		-	-	-	-	-			++			

Base technology, frontier technology

Delphi topic (Front numbers represent ID (panel-topic number))	year		Importance		Sector leading to tech realization					Sector leading to social realization					
	Tech	Social	W/J	J	Uni	PRO	Ent	Coll	Other	Uni	PRO	Ent	Govt	Coll	Other
9-3: New functional materials made of complex heterogeneous materials through nano-scale control of structure and interface.	2017	2023	++		+	+						++			
9-4: Industrial processing technology for 3-dimensional nano-scale integration.	2018	2025	+		+	+	+					++			
9-2: Industrial technology to control nanostructures of sizes of 10nm or less using self-assembly.	2019	2026	++		+	+						++			
9-16: Manufacturing technology that uses nano-order self-assembly techniques.	2019	2027	++		++	+						++			
5-57: Japanese-made highly reliable (high robustness) and competitive (cost-minimization, microminiaturization, and weight-minimization) space equipment (for space transportation and spacecraft, etc.)	2017	2022		++		+	+				+	+			
5-64: Radical technical measures to counter the debris problem (development of debris-free space systems, collection or disposal by injection into the atmosphere of debris already remaining, etc.)	2023	2032	++			++					++				
5-60: Japan's own manned space system (manned launch vehicle, manned spacecraft)	2024	2033		+		++					++				

Appendix B: Scenes in future daily life

* The numbers shown in the parentheses indicate the Delphi topic ID (i.e. panel-topic number). The corresponding topics are listed in NISTEP REPORT No. 141.

A society in which various diagnostic technologies and systems are incorporated in daily life and health maintenance by individuals has started to prevail

Eiko Morimoto was watching a morning news show, when she suddenly got a severe headache and screwed up her face. Her husband, Koichi, looked at her anxiously. Since Eiko's stroke several years ago, which left her right arm and leg crippled, she has always been careful about her health so as to avoid another stroke, and has received home care support for daily life. Koichi suggested that Eiko should have an examination just to be safe, and accompanied her to a hospital in the city.

"The results of your examination show no abnormalities," said Dr. Honda, the physician who examined Eiko, with a smile on his face. "The temperature has been unstable over the last few days, so you may feel a little sick, but I don't see any concerning symptoms." Honda's remark eased Eiko's anxiety about a relapse. Dr. Honda himself felt relieved too, seeing Eiko leave the examination room with Koichi. He turned off the high-definition tablet terminal displaying electronic medical records and left the room. This was the last outpatient examination of the day for him. Dr. Honda decided to read the latest electronic medical journal before going home.

It has been several years since Dr. Honda obtained his medical license, finished his clinical training, and started working for this hospital. At first, he had his hands full examining patients' diseases, but recently he has been feeling that he has become calm enough to face patients. Medical students acquire skills to communicate with patients at university, but it is rather difficult to put such skills into practice. Experience needs to be accumulated. Dr. Honda learned from talking with his senior doctors that the education he received while he was a student and then an intern was quite different from that for those senior doctors. Communication methods for doctors to use when talking to patients or their families were not included in the curriculum for medical courses in those days. Dr. Honda still remembers an experience during his university days when he was deeply impressed by the preaching of a famous Buddhist monk that he listened to as a part of his medical ethics education(4-83). Through sincerely considering what life and death mean, he thought that he could foster morals as a doctor who will always face the border between life and death.

The era of "Medical Breakdown" referred to by senior doctors is an old story for Dr. Honda. When the shortage of obstetricians, pediatricians, ER doctors and doctors engaged in regional healthcare was a problem, doctors were forced to bear a heavy burden, pressed by extremely hard daily work. Senior doctors say that it was difficult to find a balance between compensation, work load, and accomplishment as a specialist.
However, at present, medical service fees have been revised so as to better reflect the reality of the medical front and doctors' medical practices are now evaluated properly. The medical service fee system has been established whereby the State guarantees compensation for safe and secure medical treatment (4-70).

Furthermore, the original Japan Medical Standard system was established (4-71) and medical treatment is now often expressed with the term "medical social system that enables the optimum management of quality and resources" (4-72). In fact, imbalances, such as the concentration of doctors in urban hospitals, have been corrected gradually, and the equalization of healthcare has been progressing. Co-medical manpower has been strengthened and hard work at the medical front is being reduced.

Medical safety education, using experience-based medical treatment simulation technology, has been enhanced (4-84) and citizens' sense of trust in doctors and medical institutions has been growing. Doctors, less busy than before, now have more time to talk with each patient. Dr. Honda himself reaffirms that good communication strengthens ties between doctors and patients. Eiko, who he examined a little while ago, and her husband Koichi, who always accompanies her, both looked nervous at first. They usually go to their personal doctors in their neighborhood and seldom visit the city hospital where Dr. Honda

works. They said that they felt awkward at first and could not talk frankly to doctors in such a large hospital.

