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Comprehensive Analysis of Science and Technology Benchmarking and Foresight

May 2005

National Institute of Science and Technology Policy
Ministry of Education, Culture, Sports, Science and Technology

This report is a summary of the results of several studies conducted as part of the following two large projects by the National Institute of Science & Technology Policy (NISTEP) with the support of the Ministry of Education, Culture, Sports, Science and Technology with Special Coordination Funds for Promoting Science and Technology: "Science and Technology Foresight Survey" (FY 2003-2004, led by NISTEP, commissioned to the Institute for Future Technology) and "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (FY 2003-2004). The studies addressed here are "Benchmarking Research & Development Capacity in Japan" (lead by NISTEP, commissioned to the Mitsubishi Research Institute and the Japan Research Institute), "Analysis of Socio-Economic Impact of Science and Technology Policy in Japan," and "Achievements of National/Public Universities and Public Research Organizations" (led by NISTEP, commissioned to the Mitsubishi Research Institute).

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Preface

To provide fundamental information for the formulation of the Third Science and Technology Basic Plan, the National Institute of Science and Technology Policy conducted two major projects with allocations from the Special Coordination Funds for Promoting Science and Technology for the two years following FY 2003. They are the "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" ("Basic Plan Review") and "Science and Technology Foresight Survey" ("Foresight Survey").

This report presents the findings from the comprehensive analysis of the following three constituent studies of the Basic Plan Review:

- Benchmarking Research & Development Capacity in Japan
- Analysis of Socio-Economic Impact of Science and Technology Policy in Japan
- Achievements of National/Public Universities and Public Research Organization,

and of the following four studies for the Foresight Survey:

- Study on Social and Economic Needs
- Study on Rapidly-Developing Research Areas
- Scenario Analysis
- Delphi Analysis

Detailed results of these individual studies have been published separately.

The purpose of these seven studies is to provide a basis on which priority science fields and areas can be discussed while formulating the Third Science and Technology Basic Plan and where topics and perspectives to be addressed can be identified. This report comprises diverse analysis results regarding the state of and trends in these fields and areas.

We hope that this report will prove helpful in developing the Third Science and Technology Basic Plan, which will lay the foundations of Japan's science and technology policy in FY 2006 and beyond.

May 2005

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Part 1 Study Plan and Design Overview

1. Background of study

Japan’s science and technology policy has been implemented according to the Science & Technology Basic Plans (hereinafter “the Basic Plans”), which are established every 5 years. In the First Basic Plan, which covered 1996-2000, over 17 trillion yen was invested in science and technology by the government. The Second Basic Plan, which started in 2001 and is still in effect, is concentrating government funds on four major science fields: life sciences, information and communications, environmental sciences, and nanotechnology & materials. Before developing the next Basic Plan, it is essential to systematically analyze and evaluate the results of these previous science and technology policies. This is also important from the viewpoint of public accountability regarding public spending on science and technology fields.

Aware of these needs, the National Institute of Science and Technology Policy (NISTEP) has conducted the “Study for Evaluating the Achievements of the S&T Basic Plans in Japan” (hereinafter “the Basic Plan Review”) on the First and Second Basic Plans. Three of the studies covered in this report—”Benchmarking Research & Development Capacity in Japan,” “Analysis of Socio-Economic Impact of Science and Technology Policy in Japan,” and “Achievements of National/Public Universities and Public Research Organization”—are projects conducted under the Basic Plan Review.

Meanwhile, prioritization for the next Basic Plan requires holistic foresight of such issues as the potential development of impacts of science and technology (fields, areas, and even specific technologies), what society expects from science and technology, and the latest trends in basic research of platforms from which to advance technology.

In light of this, NISTEP has implemented “Science and Technology Foresight Survey” (hereinafter the “Foresight Survey”). Four of the studies examined in this report—Study on Social and Economic Needs, Study on Rapidly-Developing Research Area, Scenario Analysis, and the Delphi Analysis—have been conducted as part of the Foresight Survey.

The Basic Plan Review and the Foresight Survey both lasted for two years, FY 2003-2004, supported by the Special Coordination Funds for Promoting Science and Technology.

2. Report outline

This report presents a comprehensive summary of the outcomes of the seven studies (Chart 1), from the perspective of helping develop a prioritization strategy for the Third Basic Plan. In its summarization process, the report centers on the following three analytical aspects.

I. A comprehensive benchmarking of Japan’s R&D capacity

With basic science as the key, the level of Japan’s research activity is compared in both quantity and quality with those of major countries to identify its strengths and weaknesses, research portfolio by field, and so forth. Its also summarizes their changes over time.

[Related studies] (The NISTEP Report is referred to as “NR” hereinafter.)

Benchmarking Research & Development Capacity in Japan（NR No. 90）

Study on Rapidly-Developing Research Area（NR No. 95）

II. Science and technology impact analysis based on case studies

From this aspect, this report elucidates through case studies the practical impacts of science and technology on the economy, society, and people’s lives. It also examines the role played by public R&D and support in producing these impacts. Furthermore, the report describes the representative research results achieved by national universities and public research institutes through the First and Second S&T Basic Plans.

[Related research]

Analysis of Socio-Economic Impact of Science and Technology Policy in Japan（NR No. 89）

Achievements of National/Public Universities and Public Research Organizations（NR No. 93）

III. Science and technology foresight and analysis

In this regard, the report shows the state of consensus among experts on the following issues: how science and technology fields and their constituent sectors and technologies will evolve and be applied in society within the next 30 years, their potential impacts, and the role the government should assume. In addition to this consensus study, the report presents the results of a scenario analysis for which prominant experts in individual fields have described desirable future development paths of science and technology. Finally, it summarizes what is expected from science and technology in a future society.

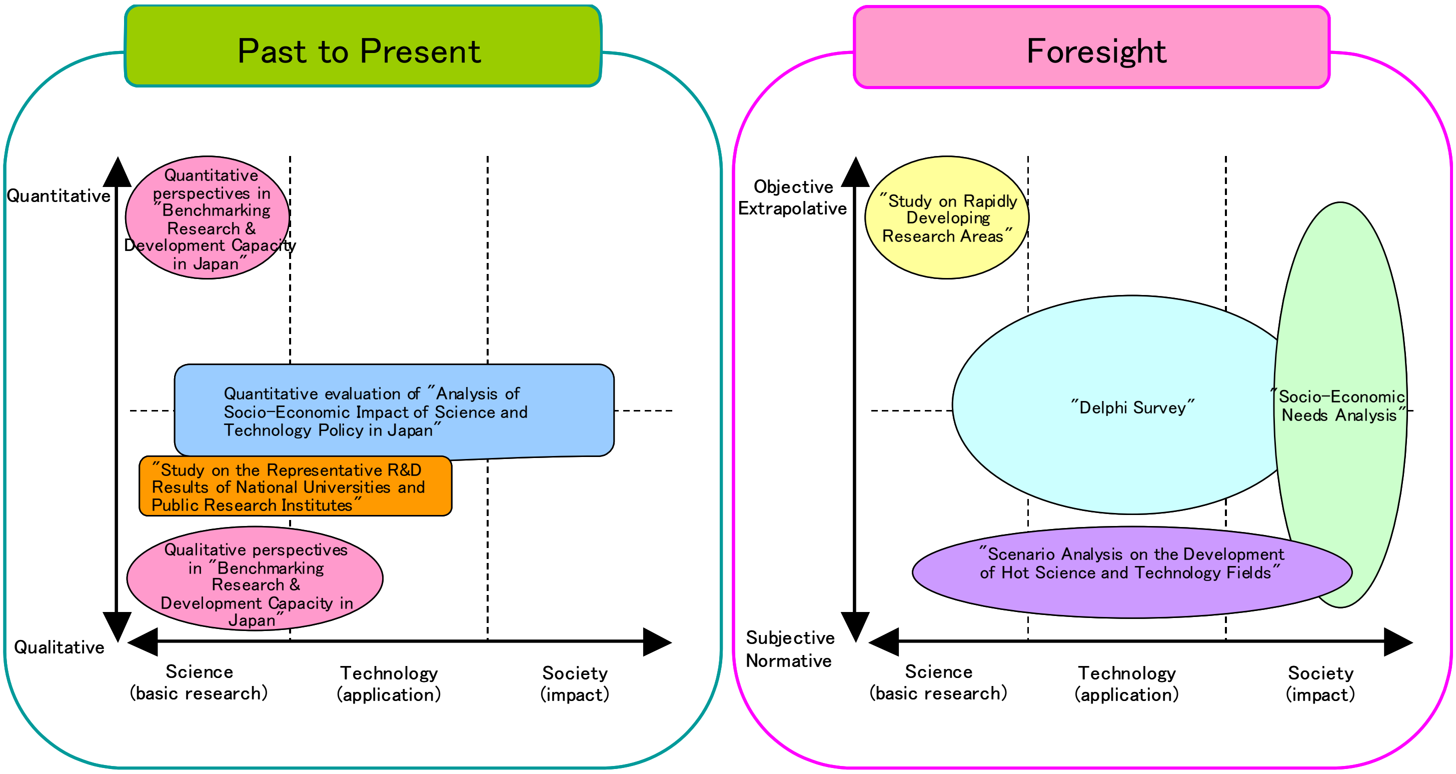
[Related studies]

Study on Social and Economic Needs（NR No. 94）

Scenario Analysis（NR No. 96）

Delphi Analysis（NR No. 97）

Chart 1 Structure of the seven studies discussed in this report



In the following section, these research projects are outlined according to sub-topic.

2.1 Outline of the seven research projects

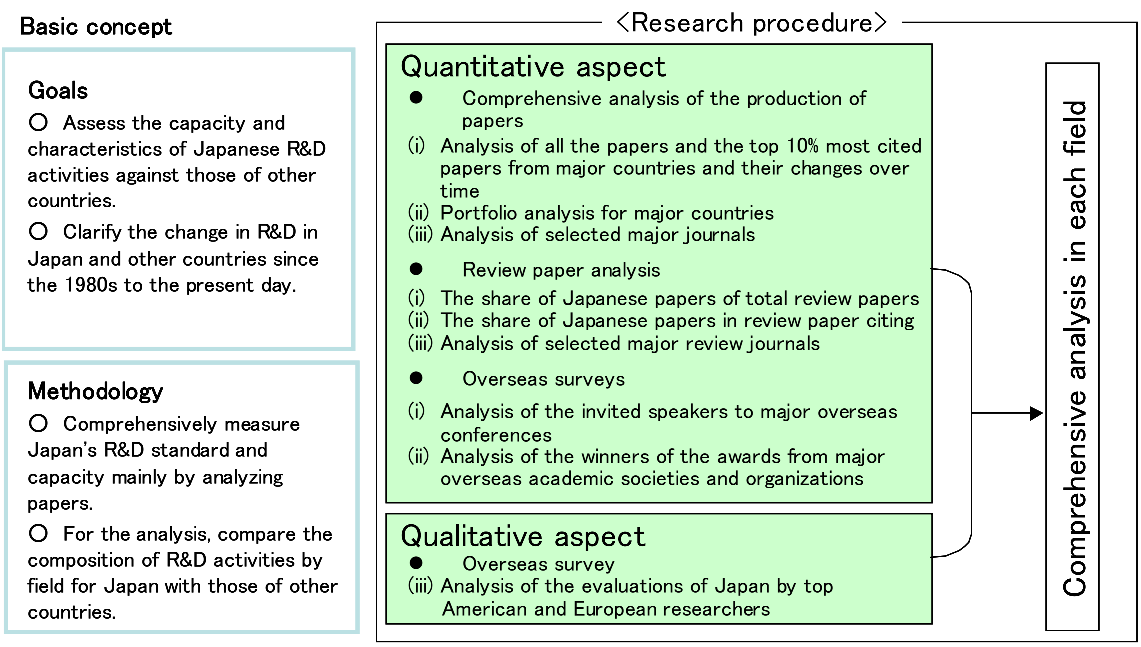
(1) Benchmarking Research & Development Capacity in Japan (NR No. 90)

This project aimed to identify the capacity and characteristics of Japanese research activities against those of other countries and to clarify changes in research activities in Japan and other countries since the 1980s up to today. Main objective of this study is activities in science, especially basic science.

Analyzing research activities based on a single measure is very difficult and even inappropriate for accurately assessing actual activities because there are diverse research fields and diverse ways of publishing research results. From this perspective, the analyses performed for this study focused on comprehensively measuring Japan's R&D standard and capacity from two aspects: a quantitative aspect, centering on analyzing scientific publications, and a qualitative aspect, involving evaluation of R&D activities in Japan by top overseas researchers and scientists (Chart 2). The project also compared the composition of R&D activities by field for Japan with those of other countries.

In the analysis of scientific papers, which constituted the major part of the quantitative study, the papers were assumed to be a quantitative indicator of R&D activities performed by scientists. The "quantity" and "quality (as measured by the top 10% of highly cited papers in each field)" of papers were analyzed by country and by field of research on a time series. For the evaluation of Japanese R&D by top overseas researchers and scientists, on the other hand, an interview survey was conducted in which experts in the USA and Europe were asked to cite noteworthy research results of Japanese research institutes and to assess the standard of their research activities and long-term achievements.

Chart 2 Benchmarking Research & Development Capacity in Japan



(2) Study on Rapidly-Developing Research Area（NR No.95）

This study aimed to identify rapidly developing research areas (hereinafter referred to as developing areas) using citation databases and to examine presence of the Japanese papers in these areas (Chart 3). Main objective of this study is activities in science, especially basic research.

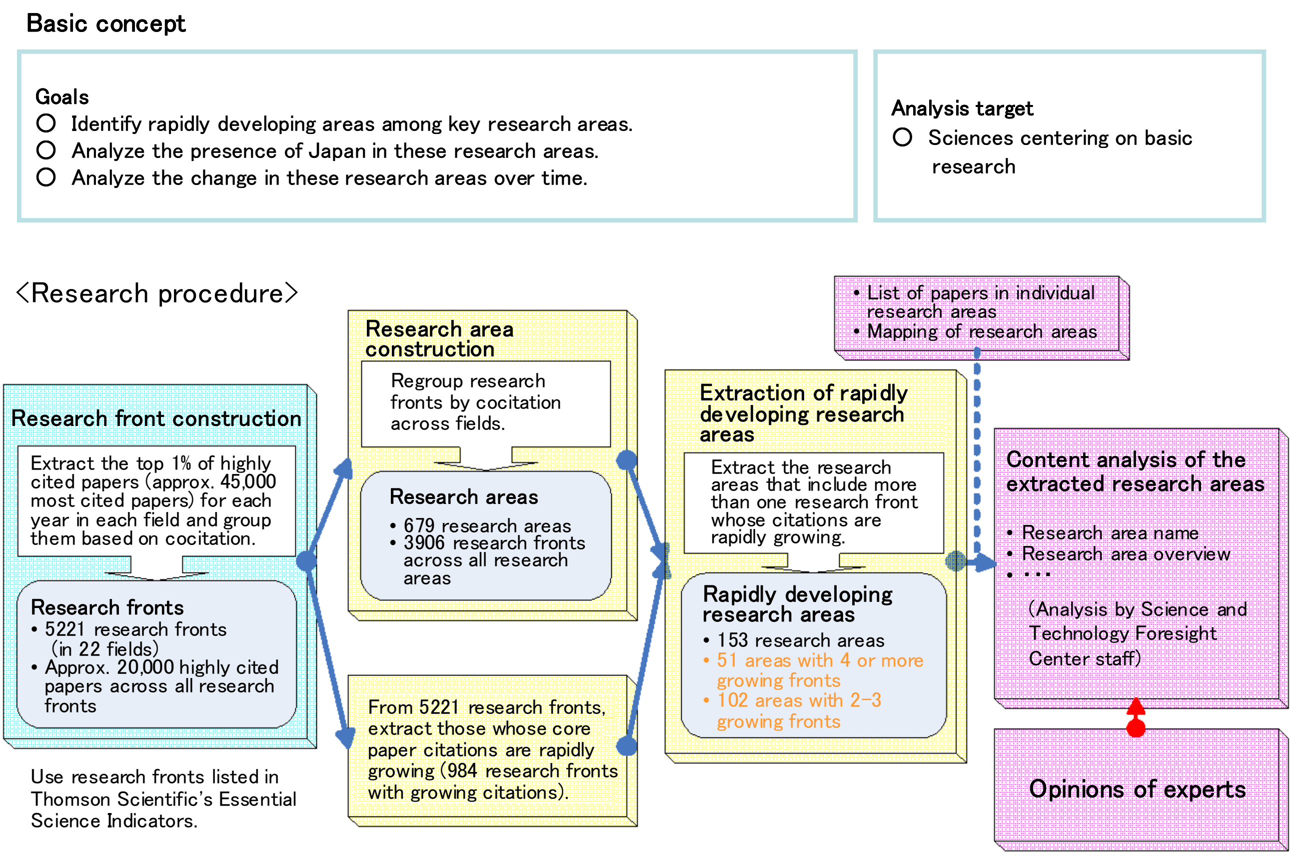
As a basic dataset for analysis, we adapted the top 1% of highly cited papers (approximately 45,000 in total) in 22 research fields (clinical medicine, plant & animal sciences, chemistry, physics, etc.) for each year between 1997 and 2002. We clustered these highly cited papers using "co-citation" to identify research areas with a proper size.

"Co-citation" is one of effective methodology to analyze citation behaviours of scientific papers, where more than one paper is cited by the same paper at the same time. Papers which are frequently co-cited are assumed to have certain similarities in their content. Thus, clusters including similar scientific papers can be produced by clustering papers by their co-citation links. In this study, these clusters of papers are called "core papers" (papers constituting the core of a research area) and the papers citing them are called citing papers.

5221 research fronts listed in Thomson Scientific's Essential Science Indicators (ESI) were used as the results of the first-phase clustering. By sub-clustering these research fronts, 679 research areas were identified.

Among these 679 research areas, 153 areas that included more than one research front whose number of citing papers is rapidly growing (hereinafter "hot fronts") were extracted as developing areas.

Chart 3 Study on Rapidly-Developing Research Area



(3) Analysis of Socio-Economic Impact of Science and Technology Policy in Japan (NR No. 89)

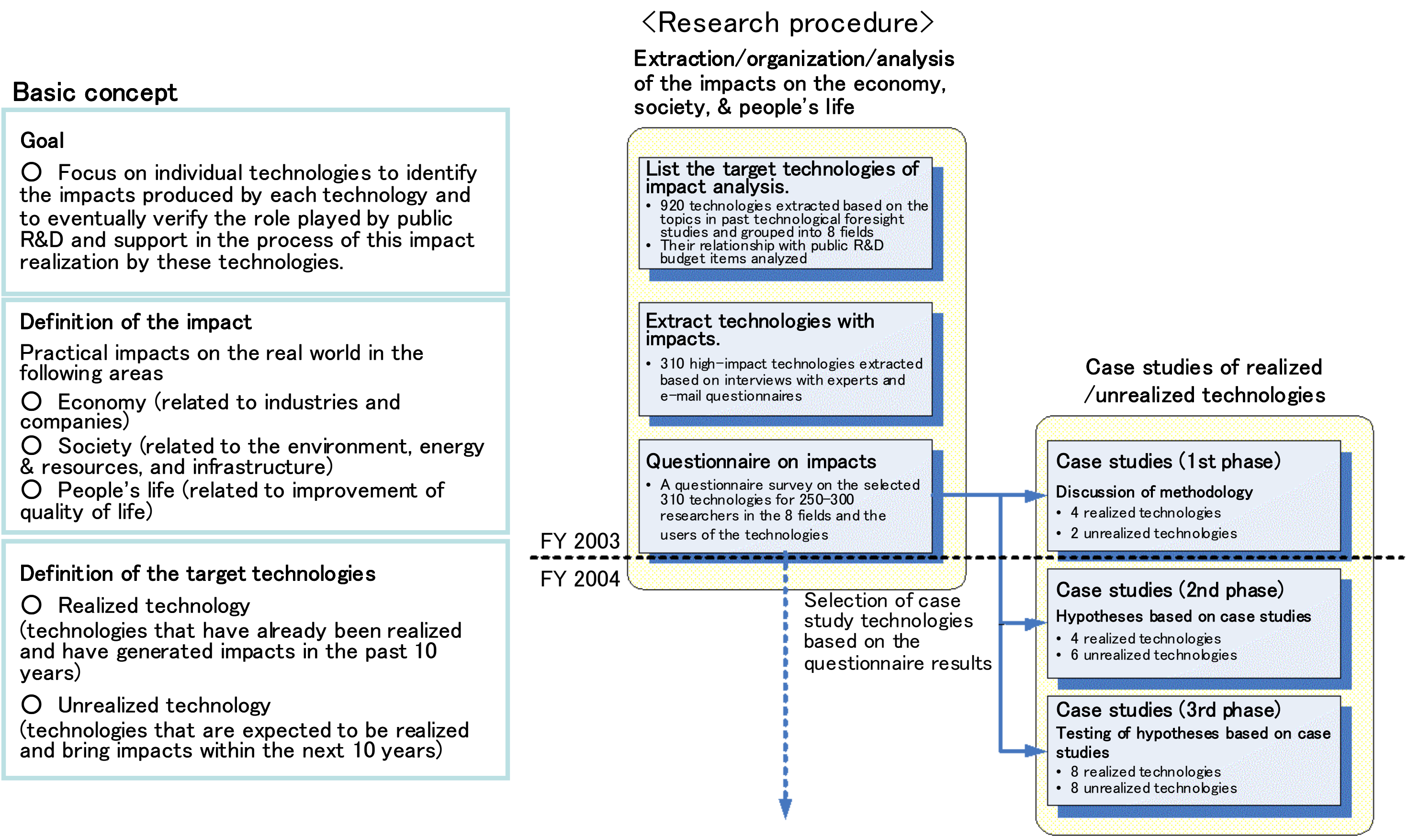
This analysis aimed to measure the impact of Japan's science and technology policy on the economy, society, and people's lives. We father analyzed the contribution of public R&D and support in the realization of these impacts. Based on the analysis, we aimed to compile a useful reference for discussion on the ideal form of public R&D and support as part of science and technology policy.

Science and technology policy, even if the target fields are specified, involves diverse measures, such as long-term R&D investment and constructing an environment for the development of new markets. Therefore, this study focused on identifying the impacts of individual technologies, rather than those of individual policy measures. We also verified the role that played by public R&D and support in the process of impact realization by technologies.

The procedure for the study is shown in Chart 4. First, 310 technologies were extracted from the eight prioritized fields (life science, information and communications, environment, nanotechnology & materials, energy, manufacturing technology, social infrastructure, and frontier) in the Second S&T Basic Plan, and they were listed in the questionnaire for a holistic analysis of their impacts. Next, technologies having large impacts were extracted based on the questionnaire results to perform case studies. For each of the eight fields, two technologies that have already been technically realized and have realized impacts in the past 10 years (current technologies) and two technologies that are expected to be technically realized and bring impacts within the next 10 years (future technologies) were selected. As a result, a total of 32 technologies were subjected to case study.

The case studies started by interviewing the people concerned and proceeded to fully clarify the impacts of each technologies that have been (or will be) realized as well as the process of their realization. Finally, the role played by public R&D and support in this process was identified.

Chart 4 Analysis of Socio-Economic Impact of Science and Technology Policy in Japan

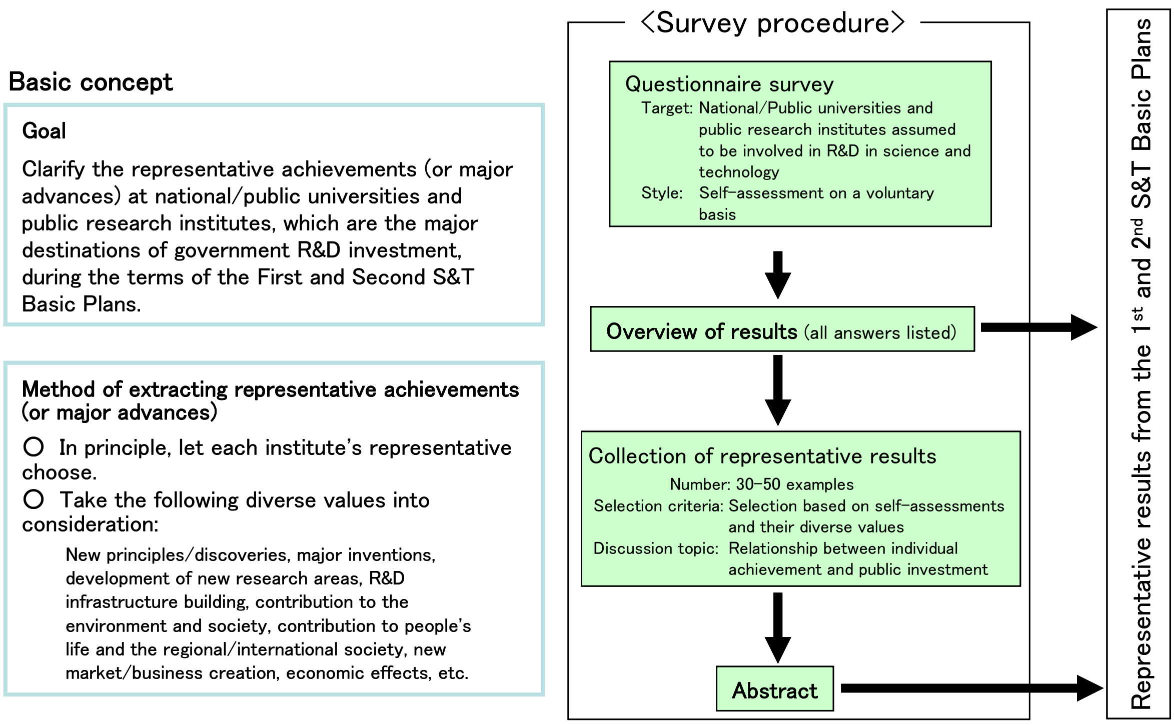


(4) Achievements of National/Public Universities and Public Research Organization（NR No. 93）

During the First and Second S&T Basic Plan terms, government R&D investment in five years increased roughly 17 trillion yen and 24 trillion yen (target), respectively. Now that discussions have begun for formulating the Third S&T Basic Plan, the government, if it is to continue increasing spending on science and technology, should actively make public the results of past R&D investment in a visible way. Aware of this need, NISTEP collected representative achievements (or major advances) made during the terms of the First and Second S&T Basic Plans at national universities and public research institutes, which are the major destinations of government R&D investment, to summarize the outcomes from diverse aspects (Chart 5).

Here, both mission-oriented research results as institutes and R&D achievements derived from individual researchers were considered to be attributed to the respective institutes. The questionnaires were therefore answered by representatives of the institutes. NISTEP asked for the achievements of their institutes, the benefit (or benefits) of these achievements, and whether the benefit(s) had already been realized during the First/Second Basin Plan term or whether it is expected in the future. All answers were made by self-assessment.

Chart 5 Achievements of National/Public Universities and Public Research Organization



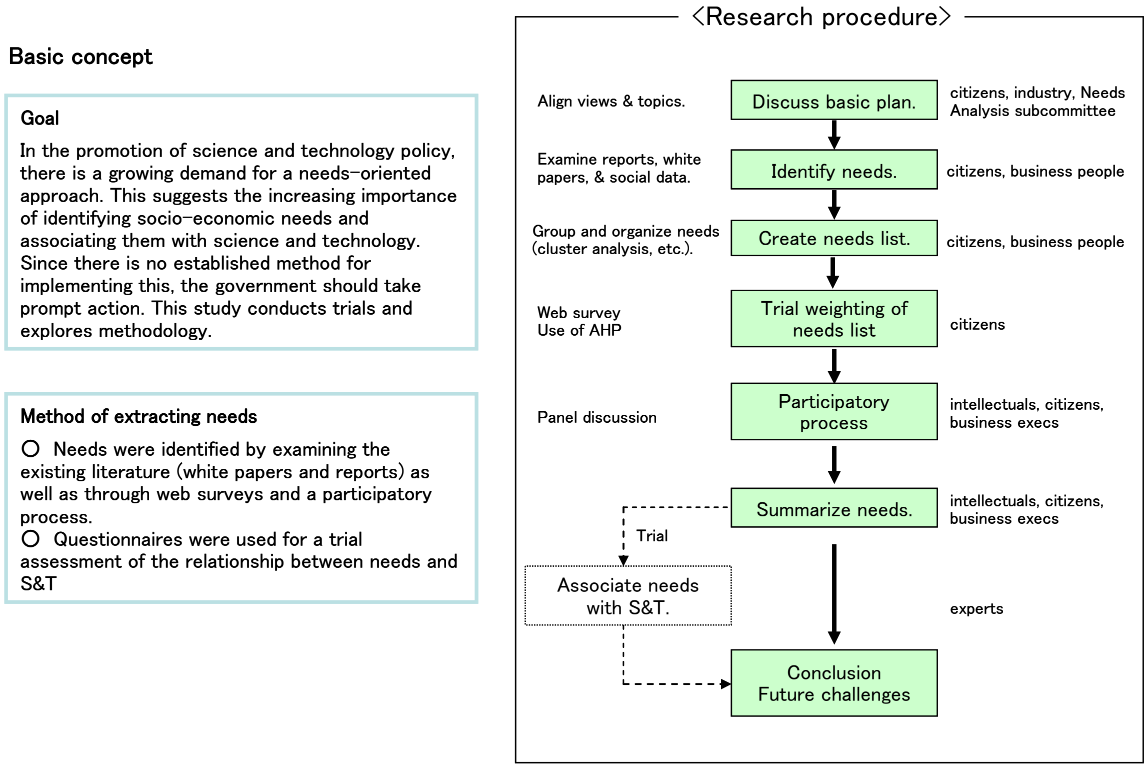
(5) Study on Social and Economic Needs（NR No. 94）

In the promotion of science and technology policy, there is a growing demand for an approach that reflects needs from society and the economy. However, there is no established method of collecting information on socio-economic needs, linking them with specific areas of science and technology, and assessing the potential contribution of science and technology to realizing the needs.

Based on this background, our "Study on Social and Economic Needs" aimed to reveal, from the public point of view, what technological and scientific needs will derive from the socio-economic changes within the next 10 to 30 years, and what priority should be given to each of them (Chart 6).

The study started by preparing a detailed draft needs list that is listed from citizen's aspects. The list was based on the need categories identified in the 7th Technology Foresight investigation, which was published in 2001, and was complemented with the additional needs found in other reports, such as white papers issued by ministries. To add a public point of view, the list was further supplemented with the industrial needs identified in the relevant literature and through interviews with intellectuals. Then, the draft needs list was structured by cluster analysis. This involved a web questionnaire survey of 4,000 people and the use of the Analytic Hierarchy Process (AHP）for weighting the need categories. Using the refined needs list, three panels (of intellectuals, the public, and business executives) discussed an ideal form of society, with an outlook for the next 10 to 30 years, to summarize the social and economic needs. In addition, a trial survey by 109 experts was conducted on how much science and technology can contribute to these listed needs.