As a result of the advancement in regional healthcare systemization technology, the home-care and hospital care that Eiko receives are connected through a seamless and close alliance (4-78). In order to create a system to "treat patients comprehensively in the region," the medical information network is indispensable. Such network functions in a truly effective manner when each household makes its utmost efforts and supplementary public and private nursing care services are optimized. In terms of technology, the lifelong regional Electronic Health Record system was introduced and accelerated the move towards integrated healthcare focusing on patients (4-80).

The dissemination of electronic medical records prompted the shift to personal medical history management by patients themselves, and examination results and medication information can be shared among all medical institutions upon obtaining consent from patients. Based on such information, a new trend in the form of the "health management agent" business started between patients and medical institutions (11-17). Information on the treatment Eiko received from her personal doctor has also been transferred smoothly to Dr. Honda at the city hospital, and he could confirm her medical history and health conditions immediately, which means he could provide proper treatment. The computerization of medical information also enables doctors to inspect examination result details visually, using moving images. This is also a merit in making a diagnosis. On the other hand, patients' personal doctors can also obtain and share information on treatment at large hospitals. The other day, Koichi said to Dr. Honda, "Patients are no longer as motivated as before to go all the way to large hospitals. We can receive healthcare of the same quality even in our neighborhood."

The direction of Japan's healthcare has changed dramatically in the last twenty years. Rather than passive healthcare that starts after patients become sick, preventive medicine with careful preparation has come to be emphasized. This trend has spread wide, not only among aged people, but also among younger generations. Firstly, this change is largely owing to "ubiquitous computing technology" that supports the enhancement and maintenance of health in daily life with software, such as through calorie counting and exercise intensity calculation (1-16). Thanks to the coming of the ubiquitous age, patients can access necessary medical information at their convenience. Citizens feel more familiar with healthcare and their interest has grown significantly.

As health data is recorded automatically on a daily basis by various health check equipment with interlocking functions, individuals can keep up-to-date with the general conditions of their own life, health, and work. Eiko also obtains various pieces of information so that she can maintain healthy blood vessels in her brain, while Dr. Honda can give her appropriate advice on her daily life (2-05). Furthermore, in order to reduce Eiko's risk of contracting a lifestyle disease in general, Dr. Honda provided medical guidance based on her biomarker examination results (4-50) and judged the risks of contracting diseases through genomic information (4-51). Family medicine education on lifestyle diseases and aging has widely spread (4-81) and the possibility of Eiko contracting a serious disease unexpectedly in the future is quite low.

However, not all diseases can be predicted. Some more time is required to create a system to accurately predict the risk of cancer or other intractable diseases by using biochips (3-18) or conducting early diagnosis and health management based on omics information and past health check data (4-46). Eiko is also instructed by Dr. Honda to carefully check her health conditions every day just in case.

Regarding the emergency medical system, a regional healthcare system that enables prompt and proper response has been established and regional disparities have been alleviated (4-66). The growth of technology for designing medical societies and medical cities (4-59) has been rapid and prominent. Nevertheless, there are still areas, such as mountainous regions, where transportation systems and other daily-life infrastructure are not sufficient. Koichi's father, who is old and bedridden, is in one of such underpopulated areas, but his care worker says that they feel no particular inconvenience as a remote healthcare system utilizing information technology and a distribution system to deliver necessary medicine and dietary supplements have been developed (12-20). However, depopulation cannot be stopped and healthcare in such areas surely faces the problem of high costs.

It is expected that the remote healthcare system will be further enhanced in the future and doctors will be able to see patients in remote areas, who cannot come to hospitals, in a manner as if they are directly facing each other. An innovative

remote system that enables the doctor to feel like he/she is placing a stethoscope on the patient and smelling the patients' breath (2-19) was developed and is soon to be commercialized, but no matter how advanced the technology is, the connection between doctors and patients should not be ignored, and doctors' communication skills may become more important. Various pathological mechanisms are also being clarified in the field of mental health (3-25). Response to childhood school refusal and learning disabilities (4-28) and early diagnosis of mental diseases (4-26) have been developed, but the most important matter is the connection between doctors and patients.

After leaving the examination room, Dr. Honda dropped in at his office in the hospital. He used the PC there to inspect the latest research reports on regenerative medicine published in an electronic medical journal. Much is expected of regenerative medicine as a means to not only cure diseases but also to recover bodily functions damaged in accidents. One of Dr. Honda's colleagues serves concurrently as a professor and a clinician, and actively continues research under an international research consortium.