Chart 6 Study on Social and Economic Needs



(6) Delphi Analysis（NR No. 97）

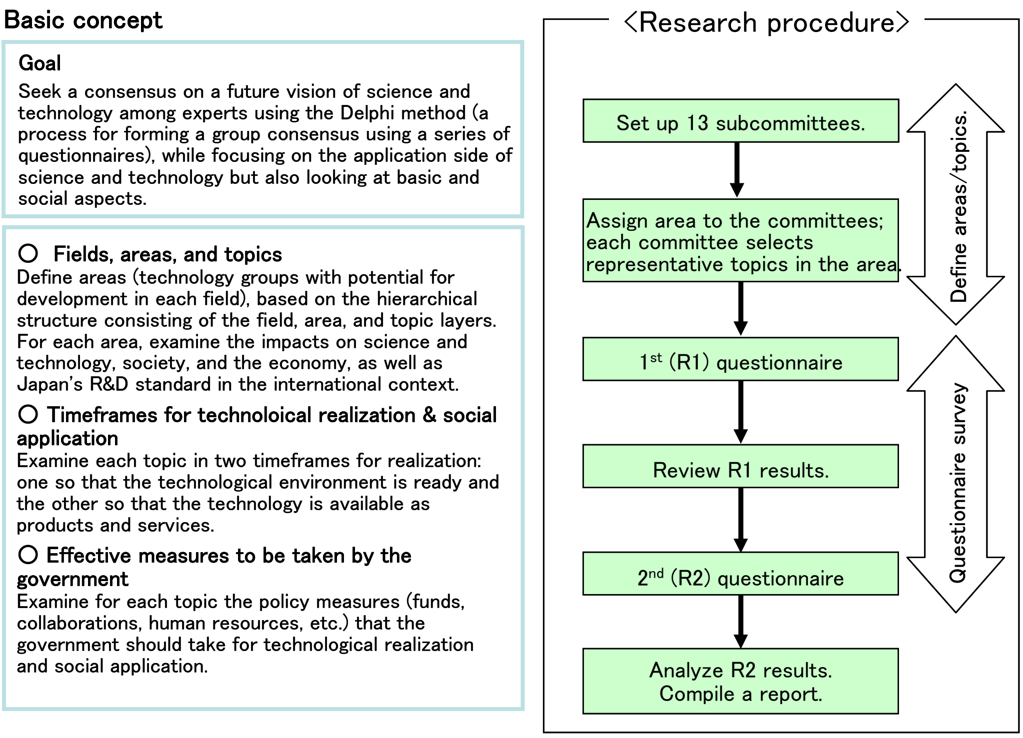
This survey centered on applied technology but covered, in part, science (basic research) and society (impacts) (Chart 7). By statistically processing the subjective evaluations by experts, it intended to find a consensus on future visions among a group of experts. This foresight survey focused on the 30-year period between 2006 and 2035.

The survey covered 13 fields: 1) information and communications, 2) electronics, 3) life science, 4) health, medical care, and welfare, 5) agriculture, forestry, fisheries, and foods, 6) frontier, 7) energy and resources, 8) environment, 9) materials and process, 10) manufacturing, 11) industrial infrastructure, 12) social infrastructure, and 13) social technology.

This survey, the eighth of its kind, is significantly different from the previous surveys in two aspects of design. The first is the definition of areas (technological subcommittees indicating potential for development in each field), based on a hierarchical structure consisting of field, area, and topic layers. A total of 130 areas were set up, and assessment was made on their impacts on science and technology, society, and the economy, as well as on Japan's international R&D standard in these areas.

The second difference is that two timeframes for realization were set to each topic, one in which the technological environment would be ready (technological realization) and the other in which the technology would become available as products and services (social application). This helps estimate the time needed for a technology to develop from the R&D stage to the commercialization stage. In addition, the survey examined the policy measures (funds, collaborations, human resources, etc.) that the government should take for technological realization and social application. The survey defined 858 topics.

Chart 7 Delphi Analysis



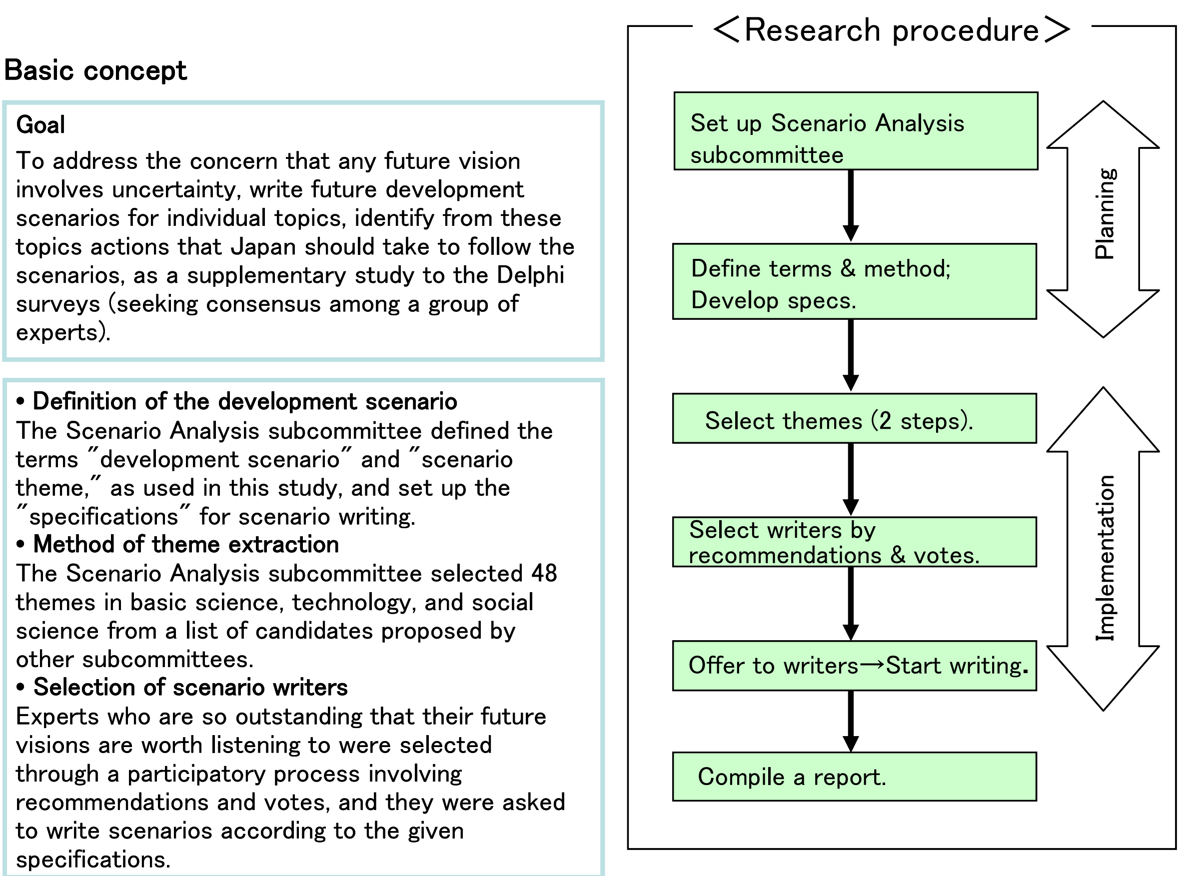
(7) Scenario Analysis（NR No. 96）

Admitting that any future vision involves uncertainty, this study aimed to derive actions that Japan should take from the future progressive scenarios written by the selected individuals (Chart 8). These individuals, who are so outstanding in specific research areas, and whose future visions are worth listening to, wrote the scenarios on the respective themes.

“Scenario Analysis” is a complementary study to the Delphi analysis (targeting consensus among experts), in that it was attempted to show subjective and normative future visions in the themes in wide areas of basic science, technology, and society impacts. Because this study was the first attempt as NISTEP, the entire process, from definition of terms to methods of the study, entailed a lot of trial and error.

The process started by establishing the Scenario Analysis Subcommittee. The committee members listed the themes that had large potential for socio-economic contributions or for producing innovative knowledge within the next 10 to 30 years, with reference to the information provided by other subcommittees. Next, they selected two appropriate scenario writers for each listed theme by recommendations and votes by the related academic organizations and or the business communities. Upon agreements, the selected individuals wrote scenarios on the assigned theme, according to the scenario specifications for writing, which consisted of three parts: analysis of past and present situation, progressive scenario (future vision), and action that Japan should take.

Chart 8 Scenario Analysis



Part 2 Study Overview and Political Implications

Part 2 describes the key findings from the related studies from the following three viewpoints. Chapters 1 and 2 explain Japan's capacity in science and technology. Chapter 3 shows the foresight for science and technology revealed by our foresight studies and their analysis results. A summary is provided at the end of each chapter.

I. A comprehensive benchmarking of Japan's R&D capacity (Chapter 1)

This chapter presents the results of the comprehensive benchmarking of Japan's R&D capacity mainly in basic science conducted by analyzing scientific papers and interviewing intellectuals abroad. It compares Japan's R&D activity with those of other major countries in both quantity and quality to identify Japan's strengths and weaknesses, research portfolio by field, and so forth. At the same time, changes in these elements over time are analyzed.

II. Science and technology impact analysis based on case studies (Chapter 2)

This chapter uses case studies to ascertain the influence and impacts that science and technology have had on the economy, society, and people's lives, and the role of public R&D and support programs in producing these effects. It also discusses the representative research results by the national/public universities and public research institutes through the First and Second S&T Basic Plans.

III. Science and technology foresight and analysis (Chapter 3)

This chapter shows the current state of consensus among experts on the following issues: how science and technology fields and their constituent sectors and technologies will evolve and find application in society within the next 30 years, what their potential impacts are, and what role the government should assume. In addition to this consensus study, the chapter presents the results of a scenario analysis for which renowned experts in individual fields have described desirable future development paths of science and technology. A summary of what is expected from science and technology in the future society is also presented. In conclusion, a holistic outlook for science and technology development is given for each field and area of research.

1. A comprehensive benchmarking of Japan's R&D capacity

To assess the present state of Japan's research activities, this chapter reveals Japan's capacity in basic science as well as its strengths and weaknesses.

1.1. The quantity and quality of Japanese scientific papers

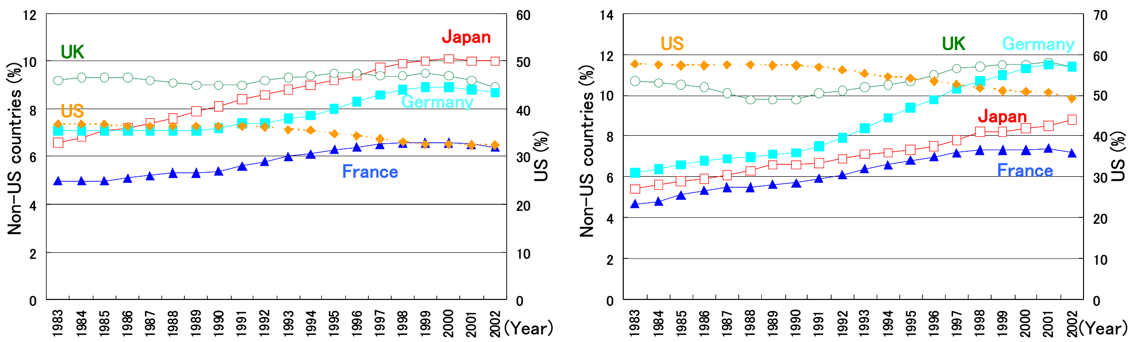
To measure research activity among scientists and researchers, this section uses scientific publications as a quantitative indicator. Chart 9 shows the change in the quantity and quality (as measured by the top 10% of highly cited papers in each field) of papers over time by country.

Japan's share of world scientific papers has steadily grown since the 1980s. The country is now ranked second after the USA, up from fourth place in the early 1980s following the USA, the UK and Germany. This demonstrates a stronger presence of Japan in terms of quantity. This also suggests that Japan accumulated more scientific knowledge and raised its position during the 1990s, a period often called the "lost decade" for Japan. Since 2000, however, Japan's growth in the share of world papers has remained at around 10%, and this trend seems to be continuing.

Japan has also steadily grown in terms of the quality of papers over the past 20 years, as its increased share of the top 10% most cited papers (hereinafter "the top 10% papers) in individual research fields indicates. Nevertheless, Japan is still ranked fourth in the world, lagging behind not only the USA but also the UK and Germany.

An interesting fact is that the German share of the top 10% papers rapidly increased between the first half of the 1990s and 2000 to equal the UK share by the 2000s.

Chart 9 Trends in the share of world papers (left) and top 10% papers (right)



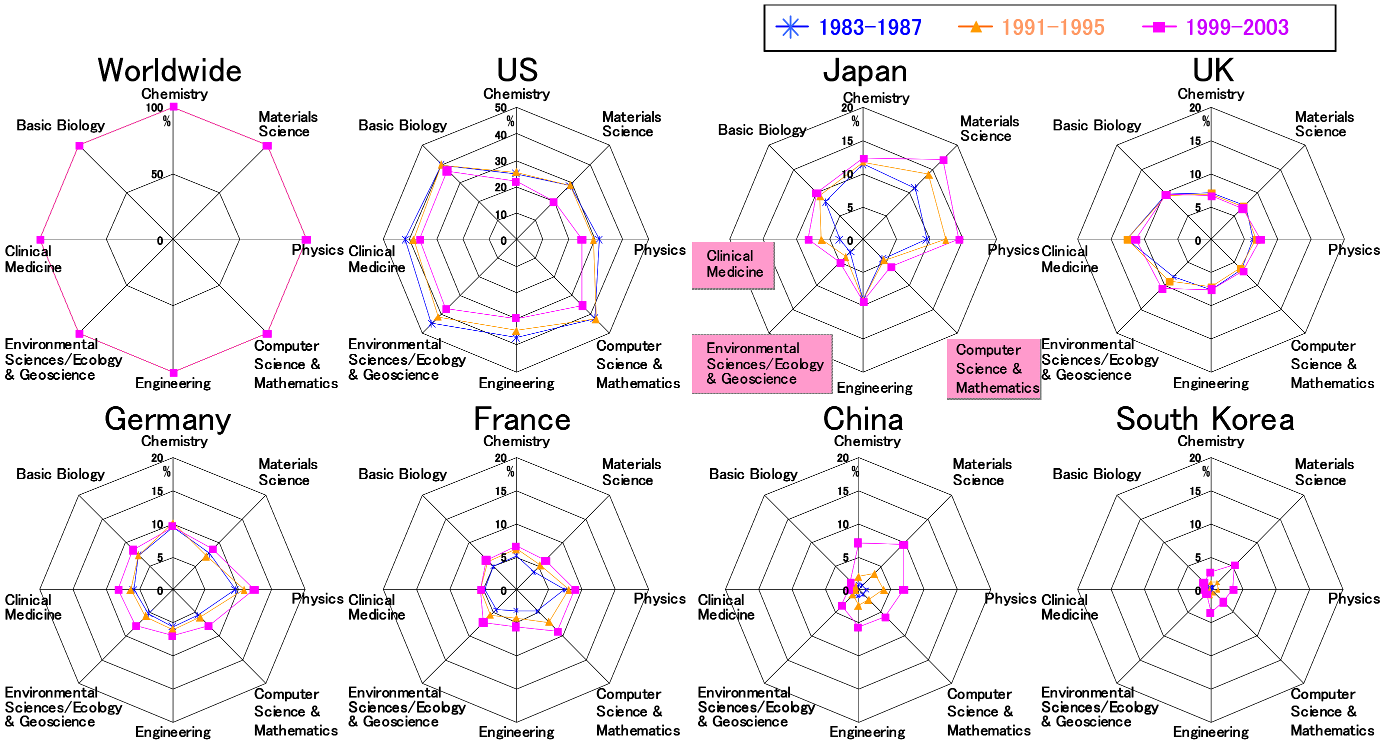
Source: Compiled by NISTEP based on "Science Citation Index, CD-ROM edition" published by Thomson Scientific

1.2. National output balance as measured by the share of scientific papers

In which fields have Japan and other countries grown in the share of scientific publications over the past 20 years? Chart 10 compares the national output balance across science fields using the world share of papers as a measure. The comparison was made for three periods, the 1980s, the first half of the 1990s, and the present.

Compared with other countries, Japan's research portfolio contains a high proportion of chemistry, materials science, and physics, and a low proportion of computer science, mathematics, environmental sciences & ecology, geosciences, and clinical medicine. This contrasts sharply with the USA and the UK, which have a high proportion of basic biology and clinical medicine. Another noteworthy point is that the research field structures of European countries, such as the UK, Germany, and France, are mutually supplementary. Such a relationship does not exist in Asia, where China and South Korea have similar portfolios to Japan's.

Chart 10 National output balance across fields



(Note 1) Relative comparative advantage indices are shown for 1983-1987 (blue line), for 1991-1995 (orange line), and for 1999-2003 (red line).

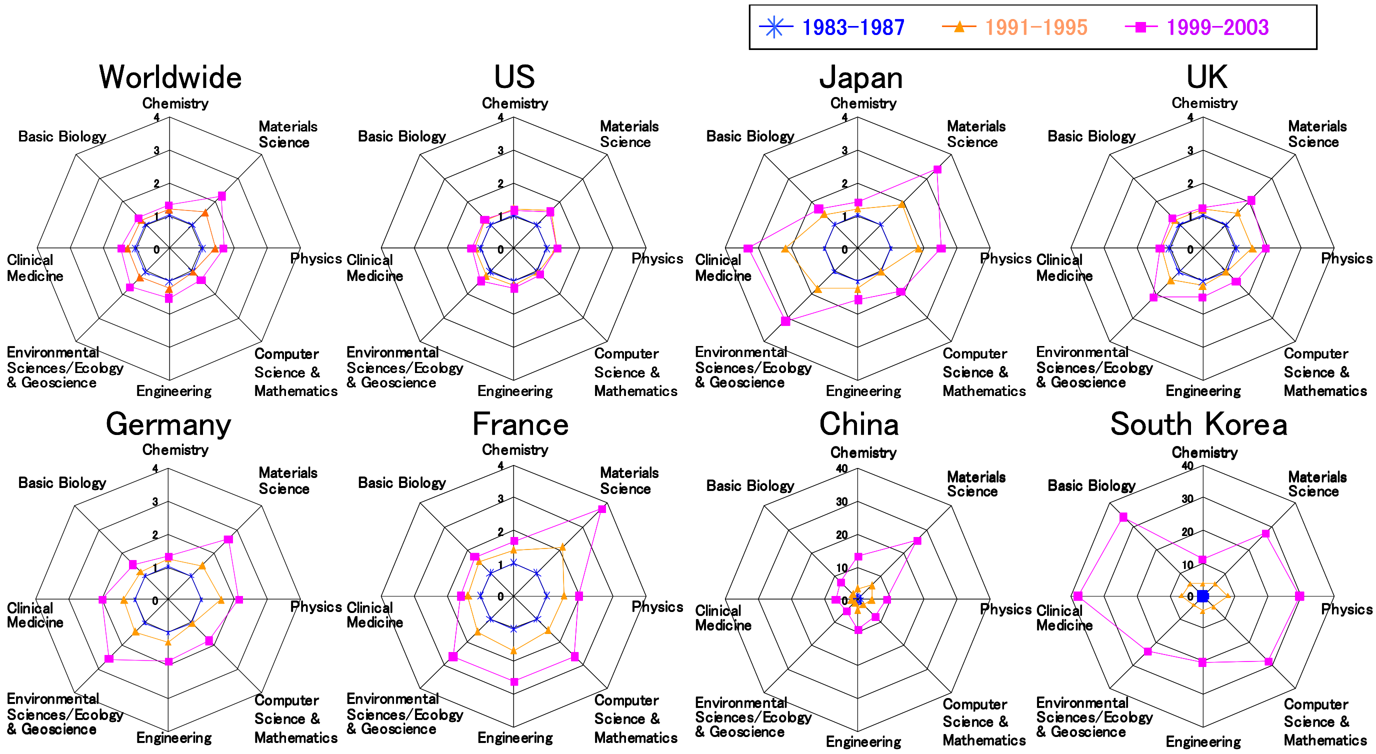
(Note 2) In this graph, 17 research fields are consolidated into eight. Basic biology includes agriculture, biology & biochemistry, immunology, microbiology, molecular biology & genetics, neurosciences & behavioral sciences, pharmacology & toxicology, and plant & animal sciences.

Source: Compiled by NISTEP based on the "Science Citation Index, CD-ROM edition" published by Thomson Scientific

1.3. Changes in the national output of scientific papers by field

In examining the national research portfolio by field, changes in the number of scientific papers produced worldwide in individual fields must be considered. Chart 11 shows how the output has changed since the 1980s up to today. The output in materials science has increased significantly worldwide, and especially in Japan, which has shown steady growth. Japan demonstrates similar growth in clinical medicine, environmental sciences and ecology, and geosciences.

Chart 11 Changes in the national output of scientific papers by field



(Note 1) The growth in the output of scientific papers is shown for 1991-1995 (orange line) and 1999-2003 (red line), assuming the 1983-1987 (blue line) level to be 1.

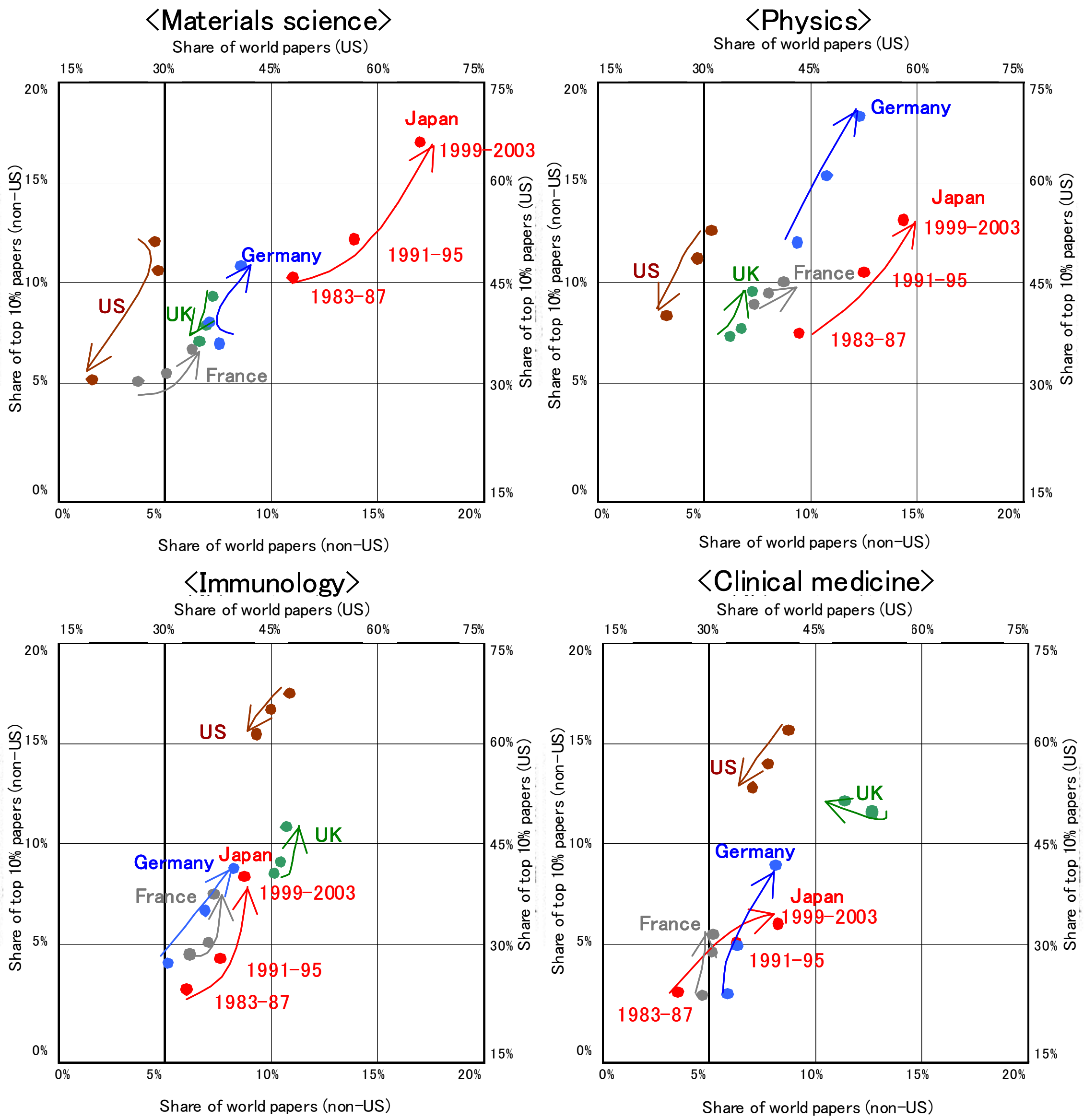
(Note 2) In this graph, 17 research fields are consolidated into eight. Basic biology includes agriculture, biology & biochemistry, immunology, microbiology, molecular biology & genetics, neurosciences & behavioral sciences, pharmacology & toxicology, and plant & animal sciences.

Source: Compiled by NISTEP based on the "Science Citation Index, CD-ROM edition" published by Thomson Scientific

1.4. Japan's share of world papers and the top 10% papers

To identify the strong and weak research fields of major countries more clearly, Chart 12 compares the selected countries' share of world total papers and the top 10% papers in specific fields for three periods (1983-1987, 1991-1995, and 1999-2003). In materials science and physics, Japan's share has increased in both world total and top 10% papers. Japan's growth has been particularly remarkable in the world share in materials science, in which Japan outperformed the UK, Germany, and France, and is now catching up with the US. In the life science sphere, Japan's share of the top 10% papers has risen considerably in immunology since 1990, to reach the level of Germany. In clinical medicine, on the other hand, Japan's share of the top 10% papers has shown only meager growth, despite a major increase in its share of world papers. During the same period, the UK, Germany, and France increased the share of the top 10% papers in clinical medicine. Thus, the comparison of Japan with other countries in the share of world scientific papers and the top 10% papers revealed that Japan has generally improved its position in the world, although the degree of improvement varies depending on the field of research.

Chart 12 Japan's share of world papers and the top 10% papers

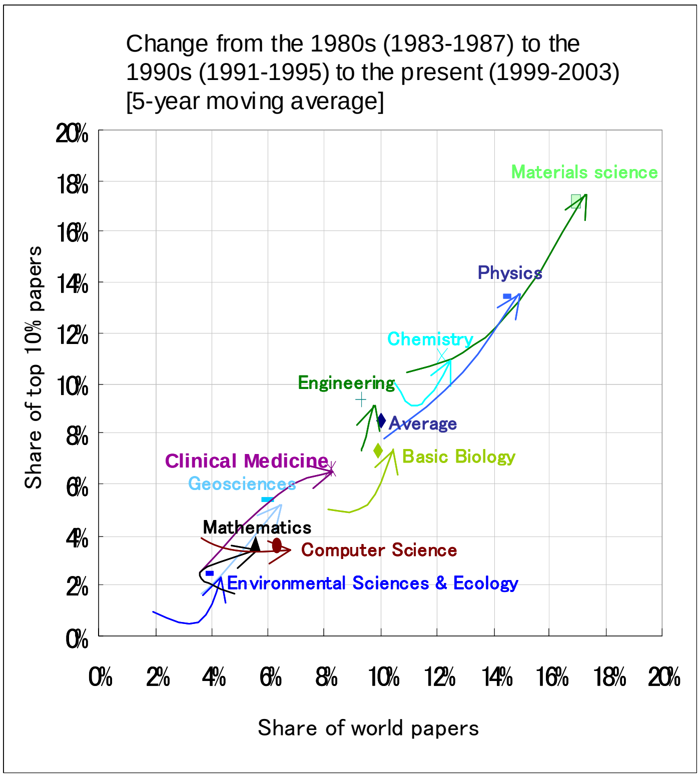


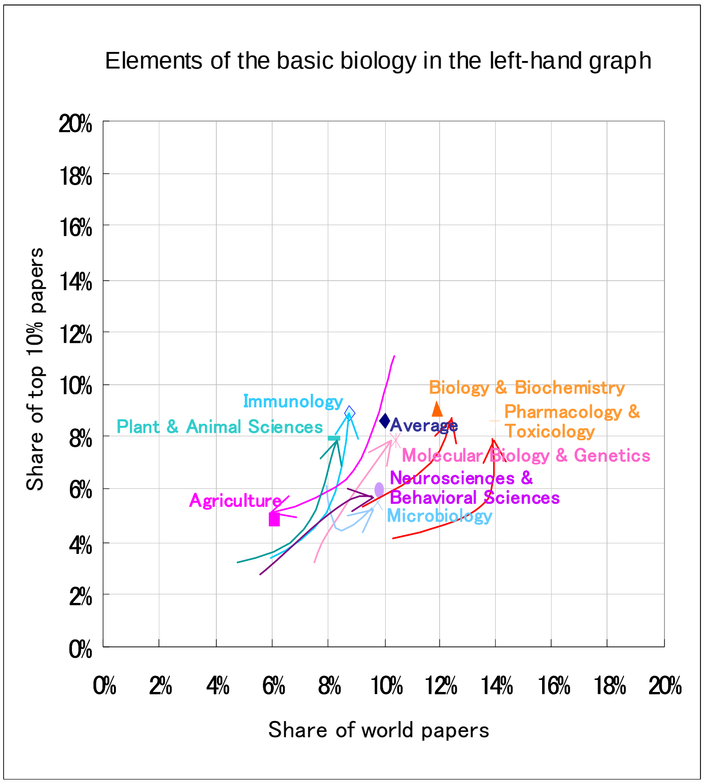
Source: Compiled by NISTEP based on the "Science Citation Index, CD-ROM edition" published by Thomson Scientific

1.5. Japan's strengths and weaknesses in basic science

Chart 13 is an assessment of the change in the quantity and quality of the Japanese research in specific areas over the past 20 years. Japan has been the world leader in the research of materials science, physics, and chemistry in both quantity and quality. The growth of japan's share in the last 20 years is particularly remarkable in materials science and physics. In immunology and molecular biology & genetics, Japan has also shown major improvements in quality. In contrast, Japan's position has been relatively weak in environmental sciences & ecology, mathematics, computer science, and geosciences. In light of this, it is time for Japan to decide whether to reinforce its strengths or overcome its weaknesses.

Chart 13 Change in Japan's share of world papers and the top 10% papers over the past 20 years





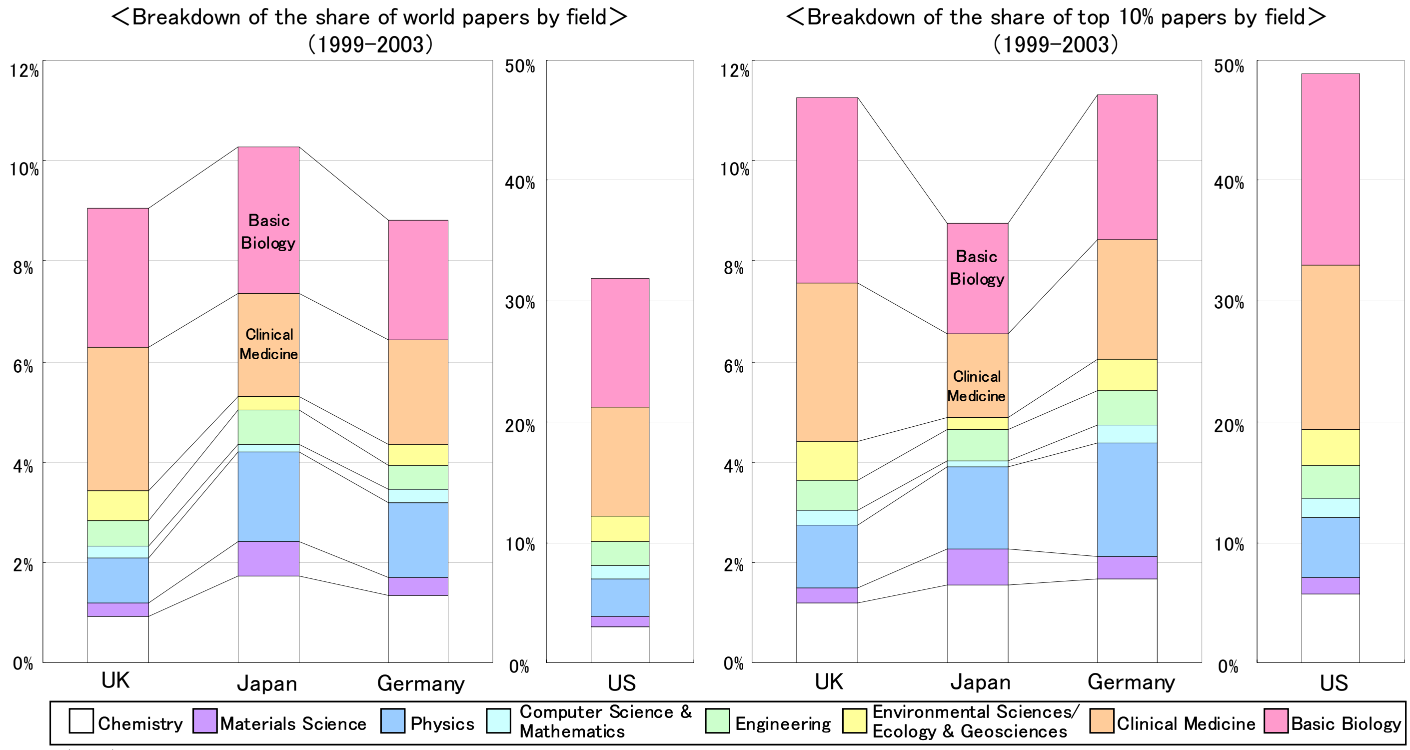
(Note 1) In the left-hand graph, basic biology includes agriculture, biology & biochemistry, immunology, microbiology, molecular biology & genetics, neurosciences & behavioral sciences, pharmacology & toxicology, and plant & animal sciences.
(Note 2) The rear end of the arrow represents the five-year moving average share for 1983-1987, and the tip of the arrow that for 1999-2003.
Source: Compiled by NISTEP based on the "Science Citation Index, CD-ROM edition" published by Thomson Scientific

1.6. Composition of the national share of world papers and the top 10% papers by field

Assuming improvements in quality to be Japan's next goal, what kind of policy should Japan develop? This requires that the government ascertain the composition of the country's share of world papers and top 10% papers by field.

Japan assumes the second largest share of world scientific papers, and its world share is greater than those of the UK and Germany in chemistry, materials science, and physics (Chart 14). On the other hand, a comparison of the national share of the top 10% papers with that of world papers for each country reveals that while the share of the top 10% papers exceeds that of world papers for the UK and Germany, this trend is reversed for Japan. Another finding is that Japan holds a smaller share of the top 10% papers in basic biology and clinical medicine than the UK and Germany.

Chart 14 Composition of the national share of world papers and the top 10% papers by field



(Note) Basic biology includes agriculture, biology & biochemistry, immunology, microbiology, molecular biology & genetics, neurosciences & behavioral sciences, pharmacology & toxicology, and plant & animal sciences.

Source: Compiled by NISTEP based on the "Science Citation Index, CD-ROM edition" published by Thomson Scientific

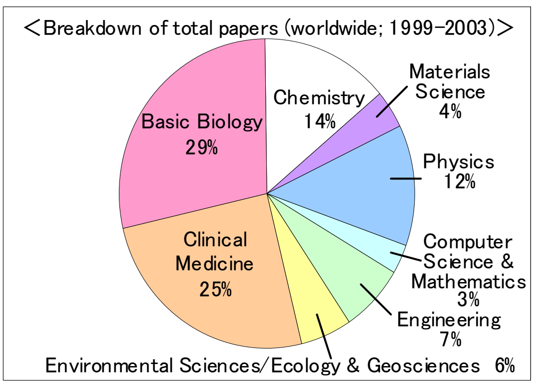


Chart 15 Breakdown of the total papers by field (worldwide; 1999-2003)

(Note) Basic biology includes agriculture, biology & biochemistry, immunology, microbiology, molecular biology & genetics, neurosciences & behavioral sciences, pharmacology & toxicology, and plant & animal sciences.

Source: Compiled by NISTEP based on "Science Citation Index, CD-ROM edition" published by Thomson Scientific

Thomson Scientific's SCI database, which has been analyzed in this study, is very commonly used for bibliometric studies worldwide. However, by examining the composition of the fields of the papers recorded in the database, we realized that over half of them fall within either basic biology or clinical medicine (Chart 15). This implies that a country's share of the top 10% papers in life sciences has a large impact on its share of the top 10% papers across all fields, which puts Japan at a disadvantage because its contribution to life sciences is relatively small.

While the validity of using the citation count as an indicator of the quality of scientific papers is still debatable, there is no appropriate alternative. In addition, this approach is attracting international attention, as demonstrated by a research paper that attempted to measure national performance, such as science and technology systems and the output of scientific papers, based on bibliometric data being published in Nature magazine. Japan needs to determine what kind of research portfolio it aims to develop in the future if it is to improve national R&D capacity in quality as well as quantity.

1.7. Japan’s strengths and weaknesses in the rapidly developing areas

In the previous section, we characterized Japan’s research activities in each field. This section investigates these fields by exploring their constituent areas in greater detail.

1.7.1. Identifying research areas by citation database analysis

In the Study on Rapidly Developing Research Areas (hereinafter “the Developing Area Study”), a citation database was analyzed to identify activities in science at research area level. As a result, 153 rapidly developing research areas (hereinafter “developing areas”) were identified. The Developing Area Study is notable for its use of the “co-citation” relationship to generate clusters of scientific papers with similar research topics in order to identify research areas.

“Co-citation” is one of effective method to analyze citation behaivours of scientific papers, where more than one paper is cited by the same paper at the same time. Papers which are frequently co-cited are assumed to have certain similarities in their content. Thus, clusters including similar scientific papers can be produced by clustering papers by their co-citation links. In this study, these clusters of papers are called “core papers” (papers constituting the core of a research area) and the papers citing them are called citing papers.

In the Development Area Study, 5221 research fronts listed in Thomson Scientific’s Essential Science Indicators (ESI) were used as the results of the first-phase clustering. By sub-clustering the research fronts, 679 research areas were formed.

Among these 679 research areas, 153 areas that included more than one research front whose number of citing papers is rapidly growing (hereinafter “hot fronts”) were selected as developing areas.

An in-depth analysis of 153 research areas was conducted, using the list of core papers (list of papers in each research area), together with the research area maps explained below.

(1) Research area mapping

The Development Area Study attempted to visually express the relationships between research fronts by mapping the research areas identified by the citation database analysis.

Chart 16 shows an example of this mapping. Each circle in this chart represents a research front, and the number next to each circle refers to the research front’s ID number. The size of a circle is in proportion to the total citation of the core papers in the research front. That is, the larger the circle, the more frequently its core papers are cited; thus, the larger the research front.

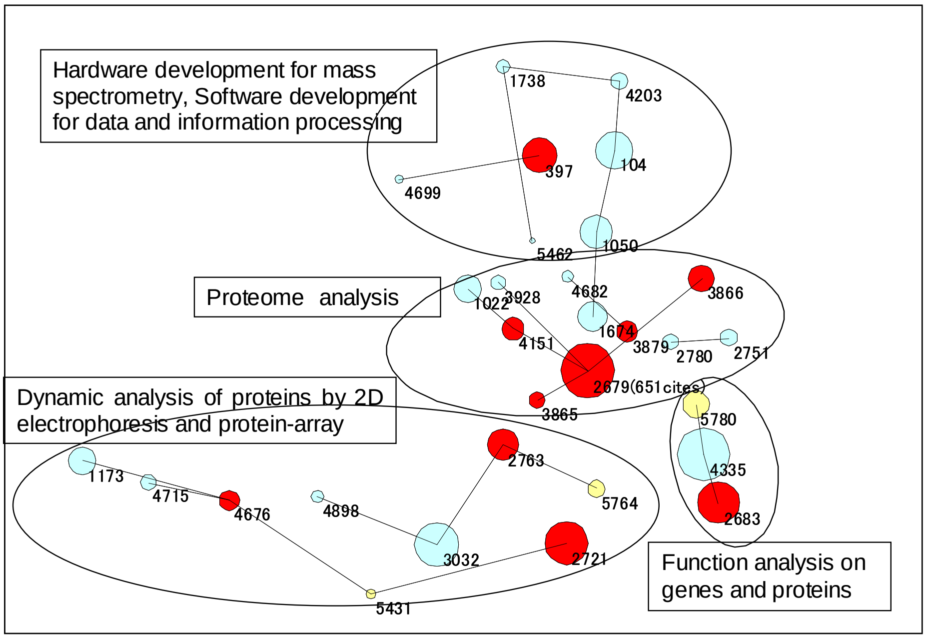
In the chart, the more frequently co-citation occurs between two research fronts, the closer the circles representing them are positioned, and vice versa. In other words, research fronts consisting of similar topics tend to be positioned closer to one another. Note that in this mapping, the relative position of individual research fronts is significant, and whether one research front is positioned above or below another, or to the right or left of another, is irrelevant.

Circles with the strongest co-citation are connected with lines. Hot fronts, i.e., the research fronts showing significant growth in citations, are represented by red circles, and those emerging in 2002 are depicted by yellow circles.

(2) In-depth analysis of research areas

The topics of individual research fronts were inferred from their research area maps and core paper lists, and the research fronts were grouped by their proximity in the maps and similarity of topic. For example, the three research fronts on the lower right-hand side on the map in Chart 16 are all related to "protein interaction analysis." Each group of related research fronts like them are circled with a dotted line and labeled with the common topic of the research.

Chart 16 Example of research area mapping (Research area name: Proteomics)



After this grouping process, the finalized content of each research area was reviewed to assign it an appropriate name ("Proteomics" in the case of Chart 16).

The results of this in-depth analysis for each research area, including the following information, are listed on two pages in the repot of the Developing Area Study.

- ○ Research area name
- ○ Statistical information on the given research area (the number of research fronts constituting the area, the number of hot fronts, the citation count of the core papers in the area, etc.)
- ○ Overview of the research area
- ○ Map of the research area

The in-depth analysis was conducted by the staffs at the Science and Technology Foresight Center, the National Institute of Science and Technology Policy, who specialize in the individual areas.

1.7.2. The results of the in-depth analysis of the research areas were reviewed by external experts for the appropriateness of the naming and interpretation of the research areas as well as for the validity of research area analysis based on co-citation.

An overview of the 153 rapidly developing research areas

The map on p. 24 shows the relationships among the 153 developing areas obtained by the analysis. While the map in Chart 16 represents the structure within a research area, the following map reflects the comprehensive relationships among research areas. To develop this map, research areas were compared in terms of the distribution of their core papers across the 22 science fields.

The individual research areas were then positioned in the map using a gravity model in which attractive forces are worked between research areas having similar patterns of core paper distribution. We sought the stablest configuration under the force field mentioned above. Therefore, research areas with similar patterns of core paper distribution tend to localize at a single site in the map. Note that the relative position of individual research areas is significant, and whether one research area is positioned above or below another, or to the right or left of another, is irrelevant.

The developing areas positioned outside the dotted circles are those in which over 60% of the core papers belong to any of the 22 fields. Hence, those inside the dotted circles can be considered inter/multi-disciplinary areas belonging to no specific science field.

Scientific papers from Japan account for 15% or more of the research areas in orange, 7-15% of the research areas in yellow, 3-7% of those in light blue, and less than 3% of the uncolored research areas. The average contribution of Japanese papers across the 153 research areas is 7%.

47 of the 153 developing research areas belong to life sciences, such as clinical medicine and plant and animal sciences. About half of them are categorized as clinical medicine. Among the remaining research areas, 33 are categorized as physics, chemistry, engineering, and materials science (chemical/physical sciences) and nine fall within environmental sciences & ecology and geosciences. Although the number is limited, research areas related to space science and mathematics are also extracted.

Another finding from the map is that roughly 30% (54 research areas) of the listed 153 areas are classified as inter/multi-disciplinary areas. This implies that a substantial part of the developing areas have an inter/multi-disciplinary nature.

(Characteristics of Japanese R&D as observed in the research areas)

The ratio of Japanese papers to the total papers constituting a research area can be considered to be an indicator of the presence of Japan in the given area. This section summarizes the results of our analysis of Japan's presence based on Japan's share of the core papers. Chart 17 shows the research areas in which papers from Japan account for at least 7.0%. In this analysis, a scientific paper was assigned to Japan if the affiliation of its author (or authors in most cases) includes at least one Japanese institution.

Our analysis of the 153 developing research areas on Japan's share of the core papers revealed that the share exceeded 7% in many areas in physics, chemistry, and plant and animal sciences. This indicates that Japan has a relatively large presence in these science fields. In contrast, Japan's share did not reach 7% in many developing areas in clinical medicine, environmental sciences & ecology, and engineering, suggesting Japan's small presence.

Despite the general assumption that Japan's research capacity is relatively weak in inter/multi-disciplinary areas, our analysis revealed that there are many inter/multi-disciplinary research areas where Japan's contribution exceeds 7%. These areas are often closely linked to the science fields where Japan has strength, such as physics, chemistry, and plant and animal sciences. These results suggest that Japan should develop new research areas rather than focus on existing areas by making full use of its accumulation of human resources and knowledge in its areas of strength.

For example, the results of the developing area analysis show that Japan's share of core papers is small in the developing areas of clinical medicine. On the other hand, Japanese papers account for over 7% of the total core papers in areas such as “Elucidation of the molecular function of prostaglandin,” “Adipocyte hormones," "Study on peroxisome proliferator-activated receptor," "Molecular mechanism of apoptosis," and "Telomerase research." These are inter/multi-disciplinary areas that combine clinical medicine with basic biology fields such as immunology and biology/biochemistry. This can be attributed to Japanese papers constituting a large part of the core papers in the inter/multi-disciplinary areas involving immunology and biology/biochemistry. One possible approach derived from this perspective is to expand joint research projects that combine clinical medicine with immunology and biology/biochemistry to strengthen Japan's presence in the developing areas of clinical medicine.

Chart 17 Research areas where Japan has a large presence

Research area name	# of core papers	# of Japanese papers	# of core papers
Study on the physical properties of perovskite manganites	47	22	47
Elucidation of the molecular function of prostaglandin	11	5	45
Organic photochromic materials and the utilization of their photosensitivity	12	5	42
High-temperature superconducting oxides	133	45	34
Study on the mechanism of host protection against microorganisms (Toll-like receptor)	55	15	27
Positive electrode material for the lithium ion secondary battery secondary cell	20	5	25
Negative electrode material for the lithium ion secondary battery secondary cell	18	4	22
Study on group-III nitride semiconductor compounds	92	17	18
Biological clock research	135	24	18
Neutrino research	117	20	17
Clay mineral nanocomposites	24	4	17
Protein folding research	24	4	17
Variational analysis of vortexes and defects by the Ginzburg-Landau energy	6	1	17
Synthetic organic reaction based on high-efficiency carbon-carbon bond formation reaction	224	36	16
Molecules associated with cerebral neocortex development and neurodegeneration	26	4	15
Algae's mechanism of carbon dioxide absorption and concentration	13	2	15
Non-commutative field theory/branes with background fields	33	5	15
Efficient metallization of organic compounds	7	1	14
Metallic superconductors and heavy fermion superconductors	106	15	14
Living radical polymerization	78	11	14
Study on the isoprenoid biosynthesis pathway in Plasmodium	64	9	14
Adipocyte hormones	184	25	14

% of Japanese papers	# of core papers	# of Japanese papers	% of Japanese papers
Self-organization	145	18	12
Functional analysis on the plant hormone, abscisic acid	66	8	12
Molecular imaging research	33	4	12
Evaluation of the effectiveness of adjuvant chemotherapy on colon cancer	34	4	12
Study on neurodegenerative diseases	258	30	12
Genome analysis of microbes	63	7	11
Study on peroxisome proliferator-activated receptor	236	24	10
Enzyme/complex catalysts	141	14	10
Plant cell function control	72	7	10
Molecular mechanism of apoptosis	190	18	9
Molecular plant science research using Arabidopsis thaliana	95	9	9
Exploration of high-temperature, high-density substances by heavy ion collisions	298	28	9
Particle cosmology based on string theory	347	32	9
Crustal and mantle material research/platinum-group element quantification	11	1	9
DNA methylation	145	13	9
Antibody treatment for lymphoma	56	5	9
Wireless communications technology	69	6	9
Physiological effects of polyphenol	23	2	9
Telomerase research	70	6	9
Quantum computing	309	26	8
Near-field spectroscopic imaging	12	1	8
Integration system for nociception and physiological function of the vanilloid receptor	111	9	8
Functional analysis on the plant hormone, auxin	68	5	7
Bioanalysis devices	209	15	7
Study on cyclooxygenase-2 inhibitors	70	5	7

1.7.3. Change in the share of papers over time

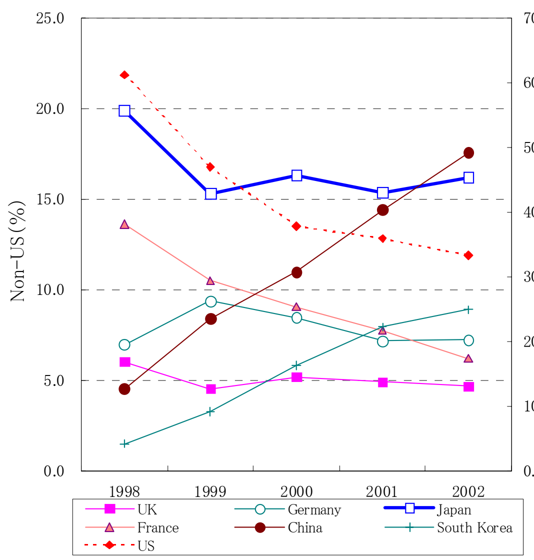
To identify the temporal trend in the share of papers, this section reviews the results of our analysis on the change in the share of citing papers over time in carbon nanotube research.

Chart 18 shows results of the analysis for the research area of “carbon nanotube.” Graph (a) in Chart 18 shows the national share (Japan, USA, UK, Germany, France, China, and South Korea) of world citing papers on carbon nanotube research for the five-year period between 1998 and 2002. A three-year moving average is used in this graph. Graph (b) depicts the change in the composition of world citing papers on carbon nanotube research by the 22 fields for the same five-year period.

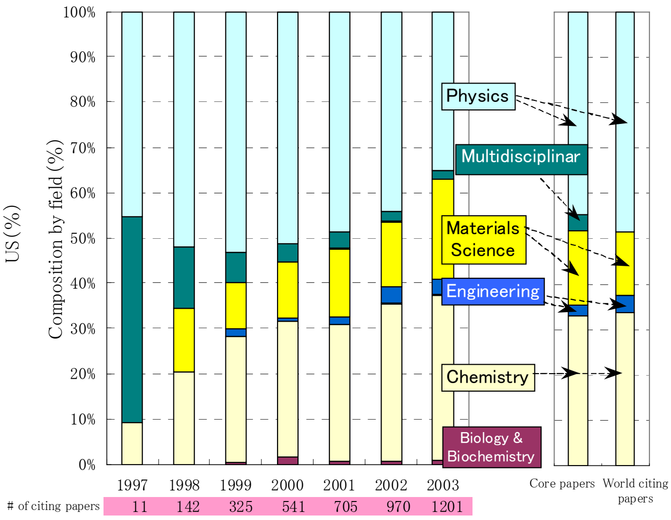
In terms of the share of world citing papers, the USA remained dominant between 1998 and 2002, although its share declined markedly from about 60% to 30%. Japan’s share also dropped from about 20% in 1998 to 15% in 2002. During the same period, China and South Korea increased their shares, and China even surpassed Japan to assume the second largest share in 2002. These results are in line with a report showing that Japan, despite its discovery of the carbon nanotube, allowed other countries to catch up because it was slow to conduct projects[1].

Chart 18 Analysis of citing papers on carbon nanotube research

(a)



(b)

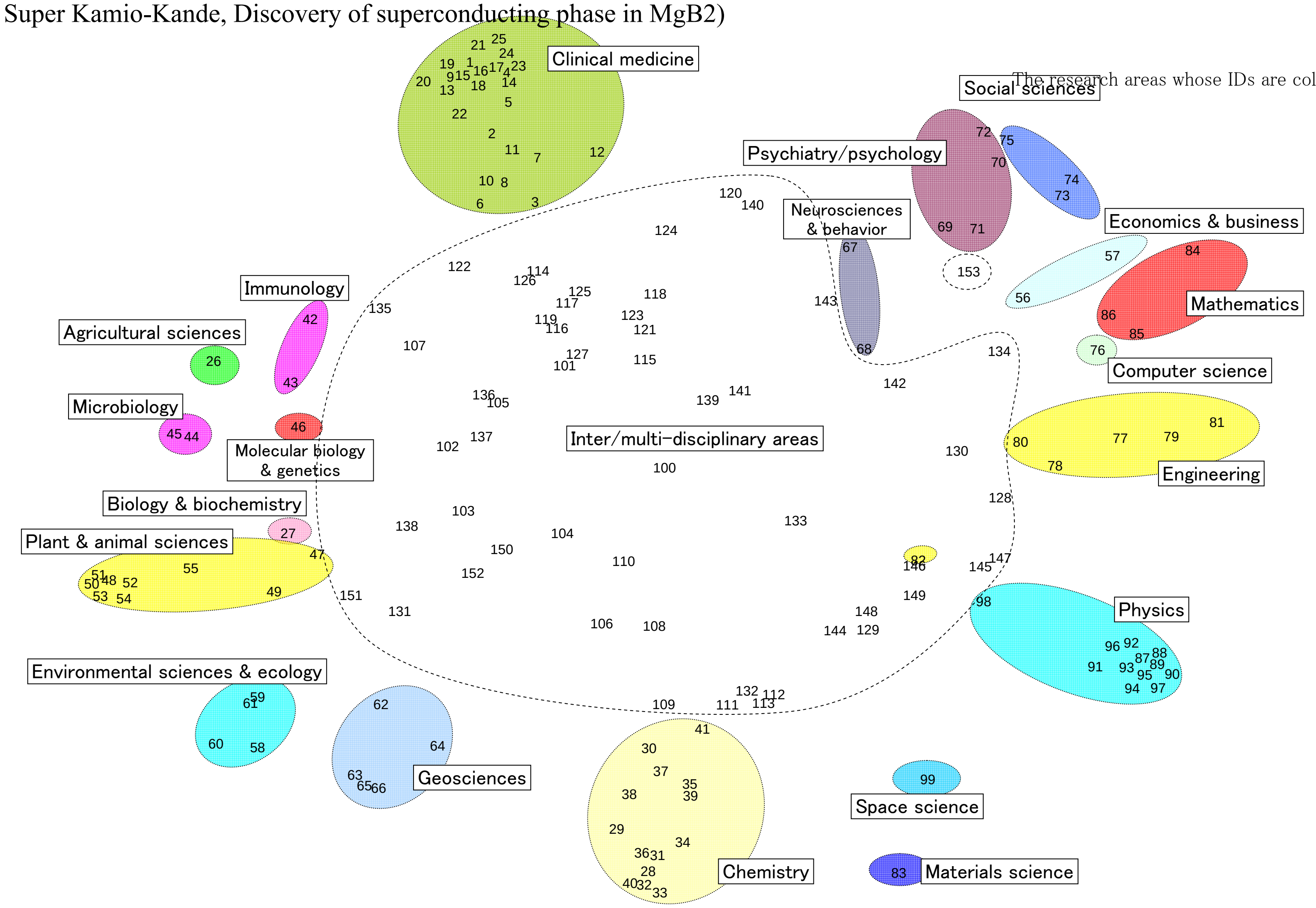


[1] A case study of carbon nanotube device technology in the “Analysis of Socio-Economic Impact of Science and Technology Policy in Japan”

The relation among the 153 rapidly developing research areas

- This figure is depicted by a gravity model. In this model, attractive forces work between RAs having similar field distribution of core papers.
- Roughly 30%, or 54, of the areas have been classified as inter/multi-disciplinary areas because their core papers belong to no specific science field. This implies that a substantial part of the developing areas have an inter/multi-disciplinary nature. Japan has been performing well in these areas.
- Japan's presence is relatively large in the research areas whose core papers mainly belong to physics, chemistry, and plant and animal sciences. Some major breakthroughs in physics were made in Japan (ex. Observation of neutrino oscillation at Super Kamio-Kande, Discovery of superconducting phase in MgB_2)

The research areas whose IDs are colored in red are the 51 areas that include four or more developing fronts.



Field	ID	Research area name
Clinical medicine	1	Study on acute coronary syndromes
	2	Study on cyclooxygenase-2 inhibitors
	3	Immune studies for the cure of disease
	4	Study on hypertension treatment
	5	Study on molecular-targeted cancer drugs
	6	Bioterrorism research on smallpox & anthrax
	7	Study on lethal arrhythmia and the prevention of sudden death caused by it
	8	Viral hepatitis
	9	Evaluation of the effectiveness of adjuvant chemotherapy on colon cancer
	10	Study on the treatment of aspergillosis and other deep mycoses
	11	Antibody treatment of lymphoma
	12	Initial treatment of hyperacute cerebral ischemia
	13	Study on the treatment of functional gastrointestinal disorders and gastro-esophageal reflux disease
	14	Hormone therapy
	15	Development of diagnostic imaging technique for circulatory disease & its clinical use
	16	Nonsurgical treatment of prostate cancer
	17	Type 2 diabetes (insulin-independent diabetes)
	18	Relation between renal disorders and cardiac disease
	19	Study on sildenafil citrate
	20	Study on bone-marrow transplantation for multiple myeloma
	21	Cardiac failure treatment research
	22	Clinical research on new drugs against leukemia
	23	Clinical diagnosis of melanoma and evaluation of the antitumor effect of interferon
	24	Anticoagulant medications in surgery
	25	Pancreatic cancer chemotherapy

Field	ID	Research area name
Agricultural sciences	26	Physiological effects of polyphenol
Biology & biochemistry	27	Protein folding research
Chemistry	28	Self-organization
	29	Enzyme/complex catalysts
	30	Inorganic/organic hybrid materials
	31	Ionic Liquids
	32	Living radical polymerization
	33	Synthetic organic reaction based on high-efficiency carbon-carbon bond formation reaction
	34	Solvent effect/density functional approach based on a computational chemical technique
	35	Devices for Bioanalysis
	36	Dendrimers
	37	Application of nanocrystallites to biotechnology
	38	Microwave-assisted organic synthesis
	39	Molecular devices/molecular machines
	40	Efficient metallization of organic compounds
	41	Organic photochromic materials and the utilization of their photosensitivity
Immunology	42	Immunity research on CD4 and CD8 memory T cells
	43	Study on the mechanism of host protection against microorganisms (Toll-like receptor)
Microbiology	44	Biofilm research
	45	Gene expression profiling of Escherichia coli
Molecular biology & genetics	46	DNA methylation
Plant & animal sciences	47	Biological clock research
	48	Plant cell function control
	49	Terrestrial plant growth promotion with increased atmospheric CO2
	50	Functional analysis on the plant hormone, abscisic acid
	51	Research in molecular plant biology using Arabidopsis thaliana
	52	Functional analysis on the plant hormone, auxin
	53	Plant genome research
	54	Flavonoid research
	55	Algae's mechanism of carbon dioxide absorption and concentration

Field	ID	Research area name
Inter/multi-disciplinary areas	100	Function of the nerve terminal protein regulating neurotransmitter release
	101	Molecular biological study on cell survival signals
	102	Study on G-protein-coupled receptor structure and function
	103	Cell membrane channels
	104	Metabolomix
	105	Effect of aging and calorie regulation on gene expression profiling
	106	Molecular imaging based on green fluorochrome
	107	Oxidation stress of active oxygen on the cardiovascular system
	108	Proteomics
	109	Clay mineral nanocomposites
	110	Influenza research
	111	Positive electrode material for the lithium ion secondary battery secondary cell
	112	Near-field spectroscopic imaging
	113	Negative electrode material for the lithium ion secondary battery secondary cell
	114	Study on peroxisome proliferator-activated receptor
	115	(1) glutamine receptor, (2) inhibition of cancer growth
	116	Molecular mechanism of apoptosis
	117	Adipocyte hormones

Field	ID	Research area name
Inter/multi-disciplinary areas	118	Study on regeneration from stem cells
	119	Gene expression analysis based on DNA microarrays
	120	Need for autism screening
	121	Effects of air pollution particles on human health
	122	Elucidation of estrogen receptor function
	123	Molecular imaging research
	124	Practical treatment planning for depression
	125	Elucidation of the molecular function of prostaglandin
	126	c-MYC gene function research
	127	Telomerase research
	128	Econophysics/financial market data analysis and mathematical models
	129	Crustal and mantle material research/platinum-group element quantification
	130	Computational learning theory support/vector machines and boosting
	131	Microevolutions
	132	Mesoporous Materials and Nanowires
	133	Numerical analysis based on the finite-element method, meshless method, etc.
	134	New applications of the Monte Carlo method
	135	Clinical & basic research on drug-resistant bacterial pneumonia

Field	ID	Research area name
Inter/multi-disciplinary areas	136	Genome analysis of pathogenic microbes
	137	Role of histone deacetylation
	138	RNAi (RNA interference)
	139	Study on neurodegenerative disease
	140	Development of multiple sclerosis diagnosis/treatment methods
	141	Integration system for nociception and physiological function of the vanilloid receptor
	142	Nicotinic acetylcholine receptor in the brain
	143	Corticotrophin/release hormone/receptor inhibition and anti-stress/-anxiety/-depression effect
	144	Carbon nanotubes
	145	Study on group-III nitride semiconductor compounds
	146	High-dielectric constant gate insulators
	147	Nuclear fusion
	148	Study on polymeric light-emitting devices
	149	Organic electronics
	150	Study on the isoprenoid biosynthesis pathway in Plasmodium
	151	Basin ecology
	152	Carbon fixation by forest and other terrestrial ecosystems
	153	(1) Analysis of the causes of delayed speech development (illiteracy) and tutorial methods (2) Reliability & validity assessment of pedagogical/psychological data analysis

Field	ID	Research area name
Economics & business	56	Fairness in the age of growing workforce diversity
	57	Knowledge- and IT-based organizational/business theory
Environmental sciences & ecology	58	Environmental pollution and risks caused by persistent organic halides
	59	Environmental pollution and biological effects caused by new chemicals
	60	Ecology for predation avoidance
	61	Plant diversity mechanism and function
Geosciences	62	Limitation to biological activity from biogeochemical factors of biophile elements in the ocean
	63	Research on global climate change
	64	Climate change and atmospheric aerosols
	65	Paleoclimate change on a global scale
	66	Elucidation of the structure of terrestrial planets
Neurosciences & behavior	67	Development of drugs to improve dementia in patients with Alzheimer's disease
	68	Molecules associated with cerebral neocortex development and neurodegeneration
Psychiatry/psychology	69	Neurotic disorders, stress-related disorders, and somatoform disorders
	70	Drug treatment of schizophrenia and its effects
	71	Schizophrenia
	72	Non-drug treatment of mental illnesses (depression)
Social sciences, general	73	Behavioral analysis in law and economics
	74	Regional economic development and networks
	75	Bed-side nursing services

Field	ID	Research area name
Computer science	76	Wireless communications technology
Engineering	77	Trace element analysis of environmental and biological materials
	78	Behavioral analysis of materials and new substance creation in a high-energy environment
	79	Intellectual control of turbulent flows
	80	Image encoding and compression technology
	81	Cartilaginous tissue research
	82	Mass spectrometry and drug discovery/tailor-made medicine
Materials science	83	Biomaterials
Mathematics	84	Spectral analysis
	85	Morphogenesis and differential equations
	86	Variational analysis of vortexes and defects by the Ginzburg-Landau energy
Physics	87	Neutrino research
	88	Exploration of high-temperature, high-density substances by heavy ion collisions
	89	Particle cosmology based on string theory
	90	High-temperature superconducting oxides
	91	Study on the physical properties of perovskite manganites
	92	Non-commutative space/structural string theory
	93	Quantum computing
	94	Metallic superconductors and heavy fermion superconductors
	95	Nonlinear phenomena research
	96	Study on specific optical phenomena
	97	Non-commutative field theory/branes with background fields
	98	Molecular motors
Space science	99	The mechanism and evolution of the universe

% of Japanese papers among the core papers

- 15%~
- 7%~15%
- 3%~7%
- 0%~3%

1.8. Japan's strengths and weaknesses as observed by leading scientists and researchers overseas

It is generally accepted that quantitative indicators based on the citation count of published scientific papers and the utilization of patents are objective to a certain extent and are thus available as evaluation references. However, it is argued that quantitative evaluation methods are not always applicable. In fact, in some research areas, scientists tend to choose other forms than writing papers to publish their research results. In these areas, the number of publications and citations may not be effective measures of research activity. Hence, we conducted an interview survey of leading scientists and researchers in the USA and Europe to find how they evaluate Japanese research activities that are not limited to papers. The results are assumed to have reasonable objectivity because they involve many external points of view, although individual answers may be somewhat subjective.