Full-scale regenerative medicine will soon be realized. The ethical guidelines for clinical application of regenerative medicine (4-69) have already been shared among healthcare workers. The director of the hospital, who hired Dr. Honda, said that reconstituent blood vessel prostheses using degradable scaffolding materials such as polylactate (9-38), biocompatible materials with almost the same functions as human bones (9-39), and other new technologies will soon be adopted in the medical front. Dr. Honda himself is engaged in test research in clinical practices so as to ascertain the applicability, as general medical treatment, of the technology to cure diseases by inducing stem cells, including iPS cells, to functional cells while avoiding the risks of canceration (3-35).

In the process of developing regenerative medicine, it is essential to harmonize bioethics and research activities. Discussions among a wide variety of members of the general public (4-74) have been underway and efforts have been made to build consensus among people concerning regenerative medicine. Dr. Honda has actively participated in local meetings and workshops, as well as academic meetings, with the aim of translating the opinions of the medical front. He is very passionate about the medicine of the new era.

A society where individuals can use various types of energy selectively based on their comprehensive evaluation of value and can feel that they proactively contribute to global warming prevention and environmental preservation

It is no longer surprising to Eiji that his mail box is full of job offers again this morning. Natural energy advisors, like Eiji, have been very popular since the government increased the subsidies (8-11) for the energy independent housing or zero emission housing (6-69) five years ago. Japan utilized the emissions trading system (8-11) effectively, and managed to achieve the goal of reducing greenhouse gas emissions by 25% in 2020. However, unlike the industry sector, the consumer sector failed to meet the target. Therefore, the government offered new subsidies for eco-housing, aiming for further reduction of emissions.

Thanks to the rapid advancement of communication networks, the number of teleworkers, who live in the suburbs, had already been increasing (2-23, 2-24, 11-26). The government strategies increased the advantages of living in rural villages further, and accelerated the nationwide redevelopment of those rural areas. The zero emission housing in rural area can drastically reduce the consumption of fossil energy with the use of biomass, solar power, and other natural energies together with the home energy management system (6-52). Along with the popularization of such houses (6-35), people can now buy them at an affordable price. Highly-efficient and large-area thin-film photovoltaic cells (6-20, 9-26) have also been developed and have started to be used in some houses, and will become wide-spread in the near future. It is quite natural that Eiji is inundated with job offers, because he is a qualified professional that can design and diagnose zero emission

houses to be covered by the government subsidies.

Eiji moved to his current residence anticipating a boom in migration to rural areas. As he expected, the village he moved to has developed into a town. He now feels comfortable working at his home office, and his only complaint is that he is too busy with work. In this town, many people have long been engaged in dairy farming, pig farming, and suburban agriculture, and methane gas generated from agricultural waste (6-56) is now provided to each household through pipes. It will not be long before zero emission areas are realized nationwide by effectively utilizing waste from local agriculture and forest industries in this manner (3-56, 6-61). Because larger plots of land are available in suburban area, people can live in a large comfortable house designed to enjoy pleasant ventilation and natural lighting as much as possible (6-69). Thus being able to realize a comfortable teleworking office without commuting is also one of the merits of natural energy home located in a rural area. The groundwater with a stable temperature all year round is pumped up from three deep wells in Eiji's town, and started to be delivered and circulated to each household(6-54,7-03). Owing to the facilities, many residents now need no more than a fan even during the summer and winter, and they can make significant savings in electricity charges.

Eiji and his wife Naomi go to the common vegetable garden rented in the neighboring village once a week to grow vegetables for their own use. The village is almost "a marginal hamlet" due to aging and depopulation. Many abandoned farmlands and farmhouses are rented free of charge to urban residents for the purpose of maintaining the environment and the village activity (12-26), but not many people are interested in such offer. Eiji and Naomi rent the vegetable garden free of charge and in return participate in volunteer activities of tree trimming in the village forests twice a year. Sometimes they invite their friend Yuichi, who lives in an urban area, to join the volunteer work. The maintenance of forests depends on such volunteers at present (12-32), but people have become aware of the functions of forest (8-15), and the introduction of "the public forest finance" to support rural areas by the whole nation (12-8) is being discussed.

Micro-grid technology to optimize power supply (1-27) and other infrastructure have also been developed in this village. But villagers living in traditional Japanese houses do not consume much energy and are not necessarily in need of such infrastructure. Nevertheless, small hydraulic generators have been constructed here and there to generate electricity necessary for villagers. This village, located on the forest slope at the bottom of the mountain, has many mountain streams and is rich in water resources. The village sells surplus electricity through the smart grid networks (6-53), which financially supports the village. Furthermore, the traditional Japanese water mills have been reconstructed for power generation and for tourist attraction as well. High quality charcoal is also made in a traditional way, and shipped for the restaurant industry. A rich natural environment can be a tourism resource, but the village lacks young people who can turn it to their advantage and is barely able to survive.