As Chart 19 shows, Japan is most highly regarded for its research in nanotechnology & materials, followed by environment, information & communications, and life sciences. The environment field is particularly notable for its high marks from top overseas scientists and researchers, despite its relatively low performance in our quantitative citation analysis. These results, while clarifying the characteristics of Japanese R&D where citation analysis has failed, suggest the need for multi-dimensional assessment in ascertaining research activity.

Chart 19 A summary of the RAND and PREST reports

Fields	Advantages	Problems
Life sciences (biology & biochemistry, immunology, microbiology, molecular biology & genetics, neurosciences & behavior, pharmacology & toxicology, plant & animal sciences, agricultural sciences, clinical medicine)	[US] ○In general, Japan is recognized as a major player in research in this field. ○Many answered that Japan has made a meaningful contribution to many research fields. ○Japanese research activity is assumed to be solid. [Europe] Future development is expected as a result of increased research subsidies.	[US] ○Japan is not considered to be a producer of breakthroughs. ○Japan's research achievements are not extraordinary. [Europe] ○The amount of research is insufficient to produce desirable results. ○Japanese articles do not appear very often in international journals.
Information & communications (computer science, electrical/electronic engineering, mechanical engineering, mathematics)	[US] ○Japan is regarded to be conducting stable, high-quality research and making major contributions to a wide range of fields. [Europe] ○Japan has made meaningful achievements in applied research and very important contributions to the field.	[US] ○Overall, Japan is not considered as a producer of breakthrough research results. Some cited, as one reason for Japan's modest international reputation in research, Japan's failure to widely present its epoch-making inventions to the international academic community. [Europe] ○International exposure is lacking.
Environment (environmental sciences & ecology, energy engineering, geosciences)	[US] ○Japan's research activities are regarded as remaining outstanding over time. ○Its R&D capacity has grown markedly over the past few years. ○In general, Japan is considered to have made remarkable achievements in applied research and very important contributions to the field. [Europe] No response	[US] ○Some pointed out that more active international interaction would further raise the position of Japan. [Europe] ○Research is weak in quantity and quality ○Japanese research activities lack recognition due to the lack of attendance at international conferences and few article presentations.
Nanotechnology & materials (basic chemistry, applied chemistry, materials engineering-metal, materials engineering - polymer, materials engineering - inorganic materials, materials engineering - semiconductor, basic physics, applied physics)	[US] ○Japan's research is noted for its steady high quality. ○Its standard is regarded as the world's highest. [Europe] ○Japan is considered to have made remarkable achievements in applied research and very important contributions to the field.	[US] ○Research depth is insufficient. [Europe] ○Joint international projects with Japan usually involve difficulties.

(Note 1) The practical survey in the USA was conducted by RAND Corporation and the survey in Europe was conducted by PREST, the University of Manchester, UK

(Note 2) The four fields used for the grouping in the above table do not necessarily correspond to the fields in the Basic Plans; rather, they are the result of dividing the target 25 areas into four sectors.

The survey revealed that in some fields, top researchers abroad recognize Japanese research activities as "leading the world" or "excellent, solid, and reliable." On the other hand, some pointed out that Japanese research activities are "lacking in epoch-making projects" and "insufficient in depth of research." The following three elements were cited as constituting the insufficiency of research depth.

♦ Lack of depth in pursuing problems

Although initial approaches, such as the discovery of proteins that have essential roles, are outstanding, there are few follow-up activities for further advancement.

♦ Lack of depth in understanding

Although Japanese researchers excel practically in utilizing known notions, they rarely create new concepts.

♦ Lack of the depth of human resources

While Japan has the world's leading researchers, their successors have not been developed fully, failing to form a research community with a pyramidal structure.

1.9. Effectively presenting Japanese research results

An important perspective in discussing a practical means of gaining world leadership in research (or effective presentation of Japanese research results) is to analyze the research results where overseas scientists and researchers gave high marks to Japan. Chart 20 lists representative Japanese research achievements that earned high marks from top overseas scientists and researchers in each field.

A wide range of research achievements is listed in each field, suggesting the solid presence of Japan in the global research community. These achievements have been divided into three categories depending on the type of activity: "research results," "world-class research facilities," and "international joint research." The items cited as world-class research facilities include the Earth Simulator and Super-Kamiokande, and those cited as international joint research include the human, rice, and other genome research projects. These listings suggest that world-class research facilities and international joint projects, in addition to research results, are essential for raising the world research community's awareness of Japanese research activities.

This viewpoint cannot be derived from analyzing scientific papers. Japan should more seriously consider how to address world-class research facilities and international joint research as a means of becoming a world research leader (or effectively presenting research results).

Chart 20 Representative Japanese research achievements that earned high marks from leading overseas scientists and researchers by field

Field	Region	(1) Research results	(2) World-class research facilities (3) Joint international research
Life sciences	US	【Bio1】Sugar chain research, Glycan structure elucidation 【Bio2】Discovery of the function of the peptidolytic enzyme related to Alzheimer's disease 【Imm1】AID protein discovery, Inhibitory T-cell research, Interferon and cytokine regulation 【mBio1】Development of antibiotics【mBio2】Anaerobe-assisted environmental purification, Molecular biological application of microbes to environmental problems 【CM1】Drug safety research, Vaccine development research, Research on hepatitis (B&C), cancer, haematology, urology, and HIV 【Neu2】Selective removal and functional analysis of specific cerebral neurons, Cloning of a protein group that has later been made into an anticancer drug 【Neu3】Research in neurophysiology and cognitive brain mechanism of primates 【Pha1】 Aryl hydrocarbon receptor (intracellular receptor of toxic chemicals) research, Research on the carcinogen in burnt food, Research on glutathione S-transferase (GSTP) as an antidotal enzyme in drug toxicity 【Pha2】 Diesel immunotoxicology (relation with asthma) 【P&A1】Gene function analysis, Rice molecular genetics and its application to rice cultivation, Cell biology, plant developmental biology 【P&A2】Plant physiology, esp. photoreceptors and information transfer	【Mol1】cDNA project, Contribution to human genome sequencing 【Mol2】cDNA project, Contribution to various genome sequencing 【Agri1】Rice genome sequencing 【Agri2】Rice genome sequencing 【P&A1】Database for plant genome information sharing
	Europe	【Imm1】Cell cycle, Oncology, Molecular biological technique, Gene silencing 【mBio1】Signal transmission, Chromosome allocation 【Pha1】Chip technology-assisted toxicogenomics tests for chemicals 【Mol】Cancer genetics, Apoptosis 【Neu】Molecular biology, Cognitive neurology cytoskeleton, Research on the autonomic nervous system 【P&A】Activities related to greenhouse gas emissions, C4 photosynthesis	
Information & communications	US	【Math2】Boltzmann equation, Classical wave equation 【Math3】Formation of quantum theory, Calculus, Factorization methods 【Com1】Grid computing, Bioinformatics, Hardware for distributed computing, Fault-tolerant systems, Network technology 【Com3】Audio processing 【Com4】Computer science (esp. computer networking) 【E&E1】Ultrasmall semiconductor devices, Silicon-based single electron devices, Mesoscopic physics, Spintronics 【E&E2】Space development of radar equipment 【Mech1】Welding technology, Steel materials technology, Automation of assembly & construction processes 【Mech2】Application of synthetic substances to civil engineering construction, Carbon fibers, High heat resistance technology for synthetic substances used for rockets and engines, Synthetic substances	
	Europe	【Math】Algebraic geometry, Differential geometry 【Com】Robotics, Ubiquitous computing, Neural networks, Mobile communications 【Com】Advanced simulation in geoscience , Cluster computing, Life information science 【Mech】Advanced computer simulation 【E&E】Active-matrix liquid crystal displays	【Com】Earth Simulator
Environment	US	【En1】Research on detrimental environmental effects (e.g. storms in warm forest regions) 【En2】Research on the origins of humankind, Molecular-level research of humans 【Geo1】 Measurement of meteorological changes and climate changes using GPS receivers 【Geo2】 Measurement of atmospheric vapor distribution using delays in GPS time signals, Accurate regional weather forecasting, Simulation by mathematical models 【Ene1】Hybrid car development (esp. control algorithms) , Fuel-efficient cars 【Ene2】Development & commercialization of the hybrid car, hybrid engine, electric motor, etc.	【Geo1】Weather & climate change simulation on the Earth Simulator
	Europe	【En】Atmospheric interaction 【Geo】Clay mineralogy (esp. amorphous clay) 【Ene】Robot control systems	
Nanotechnology & materials	US	【Chem1】Nanotechnology (esp. carbon nanotubes & advanced materials), Nanobiotechnology, Semiconductor technology 【Chem2】Application of lasers to ultra-fast spectroscopy, Development of techniques to understand complex molecular mechanics 【Chem3】Nucleus research 【Mate-M1】Material science (esp. heat-conductive/conductive oxides) , Molecular beam epitaxy, High-temperature superconducting grid, Van der Waals Epitaxy, Titanium oxide 【Mate-M2】Material synthesis (e.g. YBCuO superconductor) 【Mate-S2】Carbon nanotubes and their application to fuel cells 【Basic Phy2】Nanostructure of carbon, Boron injection to carbon 【Basic Phy3】High-pressure physics, Earthquake geology 【App Phy1】Advanced materials, Nanosciences, High-temperature superconductor , Carbon nanotubes, Neutrino research, Semiconductor research	【Basic Phy1】Super Kamiokande, Experiments at KamLAND 【App Phy1】Super Kamiokande, Experiments with synchrotron radiation equipment
	Europe	【Basic Chem】Battery fuel, Organic synthesis Structural biology, Superconductivity, Spin crossover, Molecular mechanics 【App Chem】Combustion research 【Mate-Poly】Materials science, Polymer science, Quantum-mechanical analysis of the properties of practical interest 【Mate-S】Low-dimensional semiconductor structures, Nitride semiconductors 【Mate-Inorg】 Production of bulk superconductors 【Basic Phy】Neutrino physics, Cosmic-ray physics 【App Phy】High energy physics, Synchrotron radiation physics, Nucleon physics, New multi-quark states	【Basic Phy】Super Kamiokande

(Note 1) Research area names are abbreviated as follows: Agri = agricultural sciences; mBio = microbiology; Neu = neurosciences & behavioral sciences; CM = clinical medicine; Mol = molecular biology & genetics; P&A = plant & animal sciences; Imm = immunology; Pha = pharmacology & toxicology; Bio = biology & biochemistry; Com = computer science; E&E = electrical & electronic engineering; Mech = mechanical engineering; En = environmental sciences & ecology; Geo = geosciences; Ene = energy; Mate = materials science; Phy = physics; App = applied; M = metal; S = semiconductor; Poly = polymer; Inorg = inorganic.

(Note 2) Enclosed in brackets [ ] is the specialty area of the top overseas scientist/researcher who cited the item(s) that follows. The number represents the identification number of the respondent.

(Note 3) The listings in red and underlined received particularly high marks from the respondents.

Summary 1: A benchmarking of Japan's R&D capacity

1. Capacity in basic science as measured by scientific publication

   Japan's share of world papers exceeds those of the UK and Germany and is stabilizing at around 10%. In terms of quality (as measured by the share of the top 10% papers), Japan lags behind the U.K and Germany. Improvement in quality will be a major challenge facing Japan in the next decade. In this regard, Japan should analyze Germany, which dramatically improved its quality of papers in the 1990s.

2. Finding an appropriate balance among research fields

   Japan has to determine whether to reinforce its strengths or overcome its weaknesses. To seek overall quality improvement, clinical medicine should be addressed first, followed by basic biology. A decision is also needed on whether to strengthen efforts in the fields that are underperforming, such as environmental sciences & ecology, mathematics, and computer science, which serve as the foundations of other sciences.

3. Significance of multi-dimensional assessment

   There are research fields that performed poorly in bibliometrics analysis but received high marks in the study of rapidly-developing area and the survey of leading overseas researchers (neuroscience, for example). The areas prioritized by the government, such as brain science, may become one of them. Research activities should be evaluated from multiple viewpoints. One noteworthy finding is that science in Japan is regarded as "lack of depth" in certain areas; some scientists pointed out that while initial approaches are outstanding, there are few follow-up activities for further advancement.

4. Capacity in interdisciplinary areas

   Inter/multi-disciplinary areas are of great importance as demonstrated by the fact that roughly 30%, or 54, of the 153 developing areas fall within this category. They are not always the weakness of Japan because the nation has presence in some of these areas. Japan could use inter/multi-disciplinary areas to strengthen its presence in the research fields that are underperforming such as clinical medicine.

5. Effectively presenting research results in basic science

   It has been found that Japan's research achievements attract the attention of top overseas researchers when they take the form of world-class research facilities (e.g. Earth Simulator, Super Kamiokande), contribution to international projects (e.g. human genome), and continuous outcomes in basic to applied research in specific areas (e.g. sugar chain research).

2. Science and Technology Development and Its Impacts

In the previous chapter, characteristics of Japanese research mainly in basic science fields and areas were identified by analyzing scientific papers and the survey results of scientists and researchers abroad.

This chapter analyzes the outcomes of these basic sciences and their ultimate impacts on the economy, society, and people's lives. It also clarifies the role played by public R&D and support in the process of impact realization.

2.1. Analysis of the impacts of technologies and the contribution of public R&D and support

The "Analysis of Socio-Economic Impact of Science and Technology Policy in Japan" measured the impacts of Japan's efforts to promote science and technology on the economy, society, and people's lives. It also analyzed the contribution of public R&D and support programs that have proven effective in producing such impacts.

In this analysis, two technologies that have already been technically realized and have realized impacts over the past 10 years (current technologies) and two technologies that are expected to be realized and bring impacts within the next 10 years (future technologies) were selected from each of the eight fields addressed in the Second Basic Plan. These technologies were examined to identify their impacts and to measure the contribution of public R&D and support in their impact realization. Chart 21 lists the 32 technologies subjected to case study.

The next page displays the case study results for "Helical CT Technology" and "Photocatalystic Materials." For detailed results of the 32 case studies, see the reference material at the end of this report

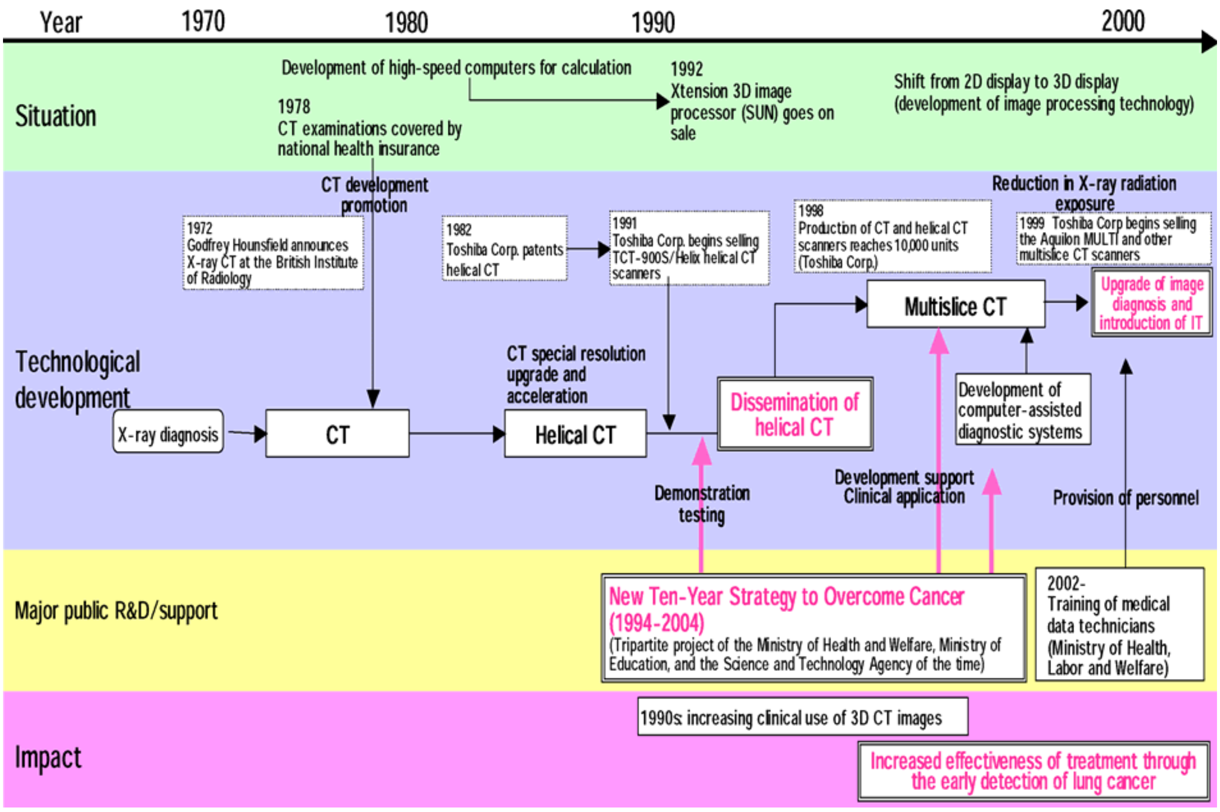
Chart 21 Case study target technologies

Field	Current Technologies	Future Technologies
Life Sciences	Helical CT Technology (Application to Early Diagnosis of The Lung Cancer)	Technologies for Utilizing Cultured Tissues from Stem Cells as Material for Artificial Organs or Tissues
	High Throughput Detection of Single Nucleotide Polymorphisms and its Application for Diagnosis and Personalized Medication	Creation Technology of Cold-Resistance, Drought-Resistant, and Salt-Tolerant Crops by Gene Manipulation
ICT	Parallel Supercomputer with High Processing Speed	Perpendicular Magnetic Recording Technology (for Hard Disk Drive)
	ITS (Car Navigation, VICS, ETC, and Traffic Management, etc.)	Ubiquitous Network
Environment	Alternative Materials of Fluorocarbons and Halons, that do not damage the Ozone Layer and cause Global Warming Problem	Gasification Melting Furnace and Ash Melting Furnace Technologies
	Elucidation Technologies of Human and Wildlife Health Effects of Endocrine Disrupters	Separation, Collection, and Isolation Techniques of Carbon Dioxide
Nanotechnology and materials	High Density and Long Lived Lithium Battery Technologies	Carbon Nanotube Devices
	Photocatalytic Materials	High Temperature Superconducting Materials
Energy	Photovoltaic System for Houses	Hydrogen Storing Alloy
	Liquid Fuel Production from Natural Gas and other Gas Sources, and its application (GTL、DME)	Fuel Cell Vehicle
Manufacturing Technology	Recycling Technologies of End-of-Life Vehicles and Electronic Waste	Microreactors for Chemical Synthesis
	Laser Processing Technology	Rehabilitation Robot
Social infrastructure	Technology for Regional Weather Forecasting	Disaster Prevention System Based on a Nationwide Network for Detecting Earthquake
	Simulation Technology on Earthquake Motion	High-Efficiency Processes for Treating Refractories and Hazardous Materials
Frontiers	Remote-Sensing Technology (Analysis and Application of Remote-Sensing Data)	Offshore Oil Rig Technology
	Synchrotron Radiation Technology	Quasi-Zenith Satellite

Helical CT technology (application to early diagnosis of lung cancer) (Life Science)

<Case study topics>

- Developing since the 1970s, the increasingly high performance of CT scanning has made an important contribution to the early detection of lung cancer. Japan leads the world in CT development. Helical CT, developed mainly by private sector corporations since the 1980s, enables the detection of very small tumors at the early stages. During the 1990s, helical CT technology continued steady progress via improved performance through the development of multislice CT by private sector firms.
- Helical CT was demonstrated in the New Ten-Year Strategy to Overcome Cancer, which was a tripartite project of the Ministry of Health and Welfare, Ministry of Education, and the Science and Technology Agency of the time. This demonstration led to the dissemination of helical CT in Japan.
- As examination technology that can detect lung cancer at the early stages, helical CT is having a broad impact on society (improving examination reliability, etc.) and people's lives (decreasing examination time, improving effectiveness of treatment through early detection, etc.).



<Economic impacts>

- Optimization of healthcare spending through the early detection of lung cancer
- Expanded markets for medical devices
  ¥49.6 billion in 2001. The market share leaders were Toshiba (47.3%), GE Yokogawa Medical Systems (32.5%), and Siemens-Asahi Medical Technologies (10.5%).
- Cost reductions through accelerated and automated examinations

<Social impacts>

- Increased reliability of examinations

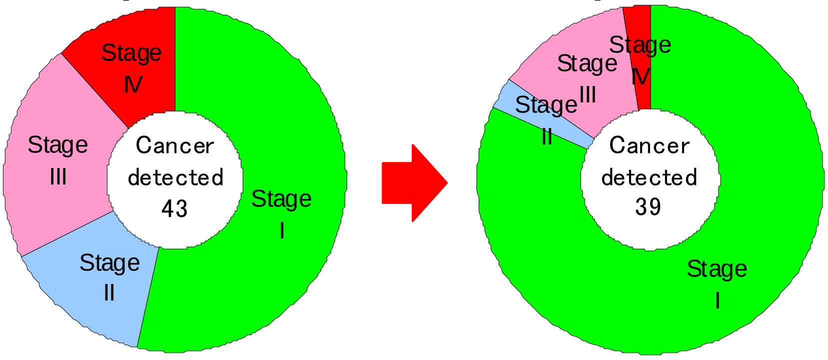
<Impacts on people's lives>

- Decreased examination time
- Improved effectiveness of treatment through the early detection of lung cancer
  Before the introduction of helical CT, 163 cases were detected per 100,000 people. After its introduction, the rate more than doubled to 361 per 100,000.
- Improved post-operative quality of life

Lung cancer detection before and after the introduction of helical CT

Before (9/1975 through 8/1993)
26,338 patients examined

After (9/1993 through 8/1998)
10,807 patients examined



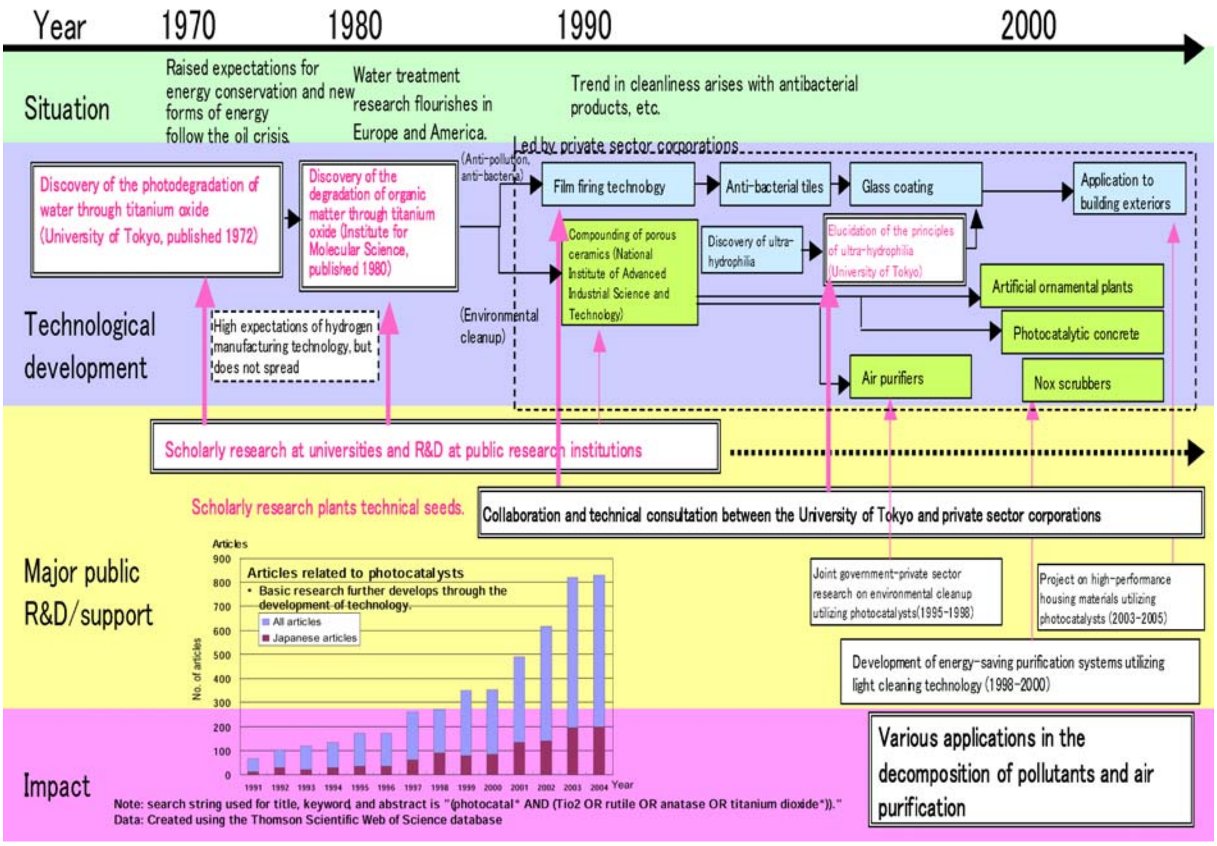
Source: Anti Lung Cancer Association (ALCA)

- The above data come from 37,145 ALCA members (90% male, average age 60) who received examinations (chest X-rays and sputum cytological exam through August 1993; chest X-rays, sputum cytological exam and helical CT scan after September 1993) through August 1999. Eighty-two cases of lung cancer were found.
- It is noteworthy that after the introduction of helical CT, more cases were detected at stage I.
- Stage I cancers (those in which cancer remains confined to a primary tumor) can often be resolved by surgery, and during the very early stages in which cancer cells are present only on the surface of alveoli, a 100-percent resolution rate is possible. Cancer advances through stages II through IV. At stage IV, cancer metastasizes beyond the primary tumor to other locations and organs. The five-year postoperative survival rates are 80% at stage I, 60% at stage II, 40% at stage III, and less than 10% at stage IV.

Photocatalytic materials (Nanotechnology and Materials)

<Case study topics>

- Scholarly research at the University of Tokyo and public research institutions led the early stages of development. The discovery of the photodegradation of water at the end of the 1960s, followed by the discovery of the degradation of organic matter, planted technical seeds.
- Basic research at the University of Tokyo did more than plant technical seeds. It provided ongoing contributions to the process of technical development through technical guidance on titanium-oxide films by private sector corporations, elucidation of the principles of ultra-hydrophilia through industry-academia collaboration, and so forth. Recently, basic research has further developed through technical development (chain model).
- The advance of thinning technology has had an impact through applications such as self-cleaning tiles and air purification.



<Economic impacts>

- An approximately ¥40 billion market for adding value to or replacing existing products such as exterior walls, air purifiers, and deodorizers has emerged (¥25 billion for members of the industry group, the Japanese Association of Photo-catalyst Products, alone).