In the meantime, some other rural areas have found new opportunities by enlarging the scale of agriculture and attracting young people. Even if biomass energy is used, organically- cultivated rice and vegetables require a lot of manpower and are rather expensive compared with foreign products (6-61, 3-56, 12-59).
However, nation's growing preference for good health and safety has led to the development of the systems of direct sales and traceability, resulting in such rural areas being supported (8-40). Now, those organically-grown products are even exported to foreign countries as safe foodstuff. As full-scale organic cultivation has been expanded, farmers have tried to reduce the use of agricultural chemicals as much as possible (8-14). The agriculture has transformed itself in Japan so that it may respond adequately to the nation's preference for health and safety, and to the environmental load-reducing.

High-value-added agriculture (8-40) provided a new income source for farm households and also changed their lifestyles. In particular, the expansion of "commuting agriculture" (8-13) and "urban-rural dual life (or weekend agriculture)" in the suburbs bring a new lifestyle to the agriculture as a whole. All-out and full-time farmers need to live close to farmland for the farm management, but "casual farmers" can enjoy such methods of commuting or dual life by small operation with efficient land use. Due to the policy and financial support for the energy saving in daily life and for aging society, "multi-habitation" has been made available even for the general public (8-26). It is no longer unusual to have two living places in rural and urban areas. This trend has been progressed by the people who are retired or quitting their office jobs. The shortening of work hours and the expansion of work sharing have also worked to promote such trend.

Eiji's friend Yuichi lives in an apartment near central Tokyo because of his work. He is working for a company which deals with a wide-range of environmental technologies, such as water clarification facilities, solar panels, and wind power generators. The job requires him to go on overseas business trips frequently. His company, which used to be a large petrochemical company, was forced to change its business due to the soaring prices of oil and the international convention on the total volume control of oil use. The company was reorganized as an environmental company in its present form several years ago. They discussed the possibility of changing into a chemical company using biomass materials instead of crude oil (3-51), but abandoned the idea because of the difficulty in getting the necessary volumes of homogeneous raw materials. The large-scale plantation farming of energy crops and the biomass resource development (6-59) have been progressed in such countries as Brazil and India. The mid-sized biomass chemical plants are often built adjacent to such large-scale farmlands. In those chemical plants, synthetic fuels are also produced and have become important export items.

Yuichi just came back from Australia after a one-week trip for the replacement of the photovoltaic plant facility (9-26, 7-48) in a desert and for the preparatory work on a new hydrogen production plant (6-27, 6-34). Remote inspection using the high-speed online network is available, but the weather, wind direction, and other subtle issues can be better understood by directly visiting the sites. Yuichi's company has a photovoltaic plant there and has been conducting power trading (7-48) using ships equipped with high-performance storage batteries (1-43). Now, the company intends to start a new hydrogen business (6-28, 6-29, 9-35) using the opportunity of replacing the photovoltaic plant facility with newly- developed ultrahigh- performance photovoltaic cells (1-44). As the use of fossil fuels is now restricted under an international convention, such new styles of energy business have much potential. When submarine superconducting cable networks (6-40, 9-21) are connected in the future, energy trade will be conducted more efficiently. Yuichi's company, in conjunction with several other Japanese companies, bid for another big project—the construction of a large-scale international photovoltaic power plant in the Sahara Desert in Africa. But their bid was unsuccessful, probably due to their high bidding price. The successful bidder was a foreign company that was going to use cheaper solar panels with lower quality.

Yuichi's company developed low-cost water purification technology (8-63, 8-67), which has been selling well. Their products have been adopted broadly in Asian countries, and penetrate now into African and South American markets. Nevertheless, it will take some more time until all people on the earth can have access to safe water because some of countries have collapsed due to the internal fighting or economic trouble. Yuichi's company adopts a policy to incorporate the construction of facilities, the transfer of operation know-how, and the effective funding in the businesses (8-64), and has succeeded in gaining market shares in developing countries because the policy was accepted. However, the competition against other companies has become severer recently. Another innovative product of the company is a large-scale desalination plant. The company constructed the desalination plant on the Atlantic coast in the Sahara Desert and is now developing a large farmland there. This farm project has become possible partly due to advances in the breed improvement of cultivated crops(7-12). Daily farm work will be conducted by local residents, but works that require highly-advanced judgment are to be done by humanoid agricultural robots that can be operated remotely from Japan. Yuichi's coworkers are dispatched to the site for the trial operation of those robots. The company is planning to make a contract with a US information company that gives the crop market forecast and the long- term weather prediction, and to plant rice, wheat, beans and other crops based on such information. They are to sell most of the harvest through markets, but a part of the harvest will be sold locally for a contribution to the local area (8-49). Yuichi's company intends to contribute to the world by total improvement of food, water, environment, and lives in this way.

High-performance storage batteries, like those that Yuichi's company uses for power trading, are also equipped in electric vehicles, enabling them to run 500 km or more on a single charge (1-43). Yuichi owns a vehicle of this type. He usually charges his vehicle with nighttime discount power but can use a wireless charging system (1-49) while waiting at traffic lights or while parking, if necessary. As this type of vehicle is rather expensive, many people still drive conventional hybrid vehicles. However, thanks to the popularization of a transportation system that automatically adjusts engine operations according to traffic conditions (12-44), mileage has been improved further. For example, vehicle speed can be adjusted so that the vehicle will not encounter any red

traffic lights on its way to its destination. Recently, a new car-sharing service (8-18) started and those who cannot afford to own electric vehicles can also use such vehicles easily.

Yuichi and his family's rental apartment located near the central Tokyo needs to be equipped with a solar power units and rainwater reuse system (6-54) by the regional agreements. If residents join the regional agreements, they benefit by receiving free hot water delivered from a waste incineration plant (8-16). Toxic materials emitted from waste incineration are completely eliminated and the plants only emit water vapor and a little carbon dioxide. Therefore, not a few communities are willing to attract a new waste incineration plant, expecting the benefit of receiving a hot water. Because the apartment where Yuichi and his family live is rather new, it is a intelligent building (1-41) where communications, room temperatures, lighting, electricity, drinking water, hot water, and drainage water are controlled comprehensively. As highly-efficient lighting using LED and organic EL has become wide spread (6-63, 6-68, 9-50), not many fluorescent lamps are used now. Old houses and apartment buildings were the bottleneck to achieving the target for reductions of greenhouse gas emissions, but a new subsidy system will promote reconstruction and renovation of those houses and buildings, so the target will soon be reached.

A society where people have begun to cope with various disasters caused by the environmental change

Mr. Suzuki transferred to the fire and disaster management division of the city government this spring. This division is the key section of the local administration concerning disaster prevention. Last year, massive earthquakes struck South America and then midwestern China. A great volcanic eruption in Iceland also caused flight cancellations throughout Europe. Natural disasters have thus become much more frequent and large-scaled all over the world. Three years ago, the city area where Mr. Suzuki lives was hit by a strong typhoon, which produced 40 casualties through rainstorms, landslides, and collapsing houses. In the southern part of the city, which is a low-lying area, many houses were flooded up to the floors. Under these circumstances, the local administration is required to take more prompt and proper actions. Technology and tools for such purposes have become more advanced day by day and administrative officers in local governments need to keep up with the latest knowledge. The roles of Mr. Suzuki and other administrative officers are becoming more and more important for protecting the lives of residents.

Since two years ago, full-scale disaster drills have been conducted twice a year in Japan, under a government initiative, with specific themes set each time (12-21). The Japanese government has also called for world attention to the effectiveness of disaster drills. The themes of today's disaster drills are tsunamis for coastal areas all over Japan including the coastal suburban city Mr. Suzuki lives, and large-scale seismic fires for inland areas. In the tsunami scenario, the epicenter is assumed to be Chili, and the disaster drills were also conducted in Chili, Indonesia, and Thailand, in tandem with Japan. Due to the recent sea level rise, these countries frequently suffer extensive damage from floods and tidal waves, and the governments have come to recognize the importance of disaster drills. Detailed tsunami predictions across the Pacific Ocean based on the simulation results with supercomputer are provided each and every second through communication satellites and broadcasting satellites to all over Japan and also to foreign countries if necessary (12-35). This wireless communication system, which started to operate last year, is also checked during disaster drills and further improvements are sought.

The emergency headquarter was set up by Mr. Suzuki and coworkers immediately after the announcement of the tsunami prediction. The headquarters issued an evacuation order to residents in the southern part of the city, and evacuated them to several junior high schools and elementary schools located on hills. Hazard maps are prepared in advance, but residents can not realize the serious risk unless they actually participate in these drills. The micro-grid networks

(1-27) that are usually used to optimize energy supply to each household can be used to check on the damage in the region and to predict the expansion of damage immediately (12-16) by their emergency mode. Mr. Suzuki switched the micro-grid networks from the normal mode to the emergency mode, and carefully checked that it would work well. He also tested whether he could remotely turn off the gas and electricity in each house, and whether movable storm surge barriers and monitoring systems would rightly operate.

The fire and disaster management division once discussed raising storm surge barriers on the southern coast of the city, but the division adopted the movable barrier of concrete panels depending on the disaster risk assessment taking aesthetic landscape and land use into consideration (12-3). The new barriers were constructed last year and can extend upward only for emergency. The new barriers are also automatically controlled by the micro-grid networks, but periodic checkups are required every six months. Water levels in rivers, landslides, and other hazardous locations can also be monitored automatically at all times. When a river rises to a dangerous level or any sign of a landslide is detected, a warning is sent to the disaster control center and the information is announced to residents in the dangerous areas (12-13) at the same time. The current water levels and forecasts, including those for upper streams, are available on the internet and are updated on a real time basis (12-01), which enables the authority to issue proper warnings and evacuation orders. Additional information, such as the population of fish in watershed areas and the growth of riverside plants, is publicized in real time and has contributed to ecological preservation.