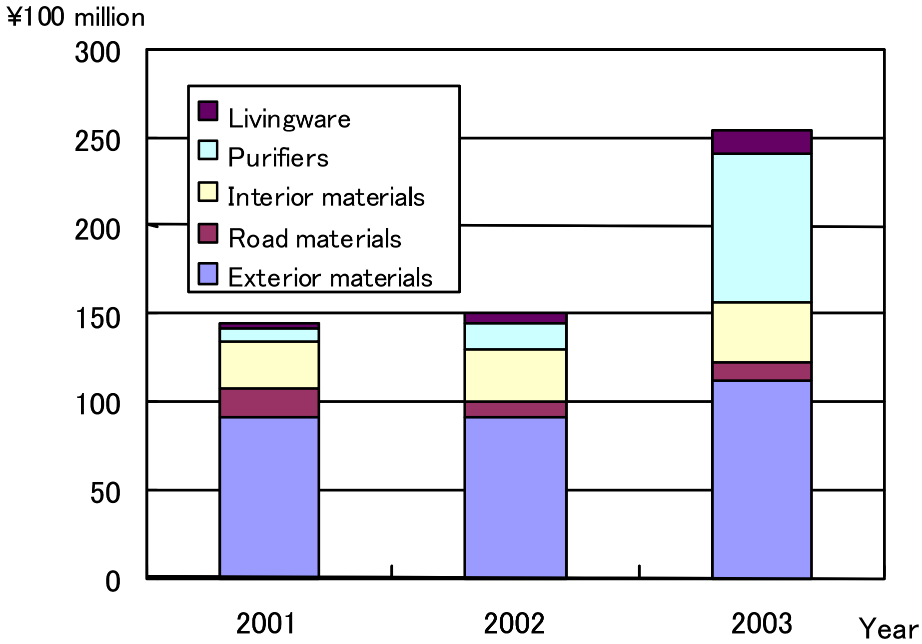
<Social impacts>

- Reduction in cleaning costs for buildings and around roads (sound-insulated walls, guardrails, etc.)
- Cleaning agricultural (greenhouse) runoff
- Potential removal of NO_x from around roads
- Potential cuts in energy needed for summer air-conditioning

<Impacts on people's lives>

- Reduction in effort needed to clean home interior and exterior walls
- Beautification of cities and roads

Market scale for products using photocatalysts



Note: The sudden increase in revenue in 2003 is due to a change in the method of calculation. (Previously, only the filter portion was counted; beginning in 2003, the value of the entire product was included.)
Source: Japanese Association of Photo-catalyst Products

2.2. Diverse impacts of science and technology

Through the case studies of the 32 technologies, their practical impacts on the economy, society, and people's lives were identified. The results show that the technologies have realized (or are expected to realize) diverse impacts on the economy, society, and people's lives. For example, in terms of economic impact, technologies such as "Photovoltaic Systems for Houses" lead to new products and services, resulting in the creation of new markets. On the other hand, "Parallel Supercomputers with High Processing Speed" help shorten the R&D period and reduce prototyping costs. The latter impacts are indirect ones compared with the former ones. Thus, our analysis results indicate that technologies contribute to the economy, society, and people's lives through direct as well as indirect impact. The following sections clarify the impacts of the 32 technologies.

(Economic impacts)

Four major economic impacts have been identified: "market (employment) creation and expansion," "cost reduction," "reduction in economic risk," and "improvement of international competitiveness." Chart 22 lists examples of the economic impacts found through the case studies.

Chart 22 Examples of economic impacts

Impact type	Description of examples	
Market (employment) creation & expansion	(Laser Processing)	Creation of a ¥300 bil. (now) laser processing equipment market (about ¥600 bil. by 2010)
	(Photovoltaic System)	Creation of a ¥150 bil. (world's largest) photovoltaic system market (about ¥400 bil. by 2010)
	(ITS Technology)	Related markets worth ¥881.4 bil. (about ¥7 tril. by 2015)
	(Photocatalytic Materials)	Related markets worth about ¥40 bil
	(Hydrogen Storing Alloy)	Potential creation of a ¥3 tril. hydrogen supplier market
	(Carbon Nanotube)	Potential creation of a ¥180 bil. display market and a ¥120 bil. chip market (2010)
Cost reduction	(Parallel Supercomputer)	Reduction in the cost of product development and prototyping for cars and drugs
	(Regional Weather Forecast)	Improved efficiency in weather-dependent businesses (retail, construction, etc.)
	(High-Temp Superconductor)	Potential reduction of a ¥370 bil. transmission loss of power
	(ITS Technology)	Potential reduction in social costs (¥1 tril.) by relieving traffic congestion
Reduction in economic risk	(Endocrine Disrupter Elucidation)	Potential recurrence prevention of health damage from chemicals by screening hazardous chemicals
	(Earthquake Motion Simulation)	Prevention and mitigation of damage caused by disasters
	(Refractories Treatment)	Potential price maintenance for agricultural produce as a result of proper wastewater treatment
Stronger international competitiveness	(Laser Processing Technology)	Improved competitiveness in manufacturing with machine/micro-processing (cars, electronics, etc.)
	(Fluorocarbon/Halon Substitutes)	Improved international competitiveness by meeting regulations ahead of overseas firms (air conditioner industry)

(Note) The numerical values (market/employment creation and expansion, cost reductions) are for Japan only.

(Social impacts)

Four major social impacts have been identified: "contribution to environmental issues," "contribution to energy and resources issues," "readiness for an aging society," and "improvement of social infrastructure and disaster management."

One social impact deriving from "Synchrotron Radiation Technology" is the improvement of Japan's international position by having the world's most advanced facility (SPring-8), which has even brought the cultural impact of solving archaeological mysteries with its analysis functions. In the area of "Parallel Supercomputers with High Processing Speed," political impacts such as influence on Japan-US trade friction and the US science and technology policy (achievement of the world's fastest computing speed by the Earth Simulator influenced US policy) have been identified. Chart 23 lists examples of the social impacts found through the case studies.

Chart 23 Examples of the social impacts

Impact type	Description of examples	
Contribution to environmental issues	(Fluorocarbon/Halon Substitutes) (Recycling) (Fuel-Cell Vehicle) (CO_2 Separation, Collection, & Isolation) (Melting Furnace)	Prevention of ozone layer depletion (fulfillment of international agreements) Further waste reduction (cars, home appliances, etc.) (760,000 t/year) Potential for a 0.5% CO_2 emissions reduction from the current level (6 mil. t- CO_2/year by 2020) Potential for a 0.8% CO_2 emissions reduction from the current level (10 mil. t- CO_2/year by 2015) Potential reduction in final disposal waste amount
Contribution to energy and resource issues	(Photovoltaic System) (Liquefied Gas Fuel)	In use by 220,000 households (world's No. 1); Potential increase in domestically produced energy (share of electricity production: now 0.1%→10% by 2030) Potential reduction in dependence on oil through diversification of energy sources
Readiness for an aging society	(Regeneration Medicine) (Rehabilitation Robots)	Potential improvement of the possibility of complete recovery from disease Potential relief of the burden on both care givers and care receivers
Improvement of social infrastructure and disaster management	(Earthquake Motion Simulation) (Remote Sensing) (Disaster Prevention System)	Improved protection of roads, bridges, buildings and houses from earthquakes More effective disaster response and management by distributing information on the occurrence of and damage from earthquakes, fires, etc. Potential for greater urban safety against earthquakes (fire prevention, early recovery of city functions)
Other	(Parallel Supercomputer) (Synchrotron Radiation) (Gene-Manipulated Crops)	Influence on U.S. science and technology policy (achievement of the world's fastest computing speed by the Earth Simulator influenced U.S. policy) The world's most advanced facility (SPring-8) has improved Japan's international position and has even been applied to archaeological studies. Potential contribution to the world food crisis and improvement of food production (Food production in arid regions and salt-damaged land in China, Africa, etc.)

(Impacts on people's lives)

Four major impacts on people's lives have been identified: "ensuring people's lives and living," "maintenance and recovery of people's health," "improvement of public comfort and convenience," and "transformation of people's awareness and lifestyles." Chart 24 lists examples of the impacts on people's lives found through the case studies.

Chart 24 Examples of impacts on people's lives

Impact type	Description of examples	
Ensuring people's lives and living	(Helical CT Technology) (Quasi-Zenith Satellite System)	Improvement of curative effect through the early detection of lung cancer Potential reduction in disasters, accidents, crimes and other damage through position detection of children and elderly people
Maintenance and recovery of people's health	(Base Sequencing Technology) (Microreactor)	Potential for the cure of intractable diseases and treatment without side effects Potential for easing the examination burden through fast, extensive lab examination and for simplifying self/daily examination by patients
Improvement of public comfort and convenience	(Photocatalytic Materials) (Lithium Batteries) (ITS Technology)	Cleaner and more comfortable lives through the use of soil-resistant tiles and anti-fogging car mirrors Improved portability with smaller, lighter electronic products (mobile handsets, mobile PCs, etc.) Potential for traffic congestion mitigation, improved driver comfort, and easier payment at gas stations, parking lots, and drive-through facilities.
Transformation of people's awareness and lifestyles	(Photovoltaic System) (Recycling)	Enhancement of energy conservation awareness Enhancement of recycling awareness

2.3. Contribution of public R&D and support to impact generation

Our 32 case studies revealed the following four types of contribution made by public R&D and support. These findings suggest the importance of indirect public sector contribution through procurement and research infrastructure building (Types (3) and (4) below), in addition to direct contribution through investment in R&D (Types (1) and (2)).

(1) Public R&D and support for basic research

Examples: Basic research projects conducted at universities and public research institutes produced technology seeds; Elucidation of principles at universities and public research institutes accelerated technological advancement; Continuous basic research activities helped the development of human resources and the accumulation of scientific knowledge, and laid the foundations of national projects.

(2) Public R&D and support in line with technological development and trends

Examples: National projects helped technologies to catch up with the world standard; Technological impacts were derived from appropriate policy adjustments to technological development; Effectiveness of technologies was verified through field-testing.

(3) Public R&D and support for basic technology and technological infrastructure

Examples: The construction of the world's highest-level facility helped improve the research environment; Observation networks and databases were constructed according to government missions in weather forecasting, disaster prevention, etc; The construction of basic technologies and technological infrastructures (standards, performance evaluation methods, etc.) vitalized nationwide R&D and promoted private sector business activities.

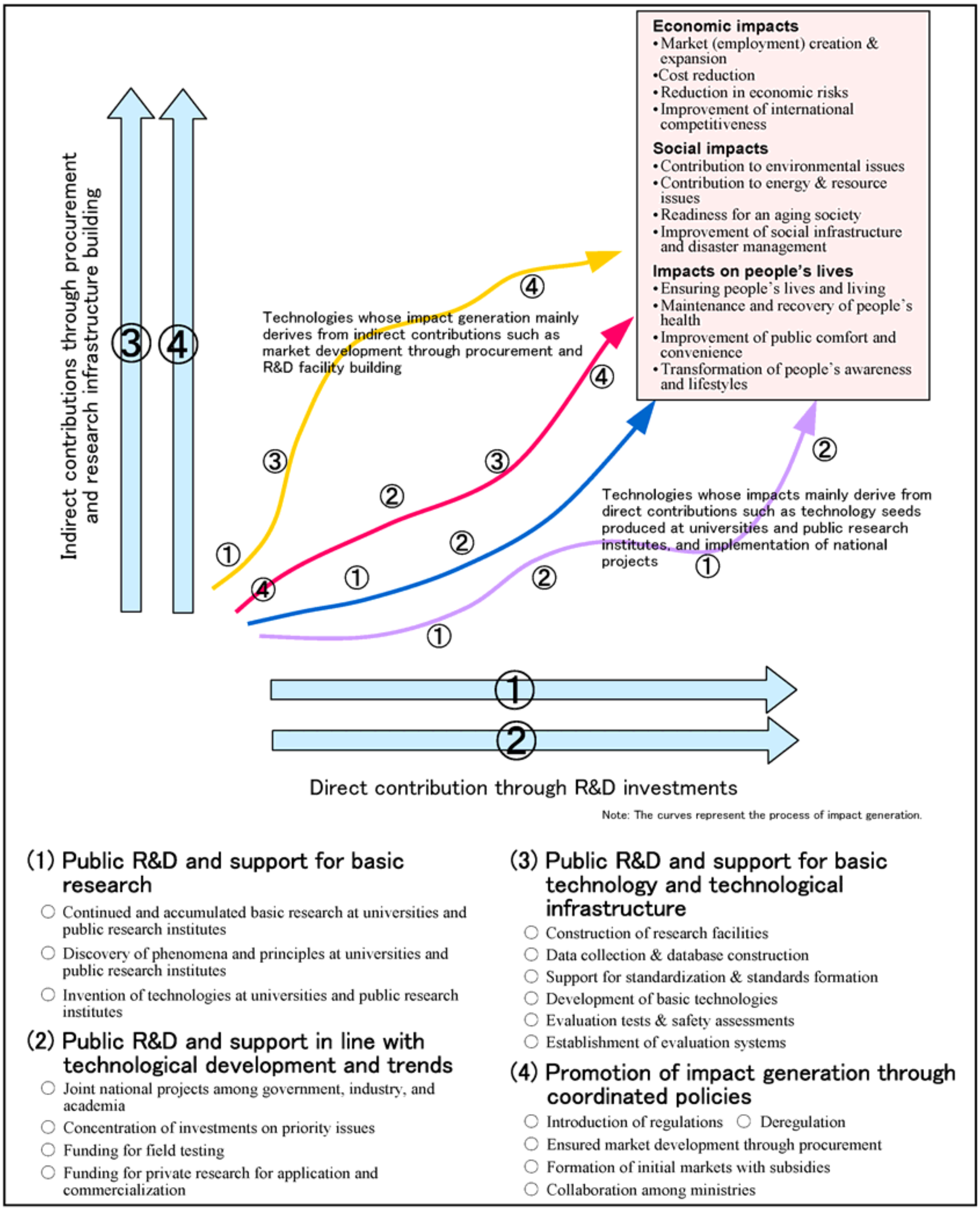
(4) Promotion of impact generation through coordinated policies

Examples of the impacts generated through coordination between R&D and non-R&D policies: The introduction of and relief from regulations promoted R&D; Government procurement enabled continuous R&D in certain areas; Subsidiary programs helped certain initial markets to form.

The process in which a technology realizes impacts can be represented by diverse paths such as the linear model and the chain model. The above four types of public R&D and support have contributed to pratical impact realization in many different ways according to the nature of the technology.

Note that these four public measures cannot work effectively if implemented independently. In addition to implementing them, the government should plan its "PATH" towards achieving the goal (socio-economic impact) and, while promoting R&D along this path, constructing an environment that allows impact generation (see Chart 25). For example, concerning urgent issues such as the environment, the declining birthrate, the aging society, and other social problems, the government should occasionally analyze its systems to identify the factors restricting impact realization. In addition, public R&D and support programs should be sufficiently flexible to respond to fast technological advancement and rapid change in the social environment.

Chart 25 The role of public R&D and support



As Charts 26 and 27 show, at least one of the above four types of public R&D and support made a large contribution to 24 out of the 32 cases studied and a moderate contribution to 7 cases, although the way of contribution varied depending on the nature of the technology. This demonstrates that public R&D and support play an essential role in the development of science and technology and in helping technologies to realize impact.

While Types (1) to (3) indicated similar trends in the contribution to impact generation between current and future technologies, Type (4) contributed primarily to current technologies. This difference can be attributed to future technologies still being in their development phase, making it too early for the government to promote impact generation.

Chart 26 Contribution of public R&D and support to identified current technologies (Large: ○, Moderate: △)

Field	Technology	Public R&D and support for basic research	Public R&D and support in line with technological development and trends	Public R&D and support for basic technology and technological infrastructure	Promotion of impact generation through coordinated policies
Life sciences	Helical CT Technology (Application to Early Diagnosis of the Lung Cancer)	—	△	—	—
	High-Throughput Detection of Single Nucleotide Polymorphisms and Its Application for Diagnosis and Personalized Medication	△	○	○	—
ICT	Parallel Supercomputer with High Processing Speed	—	△	○	○
	ITS (Car Navigation, VICS, ETC, and Traffic Management, etc.)	—	△	○	○
Environment	Alternative Materials to Fluorocarbons and Halons that do not damage the ozone layer and cause global warming	△	△	○	○
	Elucidation Technologies for Human and Wildlife Health Effects of Endocrine Disrupters	○	—	—	—
Nanotechnology & materials	High-Density, Long-Life Lithium Battery Technologies	—	—	—	—
	Photocatalytic Materials	○	○	—	—
Energy	Photovoltaic System for Houses	△	○	△	○
	Liquid Fuel Production from Natural Gas and Other Gas Sources, and Its Application (GTL, DME)	△	△	—	—
Manufacturing	Recycling Technologies for End-of-Life Vehicles and Electronic Waste	—	△	—	○
	Laser Processing Technology	△	○	△	—
Social infrastructure	Technology for Regional Weather Forecasting	○	—	○	△
	Simulation Technology on Earthquake Motion	○	—	○	○
Frontier	Remote-Sensing Technology (Analysis and Application of Remote-Sensing Data)	△	—	△	—
	Synchrotron Radiation Technology	△	—	○	—

Chart 27 Contribution of public R&D and support to identified future technologies (Large: ○, Moderate: △)

Field	Technology	Public R&D and support for basic research	Public R&D and support in line with technological development and trends	Public R&D and support for basic technology and technological infrastructure	Promotion of impact generation through coordinated policies
Life sciences	Technologies for Utilizing Cultured Tissues from Stem Cells as Material for Artificial Organs or Tissues	○	○	—	—
	Creation Technology of Cold-Resistant, Drought-Resistant, and Salt-Tolerant Crops by Gene Manipulation	○	△	○	—
ICT	Perpendicular Magnetic Recording Technology (for Hard Disk Drive)"	○	—	—	—
	Ubiquitous Network	△	△	○	—
Environment	Gasification Melting Furnace and Ash Melting Furnace Technologies for Waste Disposal	—	△	△	○
	Separation, Collection, and Isolation Techniques of Carbon Dioxide	—	○	—	—
Nanotechnology & materials	Carbon Nanotube Devices	○	△	—	—
	High-Temperature Superconducting Materials	○	○	—	—
Energy	Hydrogen Storing Alloy	○	○	—	—
	Fuel Cell Vehicle	—	△	△	—
Manufacturing	Microreactors for Chemical Synthesis	△	△	△	—
	Rehabilitation Robot	△	△	△	—
Social infrastructure	Disaster Prevention System Based on a Nationwide Network for Detecting Earthquake	○	△	○	—
	High-Efficiency Processes for Treating Refractories and Hazardous Materials Using Biotechnology-Based Waste Water Processing Systems	—	—	△	○
Frontier	Offshore Oil Rig Technology	—	△	△	—
	Quasi-Zenith Satellite	△	—	○	—

2.4. Representative achievements of national / public universities and public research institutes

A questionnaire survey was conducted to identify the representative achievements (or major advances) made at national universities and public research institutes, which are the major destinations of government R&D investment during the terms of the First and Second Basic Plans. The numbers of, and the responses from institutes were shown in Chart 28.

Chart 28 Response to the questionnaire survey

	Institutes surveyed	Response	
		No. of institutes	No. of representative achievements
National & Public universities (incl. inter-university research institutes)	103	77	566
Public research institutes	56	31	282
Total	159	108	848

Of the 848 R&D results given by the respondents, 48 examples have been selected from the viewpoint of easy understanding of the results, listed in Chart 29. The list demonstrates that the science and technology achievements at national / public universities and public research institutes have not only brought new principles, new discoveries, and major inventions but also included extensive and diverse values, such as contributing to people’s lives and communities, contributing to the international society, and to the creation of new markets and new businesses. Chart 30 describes a few representative R&D results of Chart 29.

Chart 29 Representative achievements (major advances) of national/public universities and public research institutes

Major values	Achievement	Institute
New principles/new discoveries/major inventions	A dramatic development in particle physics initiated by the exploration of neutrino astrophysics	U. of Tokyo
	Comparative cognitive science research: An evolutionary understanding of the human mind through comparative studies on primates (e.g. the knowledge and techniques acquired by the chimpanzee, the human being's "evolutionary neighbor," and their intergenerational transfer")	Kyoto U.
	The construction of the Subaru Telescope and the elucidation of the universe	National Astronomical Observatory of Japan, National Institutes of Natural Sciences
	Genomic analysis of rice: Achievement of complete rice genome sequencing	National Institute of Agrobiological Sciences
	Knowledge media technology: Remanipulation and redistribution media technology for knowledge linking, integration, and reuse	Hokkaido U.
	Essential cancer elucidation and the development of methods for cancer prevention, diagnosis, and treatment	National Cancer Center Research Institute
	Promotion of particle physics research using the B Factory	High Energy Accelerator Research Organization
	The derivation of human ES cells and the establishment of their distribution system	Kyoto U.
	Development and operation of engineering test satellite "Orihime/Hikoboshi": Development and orbital experiment of an automatic rendezvous & docking system	Japan Aerospace Exploration Agency
	Cerebral memory mechanism elucidation: Scientific research of memory	U. of Tokyo
	Development of organic EL materials and devices with high efficiency and long life	Yamagata U.
	Development of a high-speed atomic force microscope: Real-time monitoring biological molecules in a solution	Kanazawa U.
	Terabit information nanoelectronics research and development	Hiroshima U.
	New developmental engineering techniques for fish using germ cells	Tokyo University of Marine Science and Technology
Development of new research areas	Discovery of the new 113th element through the development of accelerator science research	RIKEN et al.
	Fusion between biological science and information science: Development of new information technologies from knowledge of the living world	Osaka U.
	Project for the development of a high-speed three-dimensional bio-micromanipulation system	Nagoya U.
	Promotion of the exploitation of the space environment, esp. the International Space Station	Japan Aerospace Exploration Agency
	Development of advanced comprehensive medicine for radiation disasters	Hiroshima U.
	Optical bioinstrumentation and diagnosis technology research	U. of Electro-Communications et al.
R&D infrastructure building	The Earth Simulator: Achievement of the world's fastest computing speed	Japan Agency for Marine-Earth Science and Technology et al.
	Silicon Sea Belt project: Construction of a center of system LSI design & development	Kyushu U. et al.
	Analysis of fuel cell degradation factors and establishment of the accelerated life testing method	U. of Yamanashi
	Development of an NMR magnet with the world's highest resolution	National Institute for Materials Science
	Technical support for the construction of the Cultural Heritage Online	Research Organization of Information and Systems, National Institute of Informatics

(Continued to the next page)

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Major values	Achievement	Institute
Contribution to the environment & society	Production of biodegradable plastic from raw garbage	Kyushu Institute of Technology
	Development of a micro wind-power generation system with a windbreak effect	Saitama U.
	Ozone layer monitoring with satellite sensors: Elucidation of the ozone destruction mechanism in the Northern and Southern Hemispheres	National Institute for Environmental Studies et al.
	A worldwide integrated model for global warming prevention: An impact on international climate change policy	National Institute for Environmental Studies et al.
	Development of a cloud-resolving storm simulator: Quantitative prediction of rain/snow storms	Meteorological Research Institute
	DNA identification system: Construction of a new identification system based on automatic analysis	National Research Institute of Police Science
	Elucidation of climate/environmental change based on the ice-sheet core	National Institute of Polar Research, Research Organization of Information and Systems
	A high-temperature engineering test reactor as Japan's first high-temperature gas furnace: Establishment of a technology to prepare the way for diversified utilization of nuclear energy	Japan Atomic Energy Research Institute
	Surface observation regardless of time and weather: Development of a high-resolution airborne imaging radar	National Institute of Information and Communications Technology
	Commensal microorganism-assisted revegetation of the land affected by the pyroclastic flow at the Unzen-Fugendake eruption and scientific assessment of the effect	Yamaguchi U.
	Investigation of sunken tankers and discovery of fallen rocket parts through deep-sea observation and exploration	Japan Agency for Marine-Earth Science and Technology
Contribution to people's lives & communities	Cancer treatment with the Heavy Ion Medical Accelerator	National Institute of Radiological Sciences
	Elucidation of the mother-to-child transmission path of the adult T-cell leukemia virus and regional carcinogenesis solution through transmission prevention	Nagasaki U.
	Development of the GPS-assisted snow removal support system in the Shiretomo Path	Kitami Institute of Technology
	Development of technology to apply diamond-like carbon film: Development of low-friction, high-abrasion materials through community-based industry-academia collaboration	Tokyo Institute of Technology
Contribution to the international society	Development of an antipersonnel landmine detector and its application in Afghanistan	Tohoku U.
	Development of immuno/molecular diagnostic techniques for intractable parasitosis: Application to immunology and technology transfer to epidemic countries	Asahikawa Medical College
Creation of new markets / businesses	Proposal and establishment of catalyzed asymmetric synthesis methods: Discovery, development and industrialization of practical catalyzed asymmetric synthesis methods	Nagoya U. et al.
	Development of large-diameter, high-density plasma processing equipment: Commercialization of low-damage, energy-efficient semiconductor processing equipment	Tohoku U.
	Development of Ti-Ni shape-memory alloys and a new industry related to them	University of Tsukuba
	Functional triazine dithiol: Nano-thin film application technology	Iwate U.
	Industrialization of MEMS technology: Technology transfer to the private sector and regional industry promotion	Tohoku U.
	Development of basic technologies for fast charge/discharge lithium ion secondary batteries	Yamagata U.

Chart 30 An example of achievements of national/public universities and public research institutes

Ai and her son even help researchers solve the mysteries of the human mind.

Comparative cognitive science research:

An evolutionary understanding of the human mind through comparative studies on primates (e.g. the knowledge and techniques acquired by the chimpanzee, the human being's "evolutionary neighbor," and their intergenerational transfer")

(Kyoto University)

Prof. MATSUZAWA Tetsuro with Ai and her son
http://www.pri.kyoto-u.ac.jp/ai/

The Primate Research Institute, Kyoto University, has been conducting research on the intelligence and cognition of the chimpanzee at its domestic laboratories and the animal's natural habitat in Africa. In the research project called the "Ai Project," the world as seen by the chimpanzee has been demonstrated using numbers and letters as a medium. A major discovery in implementing its basic plan has been that the chimpanzee's capacity to instantly memorize numbers is as strong as that of a human adult. In this project, researchers have also observed that chimpanzees use stone and many other tools in African forests and found that such knowledge and techniques are passed on to the next generation as cultural traditions.

By comparing human beings with their allied species, researchers have developed a research area known as "comparative cognitive science," a discipline that explores the evolutionary origin of human nature. In light of the research results on developmental changes such as imitation, observation learning, and attachment, they have shown how humans are innately equipped to learn, educate, and to build a parent-child relationship and foster companionship.

Based on their academic findings, researchers at the institute have published books on the developmental foundations of human nature so that the public can learn about it. Some of the books for non-professionals are used at school as learning materials.

Data on this research

Leader: MATSUZAWA Testuro, Professor at the Language and Intelligence Section, the Primate Research Institute, Kyoto University

Major public funds for promotion:

- Grant-in-Aid for Specially Promoted Research "The chimpanzee's acquisition of language and cognitive ability and its intergenerational transfer" (FY 1995-1999)
- Grant-in-Aid for Specially Promoted Research "Primate-originated foundations of cognition and behavior" (FY 2000-2004)
- Grant-in-Aid for Specially Promoted Research "Primate-originated foundations of thinking and learning" (FY 2004-)

Awards given for the research results

Medal with Purple Ribbon (2004), Chunichi Culture Award (2004), Japanese Society of Neurology Tokizane Memorial Award (2004), Jane Goodall Award (2001), Japanese Psychological Association Research Encouragement Prize (1998), Nakayama Award Special Prize (1996)

1－1（Continued of Chart30）

Let’s elucidate the riddles in the origins of the universe with a large accelerator

Promotion of particle physics with “B factory”

(High Energy Accelerator Research Organization)

The Belle detector
http://www.kek.jp/kids/closeup/b-news/b-factory.html

The B factory program utilizes an electron-positron collider-accelerator, and observes the decay of the b-mesons and anti-b-mesons generated. The experiment will make clear the violation of natural symmetry (violation of CP symmetry) that may constitute different physical laws for matter and antimatter. It is intended to contribute to radical progress in particle physics. Construction of tools began in 1994, and the High Energy Accelerator Research Organization (KEK) began the experiment in 1999. KEK has worked to upgrade the performance of the accelerator and the Belle detector, achieving the world’s top class of luminosity (number of collisions), which indicates the performance of collider-accelerators. As a result, b-mesons and other relevant particles have been generated in massive amounts, and in 2001, it was demonstrated with 99.999% certainty that CP symmetry violation exists in matter and antimatter in b-meson collision.

In current particle physics, there is a great mystery; whether matter and antimatter, believed to be present in equal amounts when the universe began, transformed into a world only of matter through CP symmetry violation. The Kobayashi-Masukawa model, published in 1973, is regarded as the best model explaining the violation of CP symmetry. It is hoped that KEK’s experiment will verify the model.

In addition, the B factory accelerator has contributed to the discovery of various types of new particle, which had been difficult in the past.

Data on this research

Major promoting organizations:

KEKB Accelerator Team, High Energy Accelerator Research Organization,
Belle Experimentation Group (international joint project comprising approximately 400 researchers from over 50 universities and research institutions in 13 countries and territories)

Awards for achievement:

American Institute of Physics Robert R. Wilson Prize (2004), 47th Nishina Memorial Prize (2001), 20th Inoue Prize for Science (2003), 24th Saruhashi Prize (2004), 7th Society of Japanese Women Scientists Encouragement Prize (2002), etc.

Summary 2: Science and technology development and its impacts

1. Diverse impacts of science and technology

   Our in-depth technology case studies revealed that the technologies related to the eight fields listed in the Second Science and Technology Basic Plan have had large impacts on the economy, society, and people's lives in many different ways.

2. Significance of the public sector

   Although the way of contributing varies depending on the nature of the technology, the public sector often assumes diverse and essential roles in the process of the ultimate impact generation (process of science and technology realization). To further enhance the impacts of science and technology promotion on the economy, society, and people's lives, public R&D and support need to be expanded toward the future. Our analysis also demonstrated that what the science and technology achievements at the national universities and public research institutes have brought is not limited to new principles, new discoveries, and great inventions. Rather, they include extensive and diverse effects, such as contribution to people's lives and communities, contribution to the international society, and the development of new markets and new businesses.

3. Significance of basic research

   While the process through which a technology generates an impact can follow various paths, extensive basic research is essential to any path. In other words, basic research needs to be diverse and continuous. Basic research activities contribute to impact generation by providing technology seeds, elucidating principles to facilitate private sector technology development, and fostering human resources.