Household fire alarms that are required to be installed in all houses are now connected to local fire stations through the micro-grid networks and can directly report fire outbreaks. They have decreased fire casualties significantly. In particular, the sensor system, which sequentially reports whether there are any people inside a house by way of Twitter, has drastically changed fire fighting methods. This system is also expected to be effective when rescuing people trapped in collapsed houses due to an earthquake or other incidents. Mobile phones have the function of automatic emergency call that properly tells owner's location and condition to the fire station, the rescue center, or the disaster control center. Thanks to such function of mobile phones, fishing crew members drifting on the sea were all rescued immediately after a fishing boat capsized in an accident three month ago. Rescue robots that recognize survivors by detecting far infrared radiation or carbon dioxide released from human bodies (2-51) started to be used and some municipalities, though not many at present, put such robots in place. Robots of this type were sent to the mountainous area in midwestern China when the large earthquake hit the area. The robots worked exceptionally well, while rescue workers got mountain sickness one after another.

The fire and disaster management division took the initiative to develop mutual support systems among residents (11-40) and fostered leaders of residents in each community. However, such systems do not work perfectly on an emergency basis due to the aging of residents. Close collaboration is now required with the aged and disabled people welfare division of the city government so as to ascertain current conditions of aged households and other matters. This is why Mr. Suzuki transferred from the welfare division to the current disaster management division. During today's drills, a new scenario, i.e. several aged residents are left isolated in a house that is about to be submerged, was added suddenly and the best rescue operation was discussed. Some suggested the idea of using a boat, but it seemed to be dangerous due to an expected tsunami. Therefore, they decided to request the Self-Defense Forces to mobilize a rescue helicopter. Although the Self-Defense Forces had already received more than 20 rescue requests from all over Japan, they accepted the request. In this way, the emergency drills are conducted in collaboration with such authorities as the Self-Defense Forces, the Fire and Disaster Management Agency, the Japan Coast Guard, and the National Police Agency (12-17). The drills play a significant role in helping the government establish its policies against multiple disasters that may occur simultaneously.

Dr. Nakano works as a medical doctor at a hospital in a local city that is located in the inland area of Honshu. His theme of today's disaster drills was to ascertain the capacity of the hospital to accept people injured by the synchronized large-scale fires due to a huge earthquake.
Although broadband seismic networks and observation methods have become advanced, it is still difficult to accurately predict when and where earthquakes will occur (5-8). Therefore, the drills were conducted without any preparation. Ten minutes after the earthquake occurrence, ambulance cars carrying injured people started to arrive at the hospital. Dr. Nakano first called the city headquarters to ask about the scale of casualties. And then together with hospital staff, he made a

first aid room by separating the waiting room in half. Of course there are real patients who happened to be at the hospital to receive medical care. Those who were able to participate in the drills did so, and some of them moved to evacuation shelter. Doctors judge the conditions of each person's injury based on their explanations and provide proper treatment.

In an emergency, electronic medical charts are disclosed to all hospitals and clinics. Therefore, even when an injured person is unconscious, if only his/her medical chart number is identified, doctors can know his/her blood type and medical history. One patient, who was unconscious due to head banging, had his medical chart number and therefore could receive a prompt blood transfusion. After accepting 40 casualties into the hospital, Dr. Nakano refused the acceptance of further casualties and asked the emergency headquarter to transport the injured to other hospitals. That night, doctors discussed what type of medicine and how much medicine they should store in preparation for disasters or infectious diseases (12-15) and how to divide their responsibility among nearby hospitals. Such information is shared among nearby hospitals and local governments.

Thanks to these large-scale disaster drills, we can understand what countermeasures against natural disaster are truly necessary. Last year, when disaster drills were conducted supposing that an earthquake hit many large cites including the Tokyo metropolitan area and blocked the transportation network all day long, nearly 100,000 people had trouble returning home from work. No effective countermeasures have yet been taken for this issue. Problems were that enough shelters could not be secured and that the restoration information of railways was not effectively transmitted (12-49). In the past, a great volcanic eruption in Iceland caused a disturbance of air transportation in the whole area of Europe and affected Japan in many ways. We learned that it is important to secure the practical alternatives in emergency as well as to promptly restore transportation and distribution networks, but any real action to address this issue is not taken yet (12-18).