4. Planning the "path" to the "goal"

   The government should plan its "path" to the "goal" (socio-economic impacts) and, while promoting R&D along the path, construct an environment that allows impact generation. For example, regarding urgent issues such as the environment, the declining birthrate, the aging society, and other social problems, the government should occasionally analyze its systems to identify the limiting factors of impact generation. In addition, public R&D and support programs should be sufficiently flexible to respond to fast technological advancement and rapid change in the social environment.

5. Significance of public procurement and research infrastructure building

   In the process of impact generation by technologies, the public sector's indirect contribution through its procurement and research infrastructure building is as important as its direct contribution through investment in R&D. In particular, public procurement, through which the government actively introduces new technologies, contributes largely to impact generation by technologies in that it makes the market large enough for private companies to continue technology development. In the future, procurement should be given a specific role as an industry-oriented means of promoting R&D.

3. Holistic overview of development by field and area

3.1. Social and economic needs regarding science and technology

In recent years, the necessity in the promotion of science and technology policy for approaches that reflect the needs of the society and the economy benefiting from science and technology results has been growing. Our Study on Social and Economic Needs focuses on the public, and samples and arranges areas of need. In addition, it adopts participatory processes and projects the next 30 years, overviewing socio-economic needs whose realization should be given priority. As part of the process, the perspective of industry on science and technology is also included.

As the basic design of this survey, the public's perspectives on "must haves" and "luxuries" were sought. Indeed, envisioning potential results of science and technology seeds such as rockets and robots should be further promoted to foster intellectual curiosity and raise hopes for the future. On the other hand, with global problems such as terrorism and conflict as well as the worsening deterioration of the natural environment, preserving the right to health and personal freedom enjoyed in developed societies is growing more difficult. Under these circumstances, construction of “an ideal society” would naturally require not only pursuing a utopian future, but also addressing these problems facing society.

Against this backdrop, Internet surveys and interviews with relevant parties, as well as panels of citizens, business executives, and experts, were used to extract categories of need for a future society. They were then arranged in 12 clusters of similar content (see Chart 31). These 12 needs for the future include not only those to which science and technology will strongly contribute, but also, as can be seen in XI and XII, the categories requiring initiatives of concerning in addition to science and technology.

We conducted a trial analysis of the relevancy of the type of contribution to meeting these needs by grasping which science and technology fields and areas will include initiatives to realize these need categories (see Reference Material 5). Three future scenarios were set, and for each of them, different priorities were assigned to the need categories. The areas identified through the analysis as making a direct contribution belonged to the fields highly relevant to the emphasized needs of the assumed future, e.g., areas in the health, medicine, and welfare field when health was emphasized. Regarding indirect contributions, areas in the information and communications, electronics, frontier, industrial infrastructure, and social infrastructure fields were extracted for all three scenarios. This demonstrates that these fields are fundamental and required to fulfill the various needs.

Chart 31 Need list

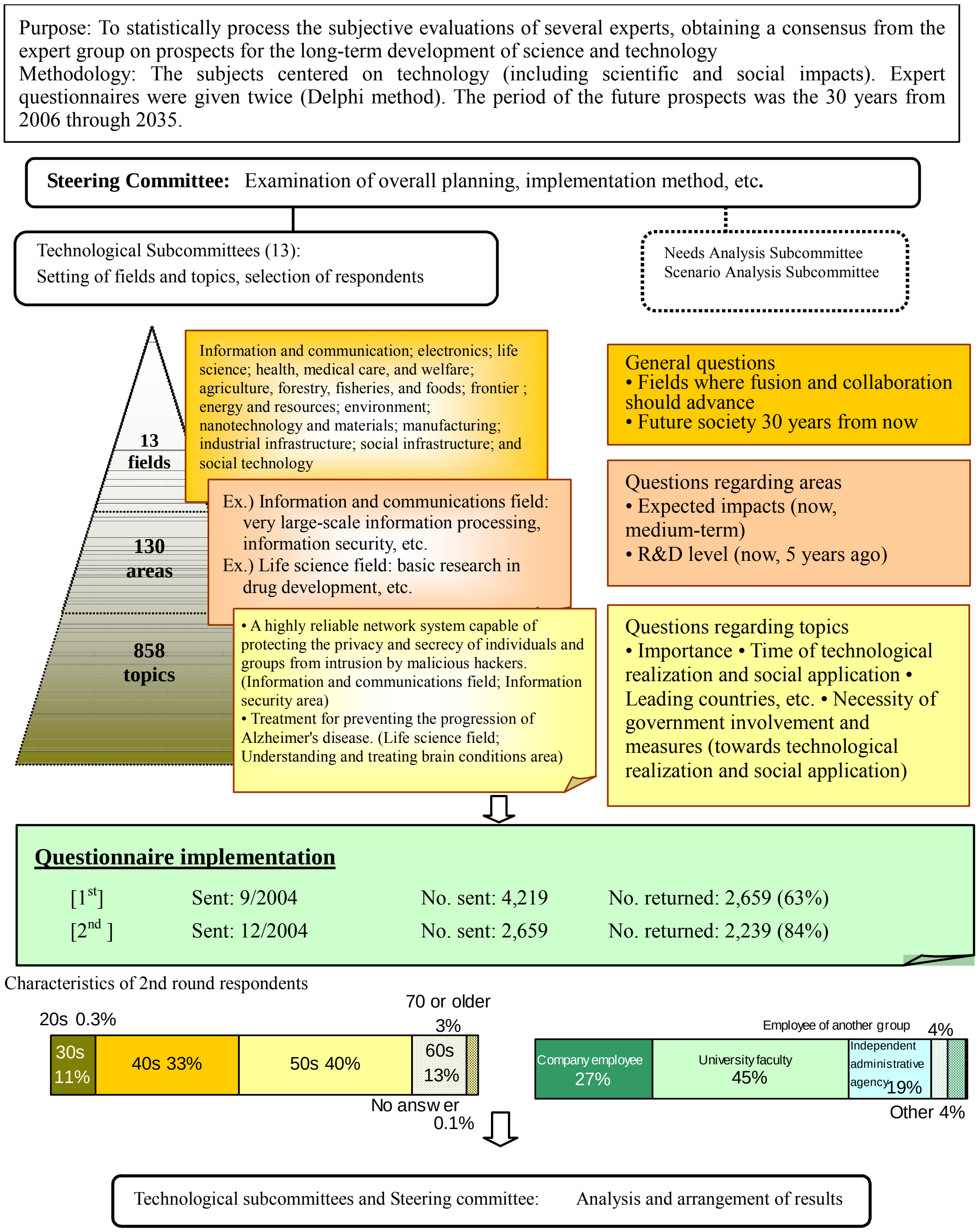
Categories	contents
I. Japan continues as a leader in scientific and technological achievement.	1) Achievements have a major impact on world science and technology development.
	2) Japan's scientific and technological achievements are demonstrated to the world.
	3) Japan contributes as a venue for training international personnel in various fields.
	4) Japan transmits its unique culture to the world.
	5) The Japanese are internationally active. (Citizen panel)
	6) Japan has the ability to speak up in the global community. (Industry panel)
II. Build hopes and dreams by seeking the challenge of uncharted science and technology territory.	1) Contribute to creating human knowledge by seeking the unknown.
	2) Provide dreams for the future through scientific and technological achievement.
	3) Dreams and hopes provide a sense of emotional richness.
III. Actively contribute to solving global problems.	1) Respond to global environmental problems (global warming, ozone layer destruction, tropical deforestation, pollution in developing nations, acid rain, desertification, loss of biodiversity, marine pollution, cross-border transportation of toxic waste, etc.).
	2) Respond to other global issues (food issues, energy issues, freshwater management, disease countermeasures, disaster prevention and damage mitigation, etc.).
	3) Respond to the social issues humanity faces in conjunction with globalization (issues related to ethnicity, religion, inner life, social norms and systems, etc.).
IV. Japan maintains its international economic competitiveness by pioneering new industrial fields.	1) Utilize high-quality manufacturing technology and energy conservation technology for innovation in basic and key industries.
	2) Take the initiative in creating international standards so that Japan can make internationally competitive products.
	3) Expand and develop the world market for Japanese cultural products such as fashion, music, and animation.
	4) Appropriately utilize new technology fields (nanotechnology, etc.).
	5) Create environments that generate leading-edge technology (Silicon Valley, etc.).
	6) Improve Japan's complicated, and expensive distribution system.
	7) Make it easy to start companies and possible for those whose companies fail to recover.
	8) Limit the degree of manager responsibility, becoming a society where it is easy to take risks.
	9) Utilize Japan's knowledge and expertise internationally (utilization of intellectual assets).
	10) Create a business vision in accordance with diversification of consumption (emphasize consumption by individuals).
	11) Enhance business person education (basic education on human communication; personnel familiar with science and technology, business, and legal practice).
V. Build new frameworks aiming for a sustainable social system (including urban-rural links and the preservation of primary industries).	1) Establish a cyclical social system in which manufactured items are returned to nature.
	2) Arrange mechanisms for the rational distribution of water, food, and energy.
	3) Develop industry that reuses, recycles, and returns manufactured items to nature.
	4) Pass on traditional techniques and foster personnel in industries supporting social infrastructure (nuclear power, steelmaking, etc.).
	5) The role of primary industries (agriculture, fishing, etc.) is reevaluated and their management is reorganized.
	6) Food self-sufficiency is enhanced (agricultural production is promoted with government backup).
	7) Self-sufficiency is possible without relying on a vast distribution system (local production for local consumption).
	8) Establish an industrial style that partners the local area while responding to the global market.
	9) Regional areas can become independent by utilizing the bounties of nature (e.g., use of hot springs).
	10) Prepare comfortable living environments (garden-city plans, etc.).
	11) Regional areas and progress are revitalized through citizen participation with attention paid to rural society and the environment.
	12) Promote urban-rural exchange (promote farm village tourism).
VI. Respond to changes in social structure (respond to the declining population due to the low birthrate and the aging society).	1) Strengthen education and reeducation systems in response to highly advanced science and technology and social systems.
	2) Enable senior citizens to make the most of their abilities.
	3) Prepare a flexible, diverse employment system, promoting personnel fluidity.
	4) Improve the environment for accepting foreign nationals (promotion of cross-cultural understanding, improvement of living conditions for foreigners in Japan).
	5) Achieve a society in which men and women are substantively equal.
	6) Prevent the declining birthrate (prepare an environment making it easy to bear and raise children).

Categories	contents
	7) People mutually accept diverse religions, cultures, and values.
	8) Pass on Japan's traditional and unique culture.
VII. Society is peaceful, safe, and provides peace of mind (prevent traffic accidents, crime, and terrorism).	1) Build a society and transportation system in which traffic accidents are rare.
	2) Build up security systems to prevent crime and terrorism.
	3) Build up protection systems to mitigate harm due to traffic accidents, crime, and terrorism.
	4) Prevent war.
	5) To maintain social order, use a science and technology perspective to show the direction in which human society should move (enlighten people concerning attitudes that lead to crime and terrorism).
VIII. Resistant to disasters	1) Prepare social infrastructure that is resistant to accidents and disasters and that makes it difficult for secondary and tertiary damage to occur.
	2) Short-term and regional long-term forecasting and prediction of weather and accidents is possible.
	3) The location and scale of accidents and disasters can be immediately grasped.
	4) Accidents and disasters can be immediately responded to, enabling rescue and prompt restoration of normal life.
IX. Able to live a healthy life	1) Medical services are enhanced by developing new medical technology.
	2) Individuals obtain appropriate information regarding their healthcare and selecting treatment methods, etc.
	3) Support for individual health maintenance efforts (self-supervised)
	4) Long, physically and mentally healthy lives can be enjoyed.
X. Individual potential expands, enabling people to experience the comfortable of life.	1) There are no worries about securing employment and income.
	2) Elderly people and people with disabilities can live independently.
	3) Various career courses are available.
	4) People have opportunities to participate in society based on individuality (people are not excluded due to age or disability).
	5) Job opportunities for the young generation are created.
	6) Living environments become more convenient.
	7) Achieve a society in which men and women are substantively equal.
	8) People live in long-lasting, roomy homes (liberation from the burden of home loans).
	9) Human life is balanced with work life, home life, and social life.
	10) The cost of living is lower, and people do not need to work to eat (work is enjoyable).
XI. Everyone is fulfilled at home and as part of society; people fulfill their various roles and support one another.	1) Reexamine the pursuit only of freedom, ego gratification, and convenience and aim for a society with standards.
	2) Be content with what one has.
	3) Mental health is maintained, and people have reasons for living (fewer than 30,000 suicides).
	4) Children have dreams and are allowed to spend their childhoods being children.
	5) People value family and personal relationships.
	6) Young people have rewarding, responsible roles and are socially independent at an early age.
	7) Partnerships among local residents are renewed.
XII. Children and adults learn purposefully, developing true scholastic ability.	1) All people prepare frameworks to foster scientific rationality.
	2) The quality of education is improved, with education that fosters true scholastic ability.
	3) A society with high academic ability by international standards is achieved (expanded funding of higher education).
	4) Education is deregulated, providing individualized, diverse educational opportunities.
	5) Places of learning and places to apply learning are closely connected.
	6) Establish new educational learning methods in which children enjoy learning.
	7) Build educational systems and environments that enhance children's intellectual ability.

3.2. Delphi Analysis

To grasp the direction of technological development over the coming 30 years, we surveyed experts utilizing the Delphi method. The same questions were repeated in the second questionnaire to draw a consensus from the respondents. Because the second questionnaires were sent with the respondent answers from the first questionnaire for reevaluation, opinions converged. The flow of the survey is depicted in Chart 32.

Chart 32 Survey flow chart



3.2.1. Forecast timeline of the most important topics

Of the 858 topics covered in the Delphi Analysis, the 15 percent with the highest priority in each of the 13 fields were selected, and their forecast time of social application were placed on a timeline as shown in Chart 33.

The information and communications and industrial infrastructure fields have a relatively high number of topics with expected early social application, i.e., by 2015. On the other hand, life science, health, medical care, and welfare, and agriculture, forestry, fisheries and foods have relatively more topics expected to be applied later, no earlier than 2015.

- Degree of importance to Japan
  - Select one from Very Important, Important, Somewhat Important, Not Important (including unnecessary, should not be implemented).
  - Regarding the degree of importance to Japan, the responses were scored in the same way as the previous survey (100-point maximum) to enable comparison.
    Importance Index= (no. of "Very Important" x 100 + no. of "Important" x 50 + no. of "Somewhat Important" x 25 + no. of "Not Important" x 0) ÷ no. of responses on importance (non-responses not included)
- Time of social application
  - For the time of social application, select one from "2006–2010," "2011–2015," "2016–2025," "2026–2035," "2036 or later," "Will not be applied," "Do not know."
  - The halfway (median) value of all responses is used as the time of realization.

Regarding the notation of the results, for the time (year) of realization, all decimals were discarded. Regarding the degree of importance, decimals were rounded to the nearest whole number.

Chart 33 Forecast timeline of the most important topics

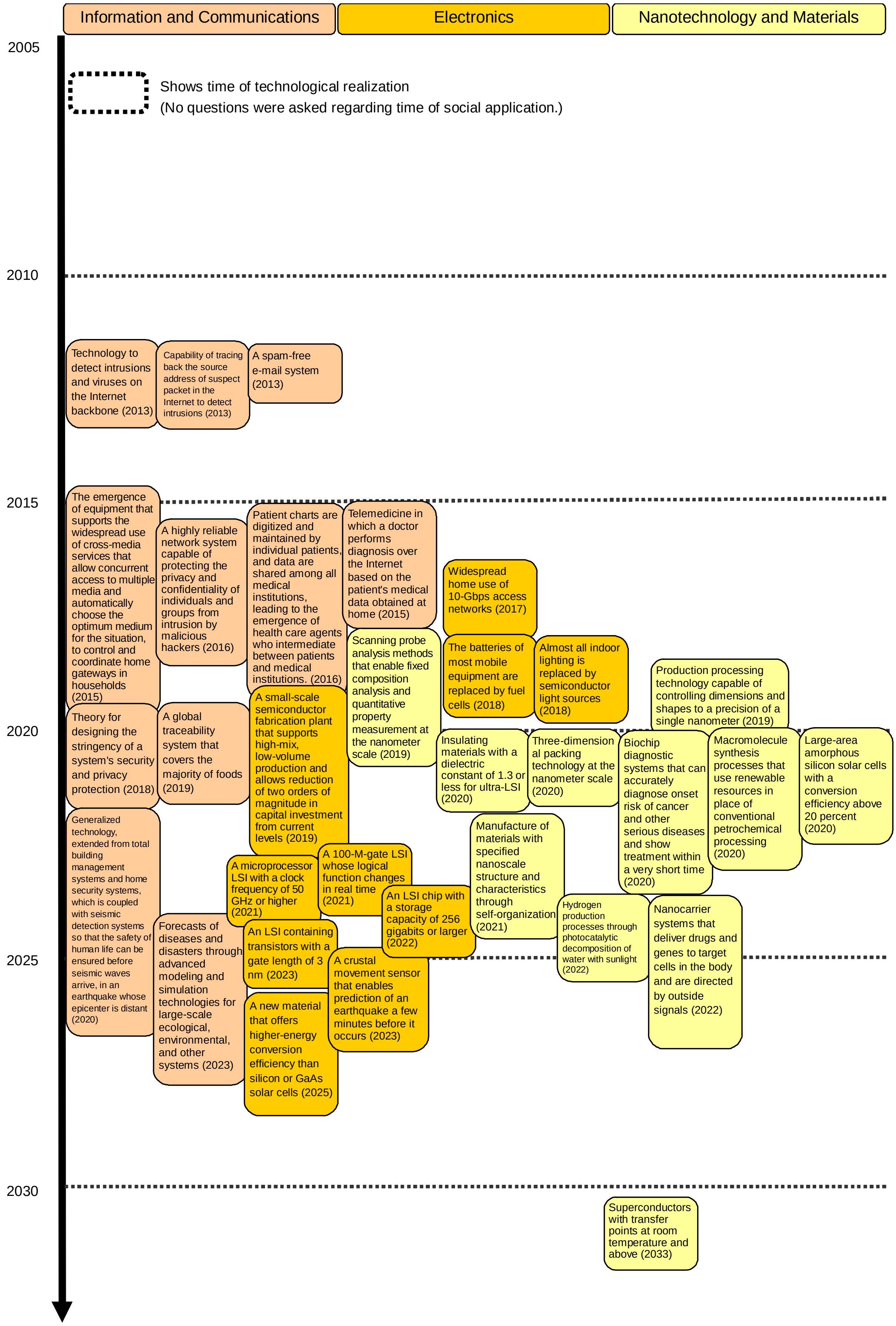


Chart 33 Forecast timeline of the most important topics (continued)

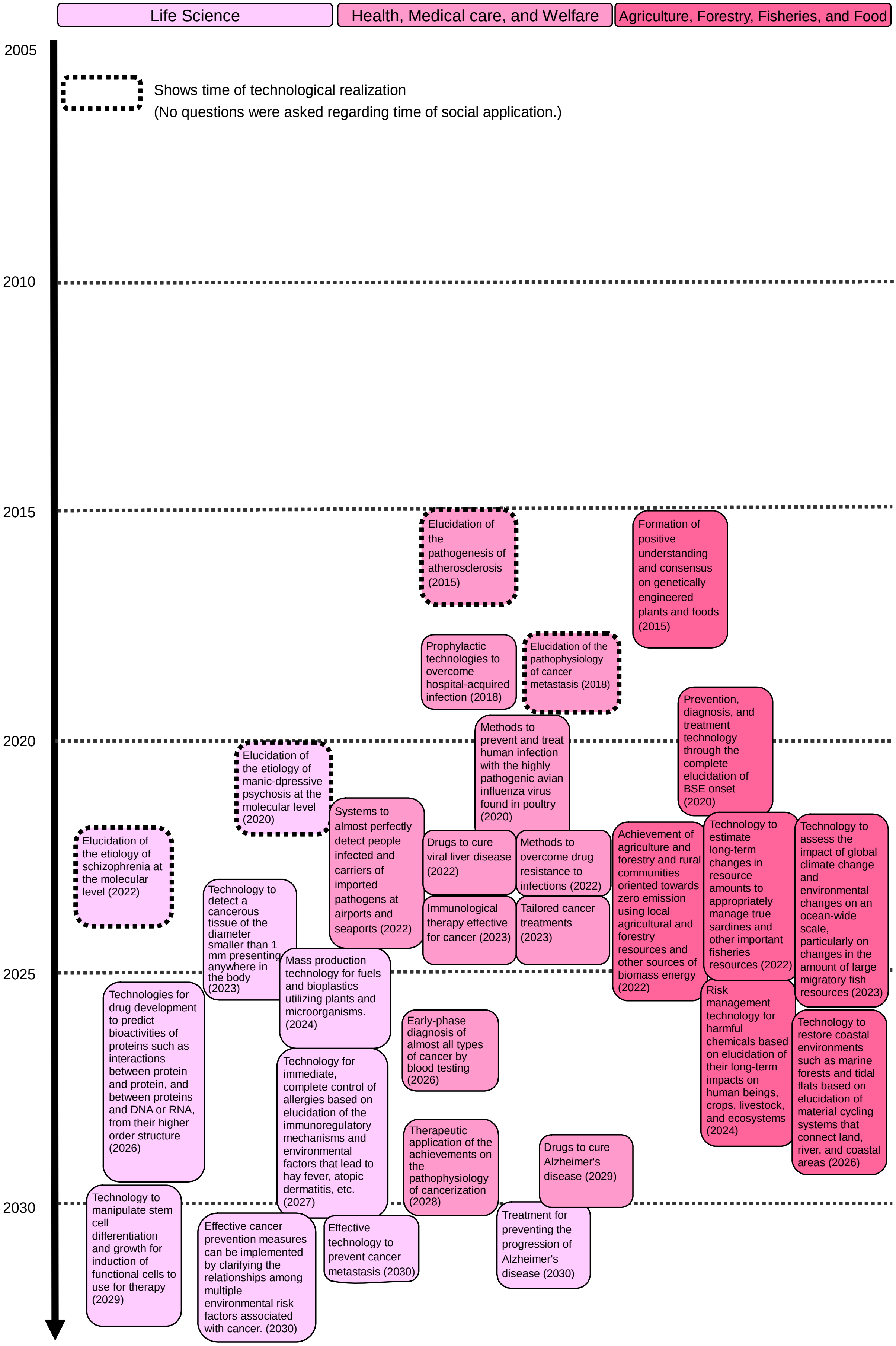


Chart 33 Forecast timeline of the most important topics (continued)

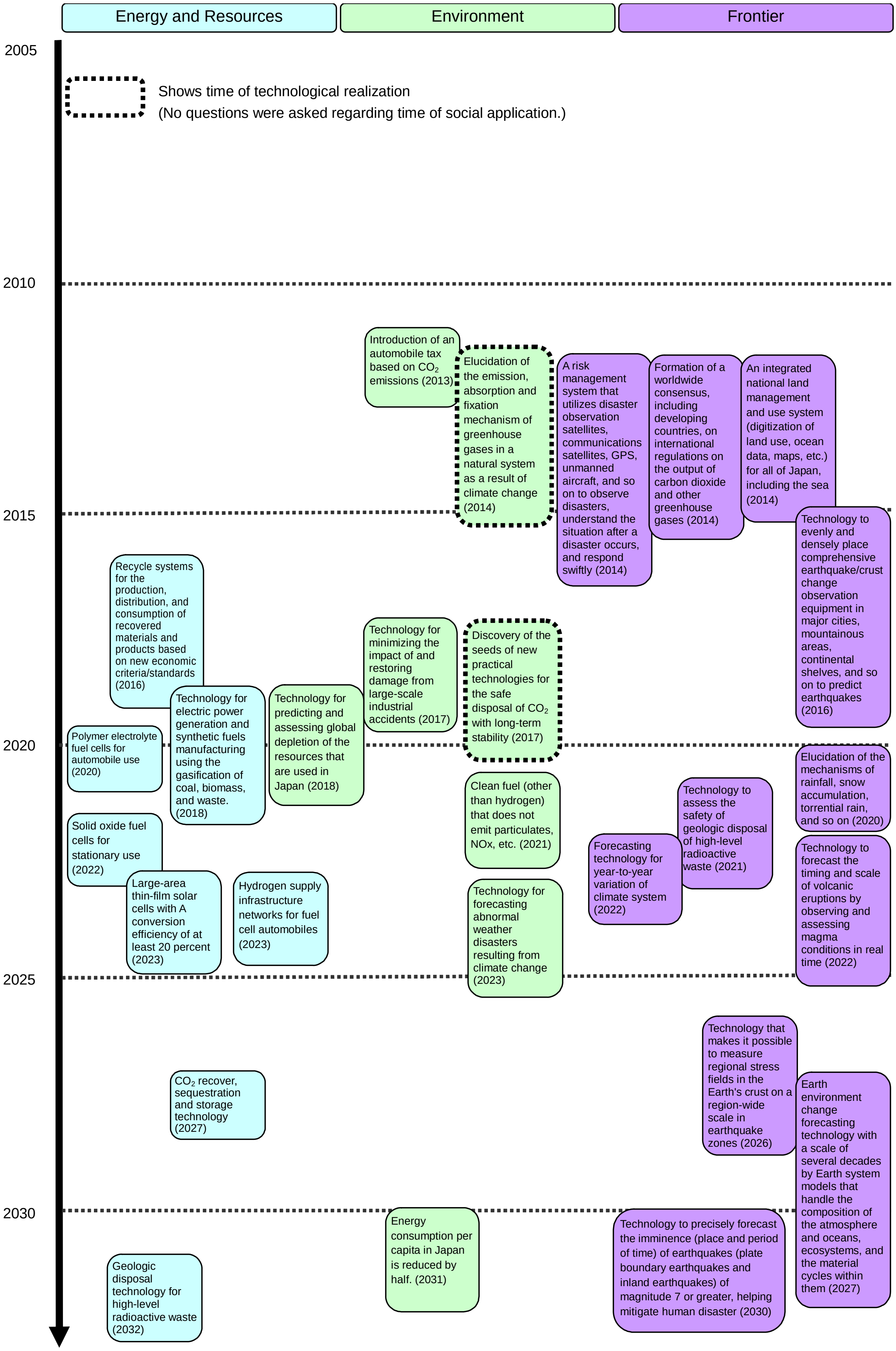


Chart 33 Forecast timeline of the most important topics (continued)

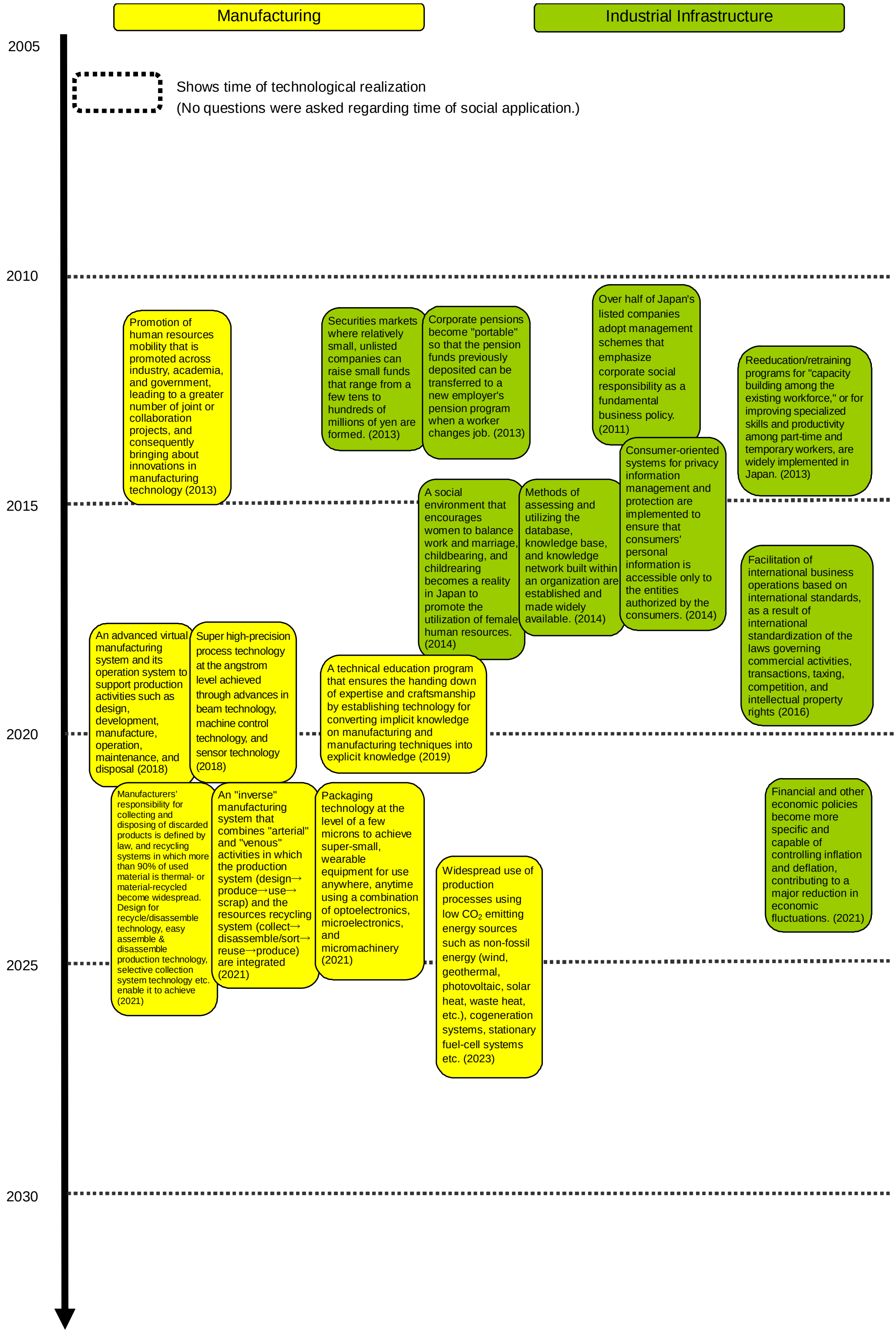
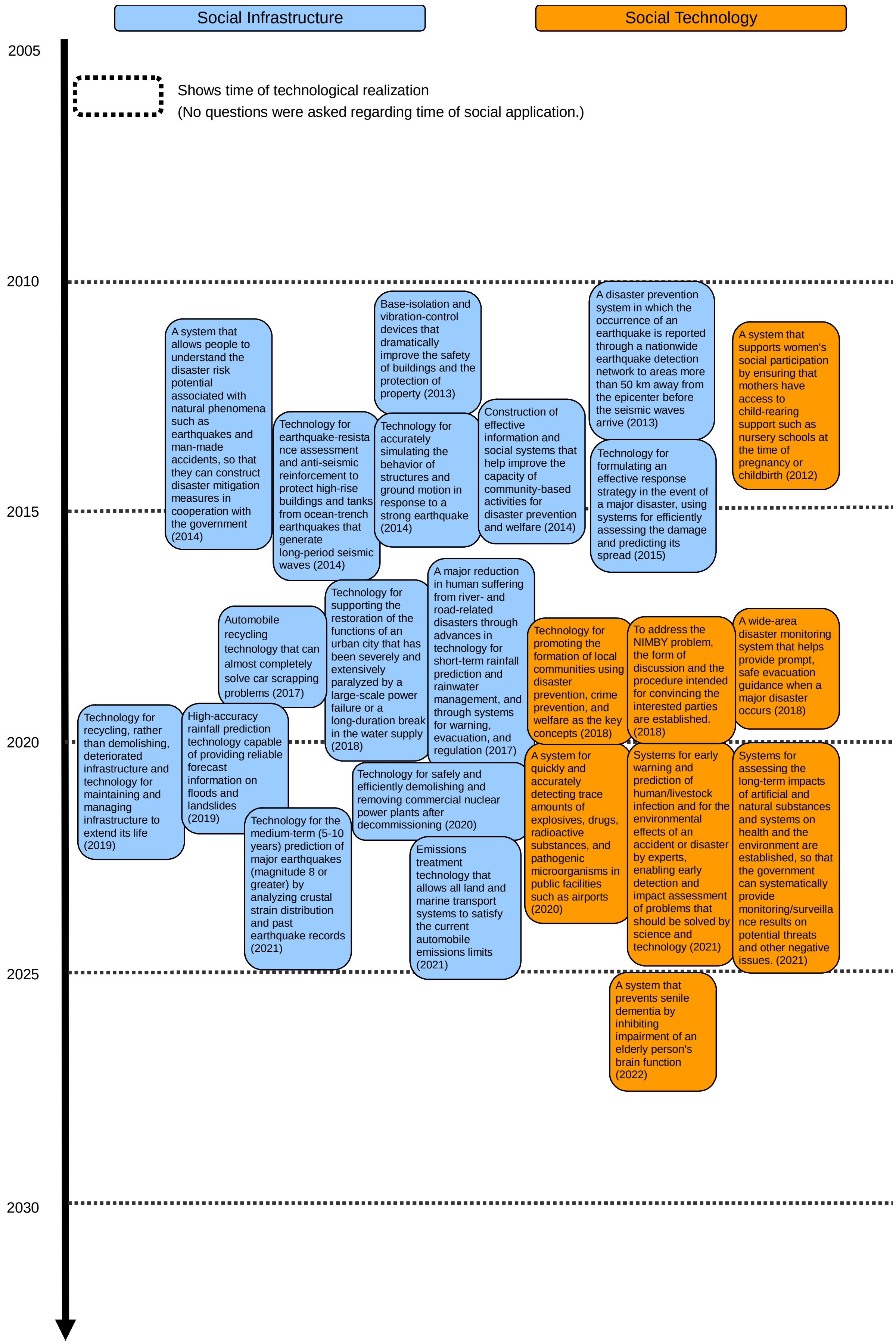


Chart 33 Forecast timeline of the most important topics (continued)



3.2.2. Characteristics of the 100 most important topics

We classified the 100 most important topics from the fifth (1992), sixth (1997), seventh (2001), and current surveys as environment-related, information-related, life-related, disaster-related, energy-related, or other in order to see changes in the topics deemed important (see Chart 34). Because the survey design this time differed from the previous seven, the continuity of the data may be arguable. Nevertheless, if we do compare the results with the previous survey, we can see that “disaster-related” increased greatly, while “environment-related,” “information-related,” and “life-related” declined sharply. In addition, topics related to securing safety increased, including evaluation of structures for soundness, early prognosis of infectious diseases and evaluation of their impact, and detection of explosives and disease organisms in public places. Combined with disaster-related and information security topics, the overall topic of “safety” emerges.

Characteristics of the 100 most important topics from each survey are as follows.

Chart 34 Changes in the makeup of the 100 most important topics

Category	Current survey	7th survey (2001)	6th survey (1997)	5th survey (1992)
Environment-related	17	26	25	28
Information-related	13	21	24	10
Life-related	19	26	17	37
Disaster-related	23	8	11	9
Energy-related	8	10	11	6
Other	21	9	12	10

*In the current survey, one topic overlaps “life” and “disaster.”

• Environment-related

A significant number of topics have been identified in relation to CO_2, NO_x, and other exhaust gases (seven topics) and a recycling-oriented society (five topics).

• Information-related

Topics related to microfabrication technology for the realization of high-performance LSI and wearable devices and to security technology such as the prevention of unauthorized network access and the detection of viruses are considered to be important.

• Life-related

Cancer-related items, such as cancer detection and elucidation of the mechanisms of cancer metastasis, account for the largest number of topics at four. There are also aging-related topics such as arteriosclerosis and Alzheimer’s. In addition, recent issues such as drug-resistance in infectious diseases, allergic disease, and elucidation of the causes of mental illness and its prevention and control are also deemed important. There are also safety-related topics such as BSE and the impact of toxic substances.

• Disaster-related

There are 23 topics in this category, more than double the number in the seventh survey, and they account for 20 percent of the 100 most important topics. Half of the disaster-related topics are earthquake-related, and they cover a wide range of areas, from prediction and simulation to policies on mitigating human damage.

• Energy-related

Topics include manufacturing processes utilizing non-fossil energy, transportation facilities using fuel-cell batteries, and solar batteries.

• Other technologies

Many topics do not fit into any of the above categories and must be classified as “other.” Most of these (seven) topics are related to human resources including education, mobility of human resoruces, transmission of skills and expertise, and equal participation of women in society.

In addition, there was no “nanotechnology” category in previous surveys, and we retained the former categories to maintain continuity. However, four topics are nanotechnology-related.

3.2.3. Characteristics of the major areas and the topics they include

In the survey, areas were chosen within 13 fields. Next, we selected topics that typify each area. (However, some topics are exceptions that do not belong to an area.)

Below, we select typical areas and summarize the expected impacts in the areas, the current level of R&D, the times of technological realization and social application of topics in the areas, and the measures that government should take towards such technological realization and social application.

<Questions regarding areas>

○ Impact

- The responses were indexed on a 10-point scale.
- Regarding increased intellectual assets, economic impacts, and social impacts, when subdivided into two indexes, the larger was taken as the relevant impact.
  Index= (No. of “Large” responses x 10 + No. of “Somewhat large” responses x 7.5 + No. of “Moderate” responses x 5 + No. of “Somewhat small” responses x 2.5 + No. of “None” responses x 0) ÷ total responses on effects (non-responses not included)

○ R&D level

- The responses were indexed on a 10-point scale.
  Index= (No. of “Leading” responses x 10 + No. of “Somewhat leading” responses x 7.5 + No. of “Even” responses x 5 + No. of “Somewhat behind” responses x 2.5 + No. of “Behind” responses x 0) ÷ total responses on level (non-responses not included)

<Questions regarding topics>

○ Time of technological realization and time of social application

- The first and last one-quarter of the answers were discarded and the half in between was used to obtain a value. The center half is used as the range of answers (represented by a bar), and the median (represented by a white or blue diamond) is used as the representative value for achievement.

○ The necessity of government involvement towards technological realization and social application

- The responses were indexed on a 10-point scale.
  Index= (No. of “High” responses x 10 + No. of “Moderate” responses x 6.7 (10 x 2 ÷ 3) + No. of “Low” responses x 3.3 (10 ÷ 3) + No. of “None” responses x 0) ÷ total responses on necessity (non-responses not included)

○ Countries currently at the leading edge and effective measures that should be taken by government towards realization (for both technological realization and social application)

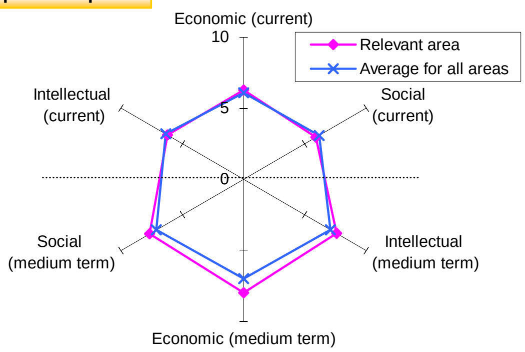
- Calculation of selection ratio (no. of selections divided by no. of “High,” “Moderate,” and “Low” responses concerning necessity.)

[Abbreviations in the charts]
Impacts:
intellectual (increased intellectual assets), economic (economic impacts), social (social impacts)
current (now; about 10 years from now), medium term (the 10 years beginning from 2016)
Measures that should be taken by the government:
HR (human resources development), Collaboration (strengthened industry-academia-government and interdisciplinary collaboration), Infrastructure (development of R&D infrastructure), Funding (expansion of R&D funding), Internationalization (Internationalization of R&D activities), Relaxed reg. (relaxation or elimination of relevant regulations), Tightened reg. (tightened or new regulations), Business startups (improvement of environment for business startups), Procurement (support through taxation, subsidies, and procurement)

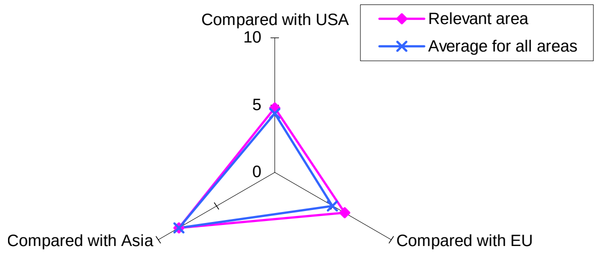
8 Ubiquitous networking

Looking at the progress of typical technologies in this area, first, the realization of improved convenience through technologies related to communications and networks is advancing. Second, elemental technology to control sensors and systems may enable the realization of complex systems involving cooperation among multiple microrobots, followed by the development of the fusion of systems with living organisms.
Hopes are high for expected impacts in the medium term (after 2015) in relation to increased intellectual assets, economic impacts, and social impacts. The R&D level in Japan has improved over the last five years relative to the USA and Europe and is now nearly equal to them.

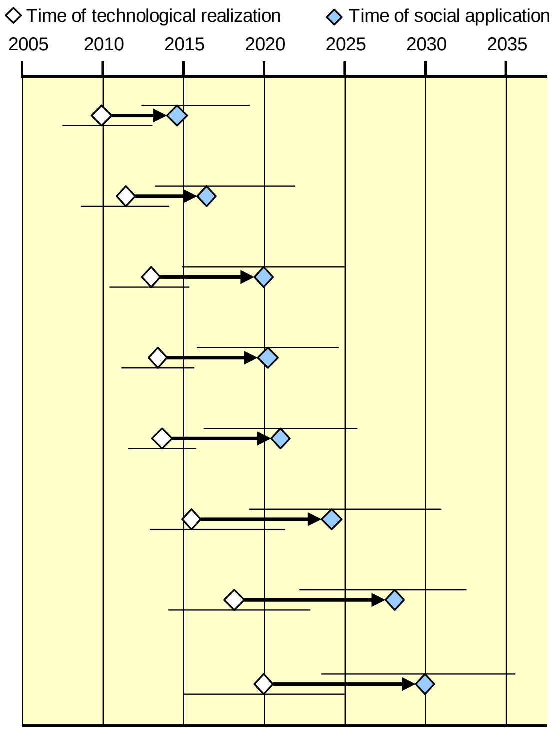
Expected impacts



Japan's R&D level



Realization timeline



67 A system to allow ad hoc communication between wireless information terminals within a certain range (with capability to seamlessly access the Internet, including applications)

61 An administration system for networks with about 1,000 users that can automatically connect terminals and operate networks with no need for a network administrator

62 Technology that allows objects to recognize mutual presence, nature, and condition so that they can automatically avoid dangerous situations and work in a coordinated manner

64 A micro communications chip or sensor that can run semi-permanently, powered by heat, light, radio waves, or noise

68 Technology to manage the identity (ID) of an infinite number of constantly emerging or disappearing objects, organize the definition and information of each ID assigned, and automatically remove obsolete data

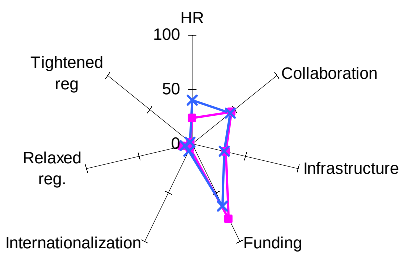
63 Technology to allow many small single-function (small-scale function) robots to cooperate and share tasks to achieve more complex functionality

65 A medical chip that can be embedded in the human body and run semi-permanently powered by bioenergy sources such as body heat or blood flow, providing vital function support such as health condition monitoring and heart pacemakers

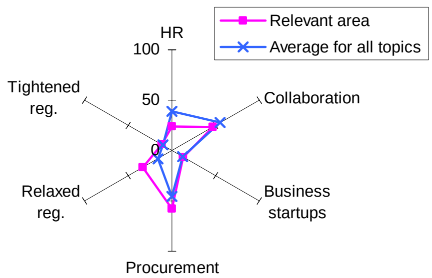
66 Medical technology based on nanochips and microsensors that have external communications and control capabilities and can be embedded in the human body or move through blood vessels

Government involvement

Effective measures for technological realization



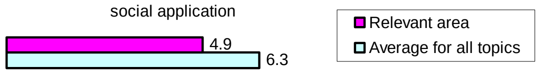
Effective measures for social application



Human resource and Funding are emphasized in technological realization. The need to develop multifaceted policies, including Human resources, Procurement, and Relaxed regulations stand outs out as a characteristic related to social application. For example, it includes Relaxed regulations on the use of radiowaves.

Necessity of government involvement towards technological realization

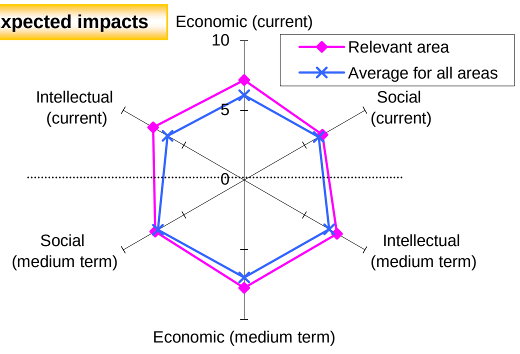
Necessity of government involvement towards social application



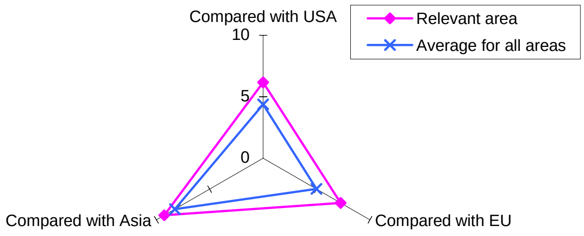
12 Optical and photonic devices

In optical electronics, Japan is in a leading position. In the medium term, increased intellectual assets and economic impacts are expected. Japan's R&D level is ahead of both the USA and Europe.
As for typical technologies, against the backdrop of the spread of broadband, the realization of 10 Gbps subscriber lines and high-frequency lasers, 100 Tbps multiplex equipment that presumes a ubiquitous network environment, and the realization of 10 THz photonics technology are forecast. In the long term, the realization of still-experimental technology such as optical buffer memory and optical communications systems for quantum information is seen as being realized around 2020 and applied in society about 10 years after that.

Expected impacts

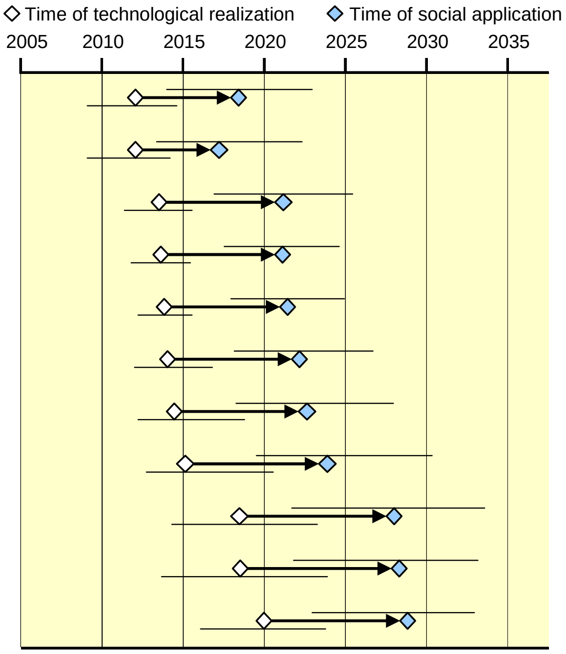


Japan's R&D level



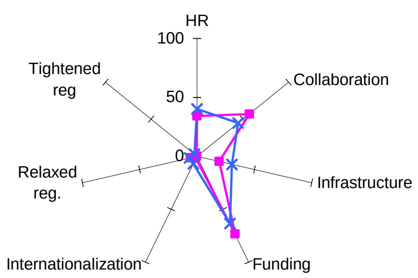
Realization timeline

17 Almost all indoor lighting is replaced by semiconductor light sources.
15 Widespread home use of 10-Gbps access networks.
19 Ultraviolet/deep-ultraviolet laser diodes
14 Organic material devices (e.g. lasers and switches).
20 Optical multiplex communications equipments capable of transmitting multiplexed signals at 100 Tbps over a single optical fiber.
18 Photonic sensing technology using an unused radio frequency range of 1-10 THz
21 Ultralow-loss (e.g. 0.1 dB/km or lower) holey fibers (photonic crystal fibers)
23 Photonic-crystal-based photonic integrated circuits.
24 Large-capacity optical buffer memory.
22 Secure optical quantum communications system.
16 Soft X-ray laser at a few tens of angstroms of wavelength.

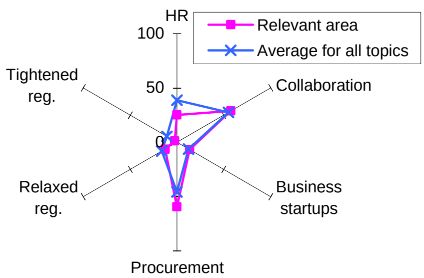


Government involvement

Effective measures for technological realization

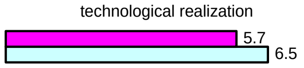


Effective measures for social application

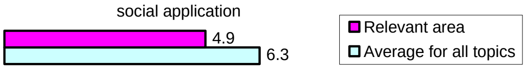


Because relatively large-scale, advanced experimental facilities are required, government involvement with Collaboration and Infrastructure are considered necessary. Regarding social application, Human resources are considered most important.

Necessity of government involvement towards technological realization



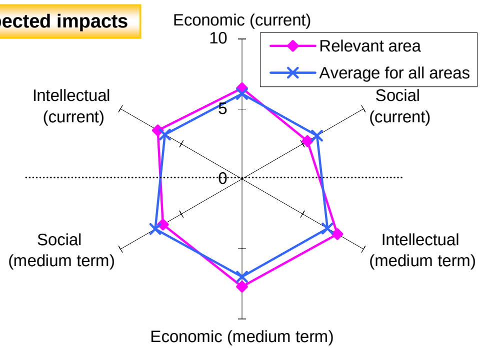
Necessity of government involvement towards social application



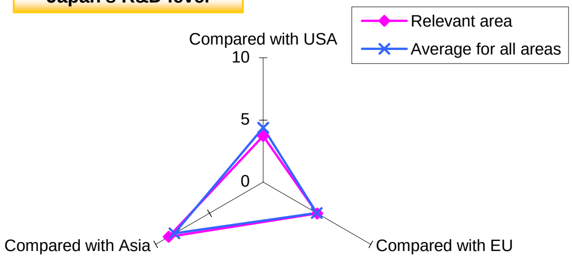
31 Monitoring and sensor technology for biological substances

This area can be considered infrastructure for the development of the various fields of life science. The expected impacts are major contributions to increased intellectual assets now and in the medium term. At the same time, because of expectations for commercialization and growth from the results of life science research, economic impacts from this fundamental area are also projected. Due to improvements over the last five years, Japan's R&D level is equal to or greater than Europe's. Technological realization of high sensitivity, improved speed and spatial resolution to measure individual subjects such as tissues, genomes, and sugar chains is projected for around 2015. However, realization of simultaneous measurement of the mutual effects of multiple substances is expected to take somewhat longer, with self-propulsion inside living bodies even further behind. Social application is expected to require at least more 10 years.

Expected impacts



Japan's R&D level



Realization timeline

33 Technology to detect a cancerous tissue of the diameter smaller than 1 mm presenting anywhere in the body.

34 Technology for molecular imaging in the body with the precision of single molecule detection.

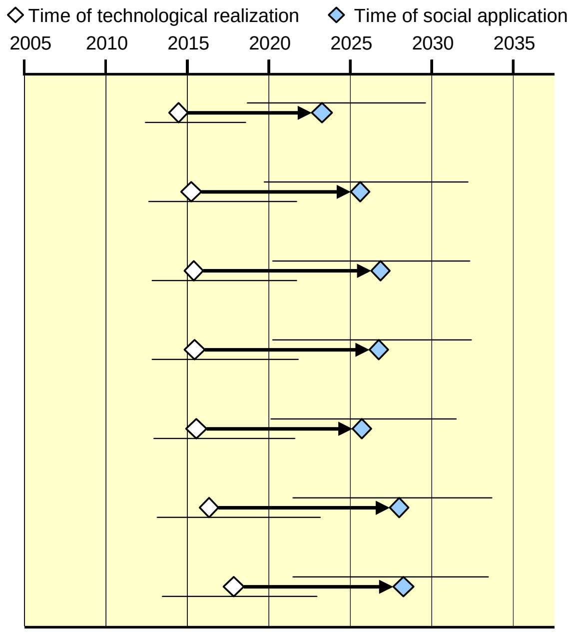
36 Technology that can sequence the whole human genome in one day.

37 Equipment that can sample a single cell and measure all kinds of mRNAs with their copy numbers within the cell.

38 Equipment to automatically analyze the sequences of sugar chains with 20 or more linked sugars with their branching and linkage patterns.

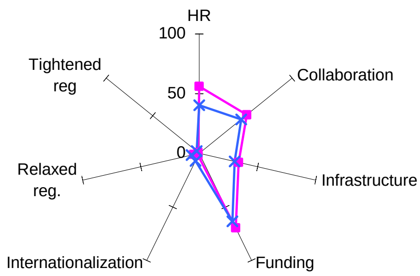
35 Technology to observe the interactions among various substances inside and outside cells, to simultaneously identify these substances, and to monitor their distribution

32 Self-propelled micromachines for diagnosis and treatment inside the body (organ lumina)

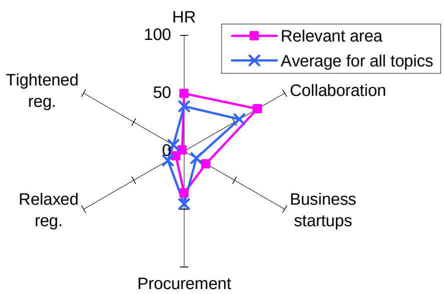


Government involvement

Effective measures for technological realization

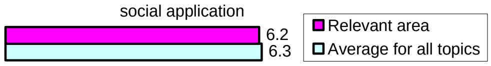


Effective measures for social application



Necessity of government involvement towards technological realization

Necessity of government involvement towards social application

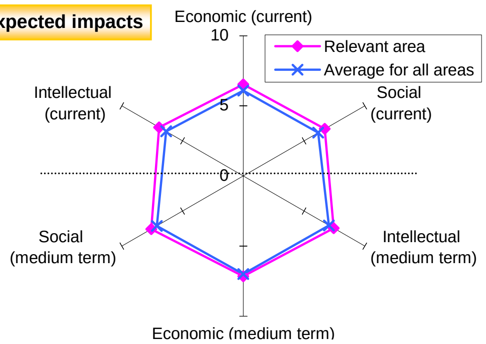


This is an interdisciplinary area fusing life science, chemistry, physics, and so on, and collaboration for applying it to basic research and equipment is needed. Therefore, initiatives on developing human resources with knowledge and experience in wide-ranging research, and strengthened industry-academia-government and interdisciplinary collaboration in both technological realization and social application are expected. Hopes are particularly high for such collaboration in the promotion of social application, where the commercialization of research results is important.

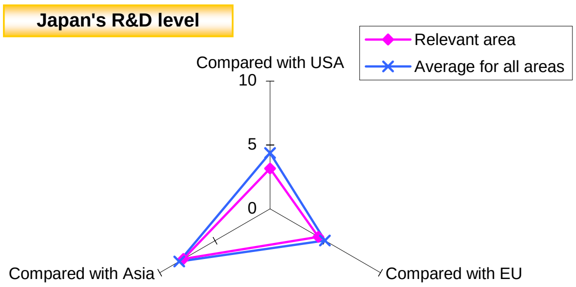
36 Personalized medicine

Typical technologies in this area are diagnostic and treatment technologies for cancer and other lifestyle-related diseases. Among these technologies, those for cancer treatment are projected to advance through a process of improvements in the drug and radiation therapies that are now the primary treatments, tailor-made treatment technology, immunological treatment technology, and genetic treatment technology, until treatment technology based on elucidation of the mechanisms of cancerization is finally realized. In addition to cancer, the main technologies for individualized healthcare, including genetic treatments for conditions such as arteriosclerosis, high cholesterol, and diabetes, are expected to advance to social application (as generally available treatment) between 2025 and 2030. Expected impacts currently include increased intellectual assets, economic impacts, and social impacts. Although Japan's R&D level still lags significantly behind that of the USA, it has improved over the past five years.

Expected impacts

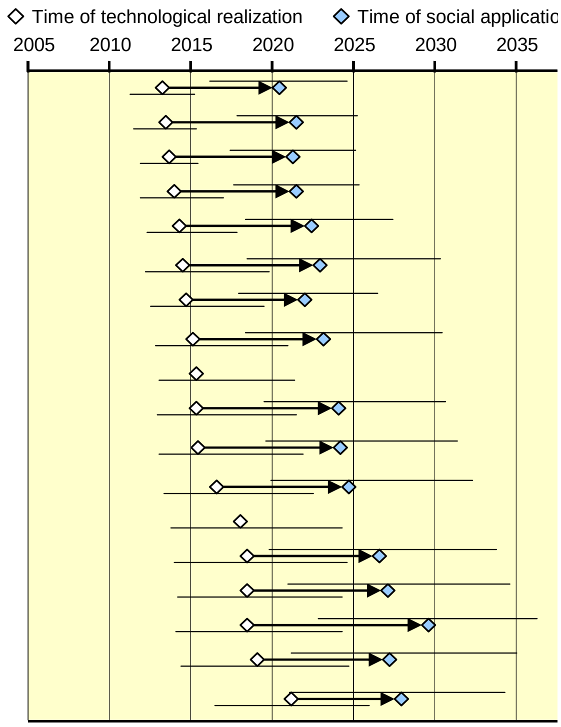


Japan's R&D level



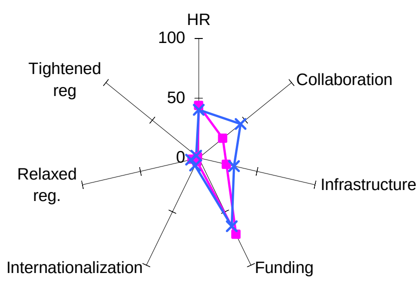
Realization timeline

15 Drug delivery systems (DDS)
13 Assays of drug resistance of cancers.
14 Effective radiological therapy and intensifying drugs for cancer treatment.
7 Oral administation of insulin
11 Hemocatharsis devices that selectively remove target substances from the blood.
16 Tailored cancer treatments.
18 Immunological therapy with high specificity and long effects against target infections.
9 Immunological therapy effective for cancer.
3 Elucidation of the pathogenesis of atherosclerosis.
17 Hypothermic treatment of cancer (an innovative treatment aiming at slowing cancer development and lengthening the time spent for coexistence with cancer).
12 Gene therapy that allows for localized treatment of atheroclerotic lesions.
8 Gene therapy of familial hypercholesterolemia.
1 Elucidation of the pathophysiology of cancer metastasis.
4 Early-phase diagnosis of almost all types of cancer by blood testing.
6 Gene therapy of diabetes mellitus.
10 Gene therapy of cancer.
5 Diagnostic methods to help select appropriate treatment of kidney disorders without performing a renal biopsy.
2 Therapeutic application of the achievements on the pathophysiology of cancerization

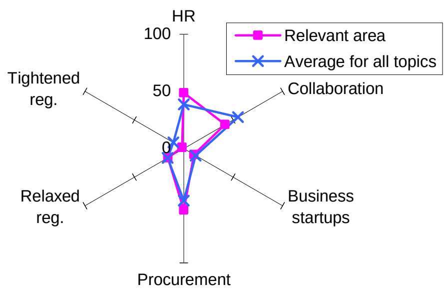


Government involvement

Effective measures for technological realization



Effective measures for social application



Expectations are high for Human resource towards social application. In the future, individualized medicine may become the primary type of healthcare in the world, but there is a shortage of personnel. Government involvement in Human resource is therefore expected.

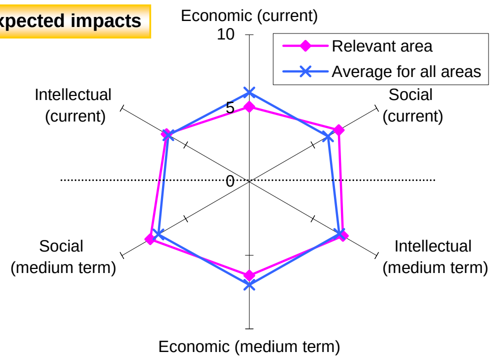
Necessity of government involvement towards technological realization

Necessity of government involvement towards social application

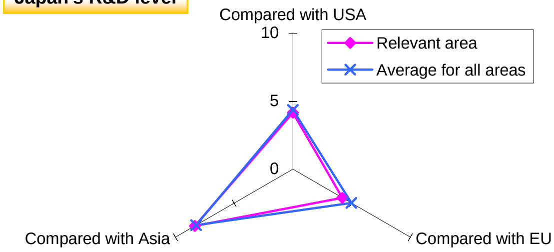
72 Focus on identification and mitigation of ecological effects (including soil and water)

As for typical technologies in this area, the technological realization of technologies for environmental monitoring and assessing the impact of human activities on the environment is first expected. Subsequently, the realization of technologies for the removal of pollutants, the recovery of ecosystems, and the control of ecosystems is projected. The time of technological realization is expected to be from about 2010 to 2015 and beyond, with social application proceeding between about 2020 and 2025.
Major effects are expected in social impacts in terms of safety, peace of mind, and quality of life. A significant increase in intellectual assets is expected through a greater understanding of ecosystems. Japan's R&D level has markedly improved over the past five years relative to Europe and the USA.