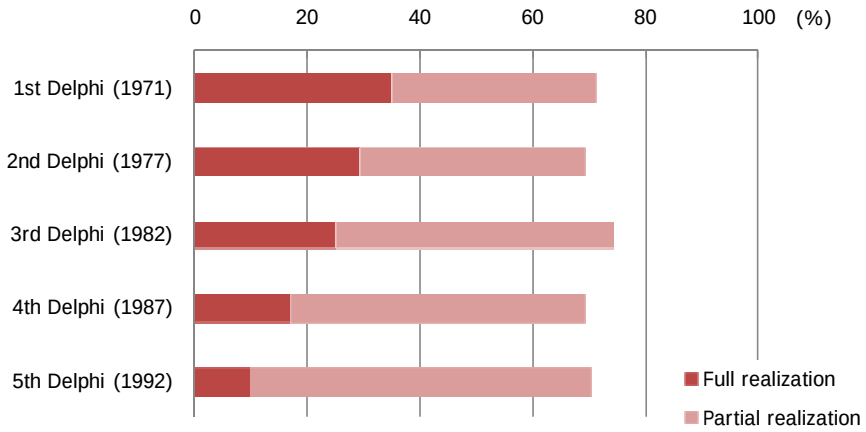
Recently, unusual weathers have often been seen, such as cool summers, warm winters, heat waves, big chill, dry weather, and heavy snowfall. In addition to affecting crop harvests, such unusual weathers have also started to damage people's health. In order to cope with the extreme weather events, over 100 countries and international organizations are developing "the Global Earth Observation System" that can comprehensively observe the earth. Our system of global whether monitoring with sensors on satellites and ground-based observation (5-02, 5-03, 5-07) is scheduled to be made highly accurate in two years, which will help to understand the origin of the extreme weather events and to contribute accurate prediction of them. Furthermore, the land-and-sea seamless database is constructed from the past 100 year observation and the data are now analyzed (5-25). The results will soon be compiled. Various types of simulation technology (2-30) and forecasting technology have been developed and are almost ready to be put into practice. It is not possible to predict at present whether global warming will further progress or whether large-scale volcanic eruptions all over the world will gradually cool the earth, but many people feel that such a prediction will become possible in the near future.

Appendix C: Reliability of experts' perspectives

How reliable are the experts' perspectives? The reliability can be estimated by looking into how many topics have been realized of all the topics taken up in previous Delphi surveys.

The ratios of realization (number of topics realized / total number of target topics) of the surveys conducted from the 1970s to the early 1990s indicates that approximately 70% of the topics have come into reality in some form. It can be seen, however, that it takes longer for full realization. Approximately 30% of topics are unlikely to come into reality even in the scope of a longer period of time, or they are likely to evolve into new development different from initial ideas.

Figure app-1: The ratios of realization by survey roud (%)

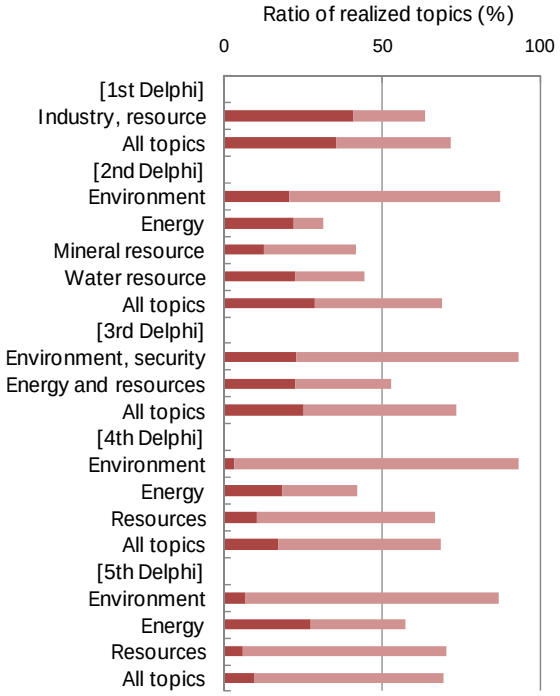


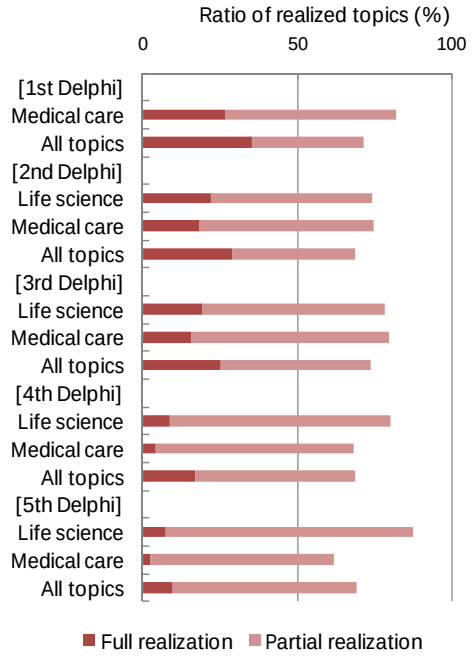
Fields relating directly to the daily life of citizens, e.g. medical care and environment, have shown generally high ratios of realization, and fields relating to information and communications have shown reasonably high ratios of full realization, although their ratios of realization including partial realization were not especially high. In contrast, fields relating to social infrastructures, e.g. transportation and energy, have generally shown lower ratios of realization. As systematic planning accounts for much in these fields, the low realization ratios indicate that the larger the scale of the planning is, the more frequently reviews are needed. The topics in fields relating to life science, medical and health care tend to have longstanding and consistent objectives, causing them to stay unchanged in multiple rounds of surveys. These topics were often predicated that it took a long time before they came into reality, but they have actually shown a tendency of earlier realization. Delphi survey is considered to have a weak point in prediction of breakthrough achievement. Fields such as life science and medical care deserve continued attention.

The past tendencies described above can provide a useful suggestion in view of the future.

Reference: "Have past foresight exercise been able to correctly indicate future directrions?" Science & Technology Trends-Quarterly Review No.38 (Jan. 2011)

Figure app-2: Ratio of realization in selected areas)





Firgure app-3: Factors of impeded realization

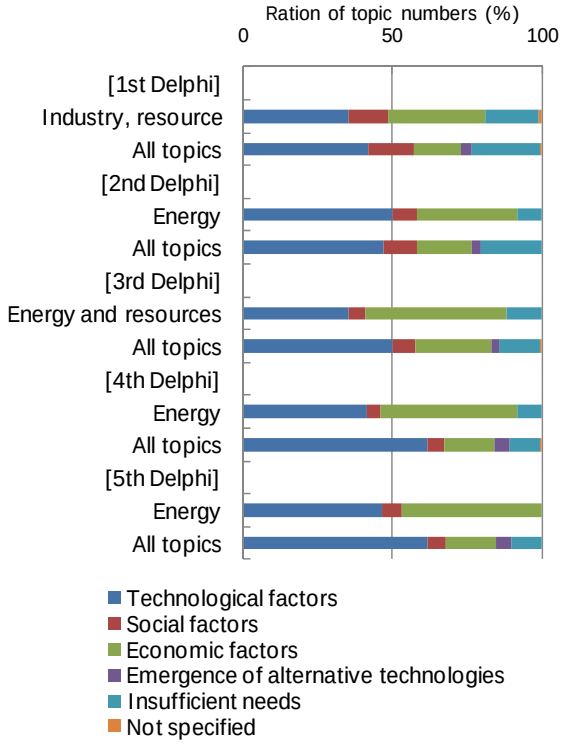
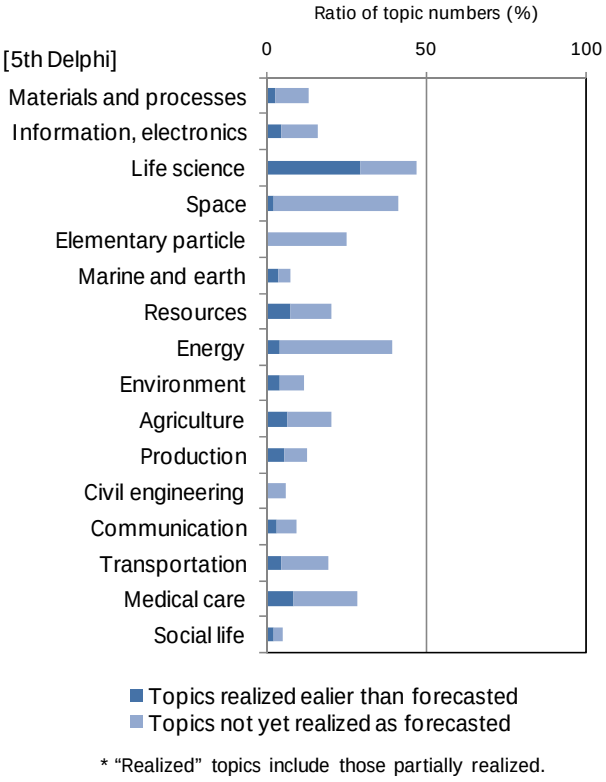


Figure app-4: Ratios of earlier realization



* “Realized” topics include those partially realized.

List of participants

(as of March 2010)

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	Tsutomu SUZUKI	University of Tsukuba
	Akira TANAKA	Tokyo City University
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	Kazuhito KAWAKITA	Nagoya University
	Akira YAMAUCHI	Nagoya University

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	Mariko FUJIMORI	Pacific Consultants, Co., Ltd.
	Tatsuo MORIMOTO	Pacific Consultants, Co., Ltd.

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	Tadashi KONOSHITA	Fukui University School of Medicine
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	Tomoyuki TAKURA	Osaka University
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	Sadao WATANABE	Jikei Medical Corporation

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	Kazuhito KAWAKITA	Nagoya University
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