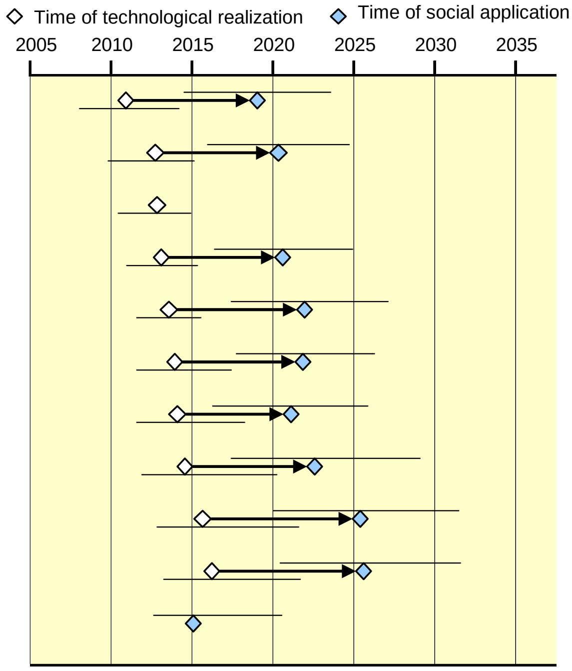
Expected impacts



Japan's R&D level



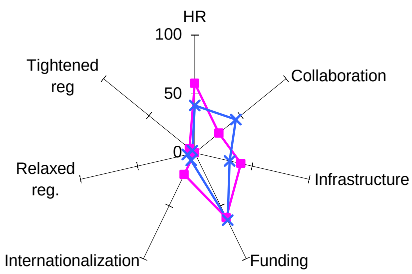
Realization timeline



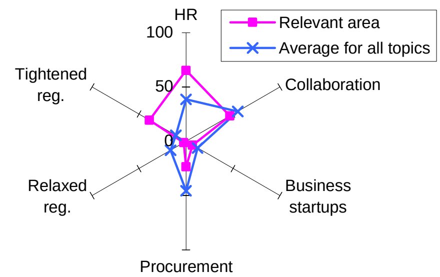
24 Environmental monitoring technology based on high-precision satellite sensors and the Internet for vegetation mapping
25 Quantitative elucidation of the effect of flow structure on tideland ecosystem structure and function
20 Elucidation of the mechanism of the effect of acid rain on flora and fauna and the ecosystem
27 Technology for addressing endocrine disruptors emitted from sewage into rivers
23 Technology for ecologically identifying invasive foreign species
29 Technology for removing dioxins and other POPs (Persistent Organic Pollutants) from ocean floor soil
21 Technology for restoring the ecosystem and the biodiversity of wetlands
30 Technology for efficient revegetation in deserts
22 Technology for conserving and restoring the genetic diversity of endangered species
26 Technology for controlling species inhibiting the conservation and restoration of the natural ecosystem
28 Establishment of a system to ensure that development projects involve setting targets concerning ecosystem conservation and restoration through a consensus-building process

Government involvement

Effective measures for technological realization

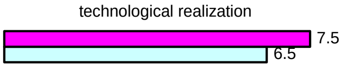


Effective measures for social application

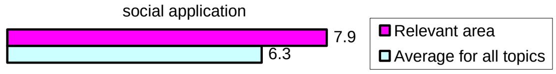


Because the conservation of biodiversity and ecosystems is a global issue, internationalization of responsive technology is needed.
In this area, there are strong expectations for Human resource in research and application. Moving towards social application, government is expected to play a role in combining S&T initiatives with Tightened regulations to reduce the impact on ecosystems.

Necessity of government involvement towards technological realization



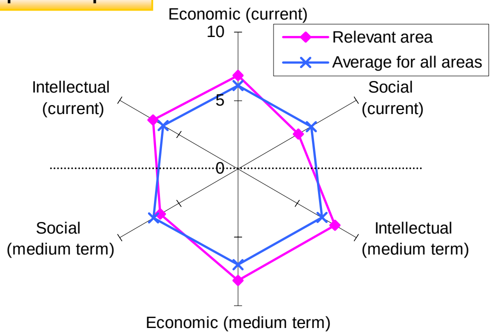
Necessity of government involvement towards social application



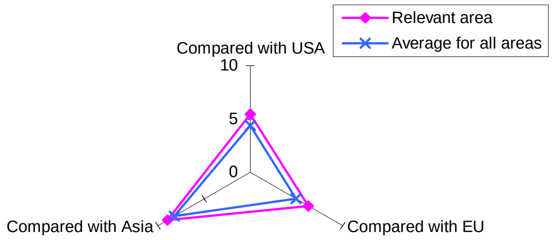
81 New materials from nanolevel structure control

Technological realization of the majority of the typical technologies in this area is projected by 2015, with social application following seven or eight years later. On the other hand, technologies such as all-organic ferromagnets and room-temperature superconductors where electron multibody effects and other complex phenomena in addition to structural control must be considered are expected to be realized after 2015, with social application around 2030. Expected current effects are significant in terms of increased intellectual assets and economic impacts. Because the social realization of typical technologies is expected after 2020, medium-term effects are expected to be even larger. Japan's R&D level today as well as five years ago is ahead of the rest of Asia and slightly ahead of Europe and the USA.

Expected impacts



Japan's R&D level



Realization timeline

42 Light, composite-structure materials from carbon nanotubes

38 Large-area amorphous silicon solar cells with a conversion efficiency above 20 percent

29 Biomedical ceramics that function approximately in the same way as human bone

37 Insulating materials with a dielectric constant of 1.3 or less for ultra LSI

39 Organic and inorganic compound materials that express new functions or innovative properties through structures controlled at nanometer level

32 Lead-free ferroelectrics with a piezoelectric modulus equivalent to PZT (Pb [Zr, Ti] O3)

41 Semiconductor diamonds at a practical level

40 Nanomaterials that show a practical, meaningful stimulus response at necessary times and places

34 Heat-resistant alloys that can bear a load of 15 kgf/mm2 (about 150 MPa) for 1,000 hours or more at a high (atmospheric) temperature of 1200°C

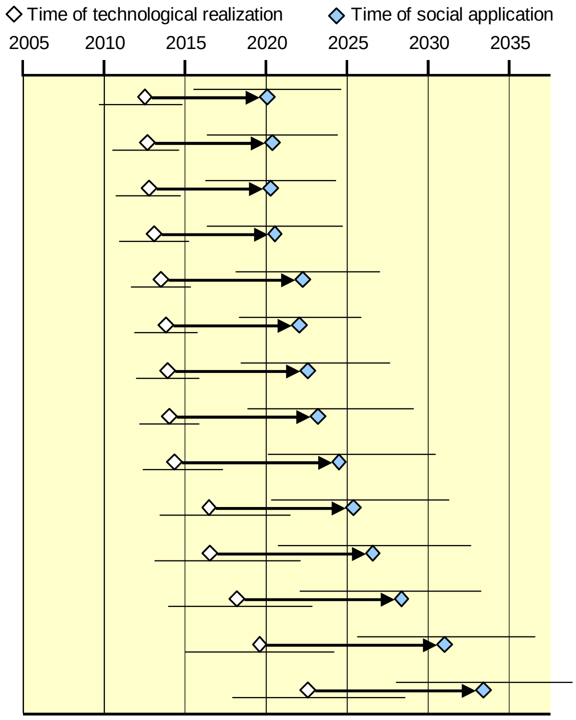
36 Anisotropic nanocomposite magnets with a (BH)max=400 kJ/m3(50.3 MGOe) or greater through the nanometer-scale control of heterostructure

31 Macromolecule materials with conductivity and environment resistance equivalent to copper at room temperature

30 All-organic ferromagnets with a Curie point above room temperature

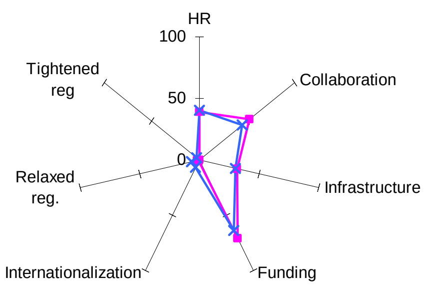
33 Macromolecule superconducting materials with a transfer point above the temperature of liquid nitrogen

35 Superconductors with a transfer point at room temperature and above

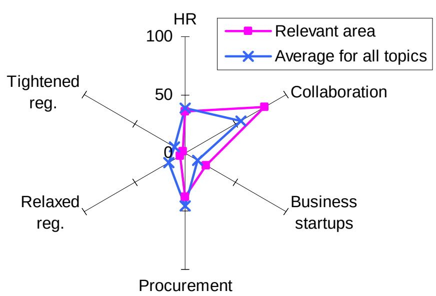


Government involvement

Effective measures for technological realization



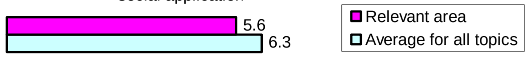
Effective measures for social application



Funding is highly desired for technological realization, as is Collaboration for social application. Stronger collaboration is needed to move the technologies realized through basic research into industry.

Necessity of government involvement towards technological realization

Necessity of government involvement towards social application



3.2.4. Characteristics of the impacts of the 130 areas

We gained an overview of the impacts of the 130 areas, utilizing the degree of the impacts (increased intellectual assets, economic impacts, social impacts) in each area. We extracted 112 areas and classified them through selection based on the criteria below.

<Selection criteria>

* Increased intellectual assets (current)

- Increased intellectual assets: top one-third in terms of contribution to increased intellectual assets in the relevant field as a whole
- Field expansion: top one-third in terms of contribution to the development of other fields

* Economic impacts (current)

- Expansion of existing industry: top one-third in terms of contribution to the development of existing Japanese industry
- Creation of new industries: top one-third in terms of contribution to the creation of new industries or businesses

* Social impacts (current)

- Safety and security: top one-third in terms of contribution to safety and security
- Quality of life improvement: top one-third in terms of contribution to improved social vitality and quality of life

* Other

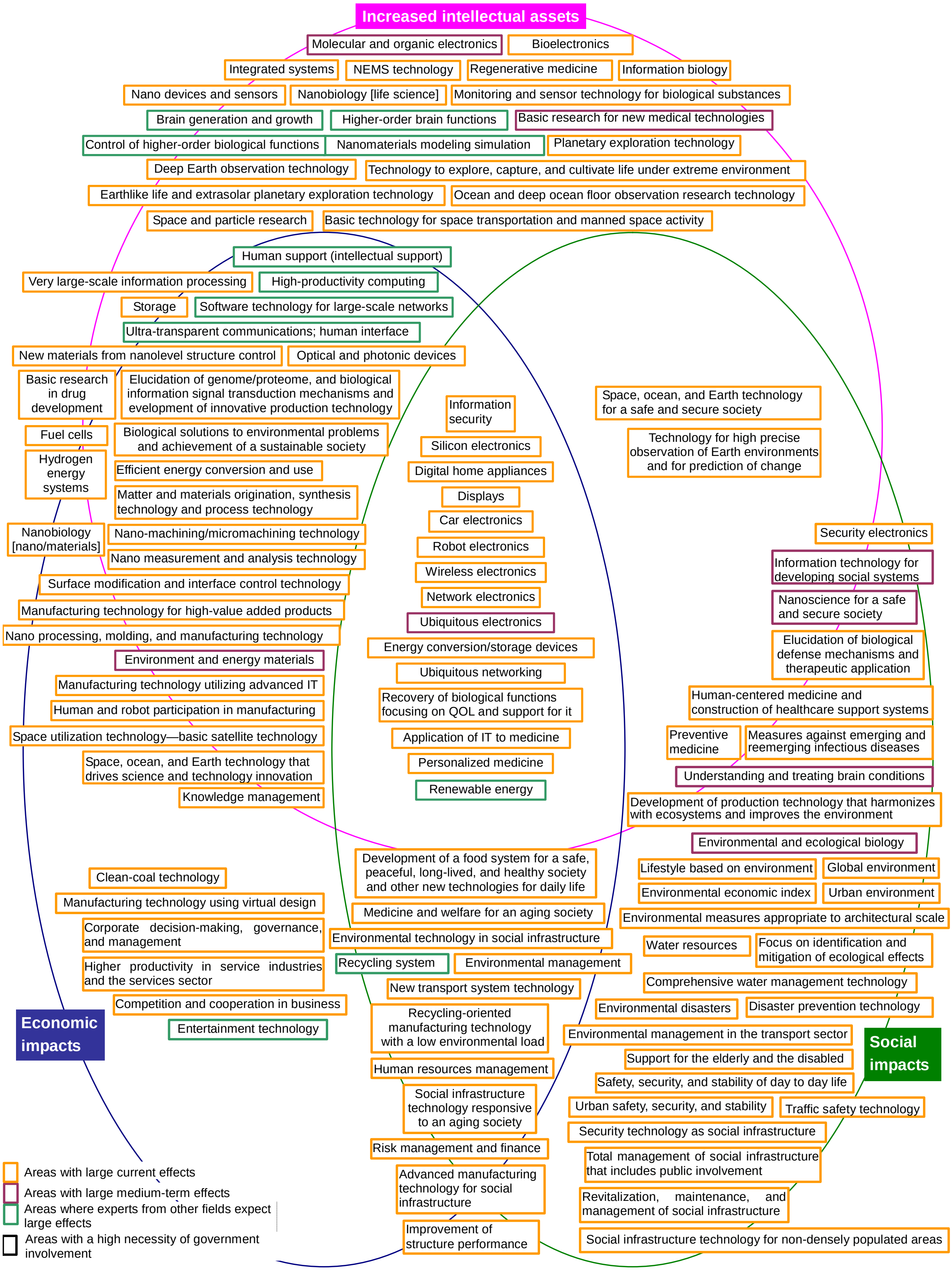
Those not in the top one-third in terms of the above six impacts, but in the following categories

- Top one-third in terms of size of expected medium-term (2016 and after) impacts
- Top one-third of evaluation by experts outside the relevant field in terms of expected current or medium-term impacts

A classification of the expected impacts of the 112 areas is shown in Chart 35. There are many areas with large impacts expected in terms of both increased intellectual assets and economic impacts. This may indicate the trend for expanded scientific and technological knowledge in many areas to bring economic development. On the other hand, there are only two areas where both large social impacts and greatly increased intellectual assets are expected.

Areas with large medium-term impacts include information technology for developing social systems and nanoscience for a safe and secure society, where the social impacts will be large. In addition, areas where experts outside the relevant field expect large impacts include technologies that form the basis for other technologies, such as high-productivity computing and software technology for large-scale networks, and brain research such as control of higher-order biological functions, higher-order brain functions, and brain generation and growth.

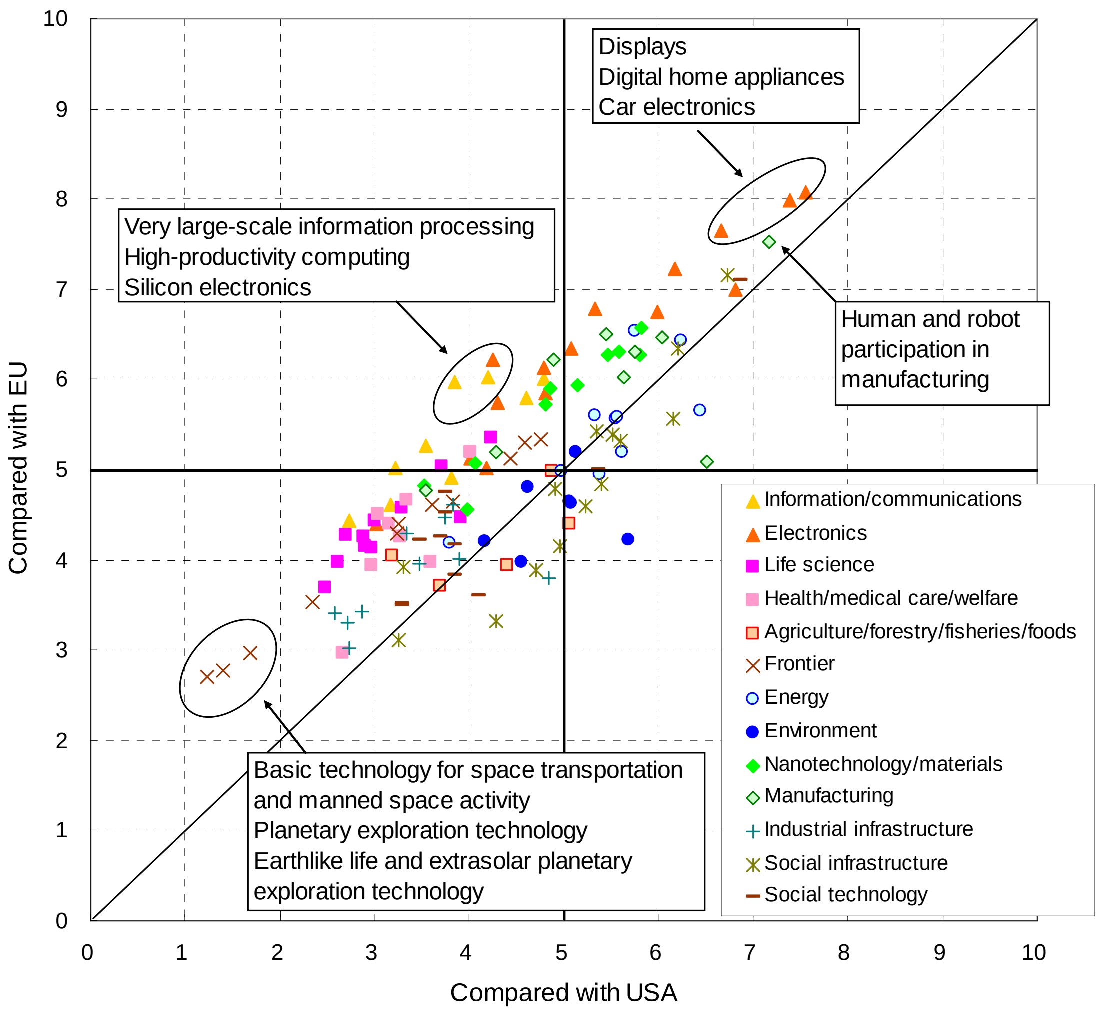
Chart 35 Areas with large impacts



3.2.5. Characteristics of the R&D levels of the 130 areas

Japan's current research and development level in the 130 areas was evaluated in comparison with the United States of America and Europe (see Chart 36). Looking at Japan's current research and development level, in the electronics and nanotechnology and materials fields, Japan is seen as above the EU over all and ahead of the USA in many areas. On the other hand, in the three fields of life science, health, medical care, and welfare, and agriculture, forestry, fisheries, and foods, Japan is slightly below the EU and trails behind the USA by a wide margin.

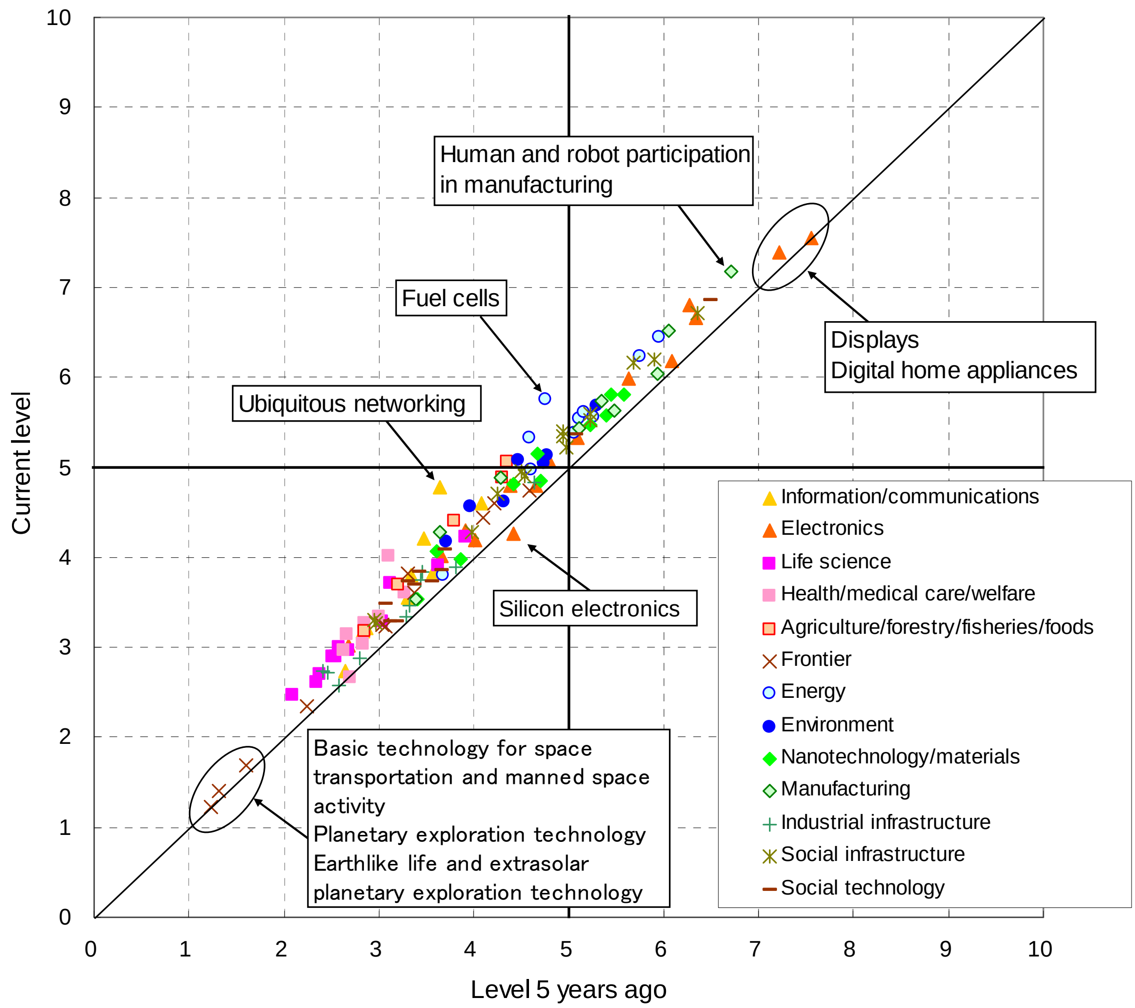
Chart 36 Comparison with current levels of USA and EU



(Note 1) Where the level is equal to the EU and the USA, the value is 5. The higher the number above 5, the higher Japan's relative level; the lower the number below 5, the lower Japan's relative level.

Comparing five years ago with today, research and development levels have improved relative to the USA and the EU in almost every area (Chart 37). In contrast, levels remain superior relative to Asia in every area, but in electronics-related areas and elsewhere, the overall gap is shrinking.

Chart 37 R&D level relative to USA today and 5 years ago



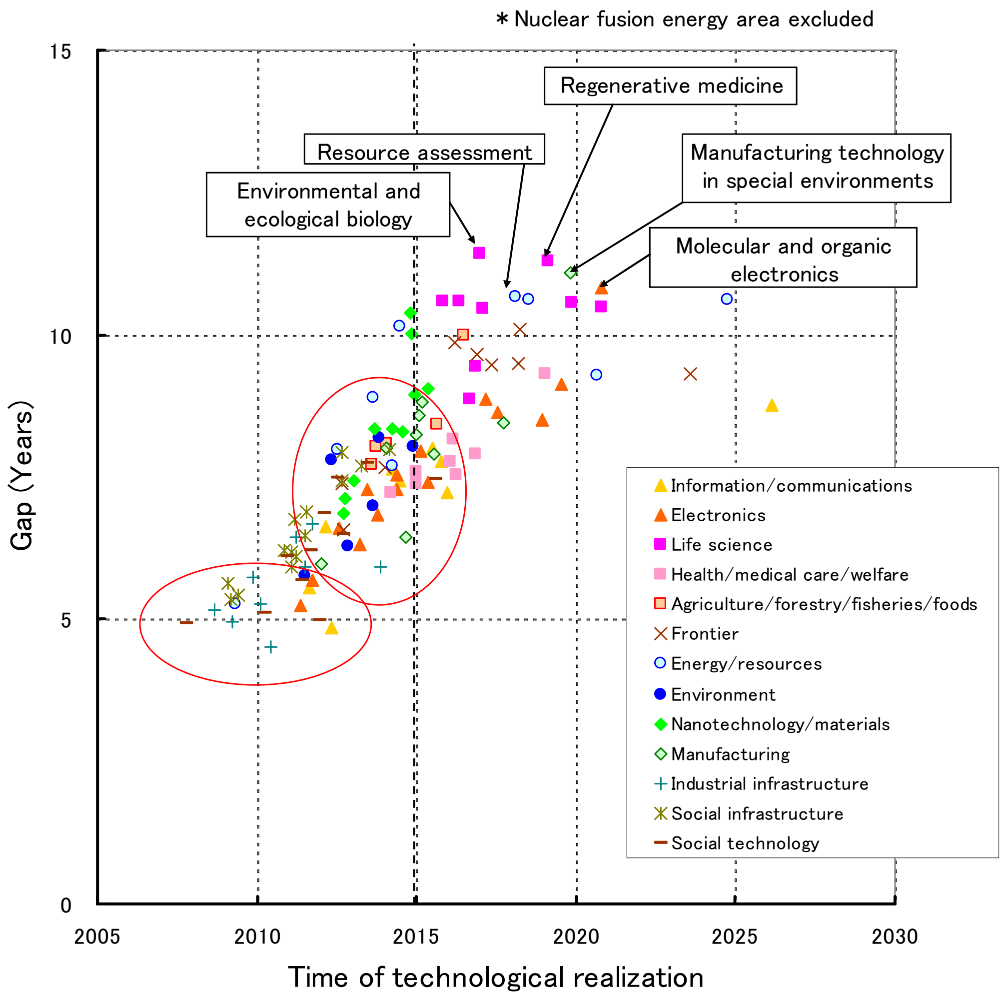
3.2.6. Time of technological realization and social application for the 130 areas

Utilizing the results of topics, the time of the realization of areas and the necessity of government involvement were examined. The values for the areas are averages of the data for the relevant topics for each area.

(1) Forecast realization times of areas

Looking at time of technological realization, 70 percent of all areas are forecasted to be realized by 2015 (see Chart 38). All areas are forecasted to be realized in 2015 or sooner in the fields of nanotechnology and materials, social infrastructure, and social technology. Most areas in the fields of information and communications, agriculture, forestry, fisheries, and foods, environment, manufacturing, and industrial infrastructure will be technoligically realized by 2015. The information and communications field, however, includes a mix of areas of early and late realization. In the life science field, all areas are forecasted to be realized by 2016 or later, with only one exception.

Chart 38 Gap in time between technological realization and social application



Looking at periods until social application for areas forecasted for technological realization by 2015, the areas can be roughly divided into those requiring around five years and those requiring about seven or eight. Areas of late technological realization tend to require more time until social application. In the fields of life science and energy and resources, time until social application is more than nine years for most areas. Areas requiring long periods from technological realization to social application are, in order of length of time, environmental and ecological biology (11.4 years), regenerative medicine (11.3 years), manufacturing technology in special environments (11.1 years), molecular and organic electronics (10.8 years), and resource assessment (10.7 years). Their technological realization is also projected for 2015 or later.

(2) Necessity of government involvement towards technological realization and social application

Chart 39 depicts the necessity of government involvement for technological realization and social application. It is clear that areas requiring government involvement towards technological realization also require such government involvement towards social application.

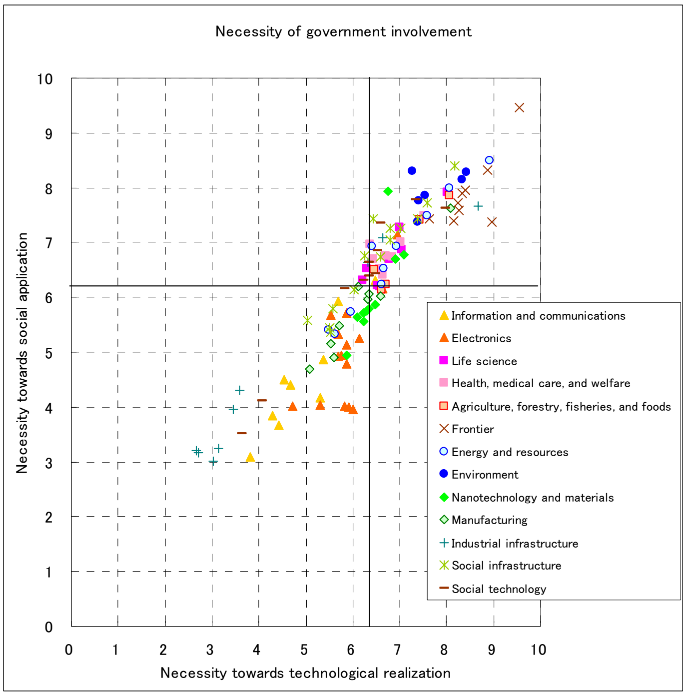
○ Areas with a strong need towards government involvement

Many of these areas require vast sums of money for large-scale facilities and equipment or necessarily affect large numbers of unspecified people, as with environmental issues and disasters. Many of these areas are in frontier and environment fields.

○ Areas with less need towards government involvement

Many of these areas are related to fields in information and communications, where private sector corporations take the lead, or to industrial infrastructure fields related to corporate management.

Chart 39 Necessity of government involvement towards technological realization and social application



Field	Necessity of government involvement	
	Technological realization	Social application
Information and communications	4.9	4.5
Electronics	5.9	4.9
Life science	6.8	6.6
Health, medical care, and welfare	6.7	6.7
Agriculture, forestry, fisheries, and foods	7.0	6.7
Frontier	8.4	8.0
Energy and resources	6.5	6.4
Environment	7.6	7.7
Nanotechnology and materials	6.4	5.9
Manufacturing	6.3	5.9
Industrial infrastructure	3.9	4.1
Social infrastructure	6.5	6.7
Social technology	6.2	6.4
Average for all topics	6.4	6.2

(3) Measures that should be taken by the government towards technological realization and social application

What measures are required from government in each field? The values for each field are calculated from the average of the topics in each area along with the average of the areas in the fields. Chart 40 depicts measures that government should take towards technological realization.

- ○ Fields where expansion of R&D funding is emphasized
  12 fields other than industrial infrastructure
- ○ Fields where strengthened industry-academia-government and interdisciplinary collaboration is emphasized
  Electronics; agriculture, forestry, fisheries, and foods; nanotechnology and materials; manufacturing; and social infrastructure
- ○ Fields where human resources development is emphasized
  Life science; health, medical care, and welfare; frontier; and industrial infrastructure

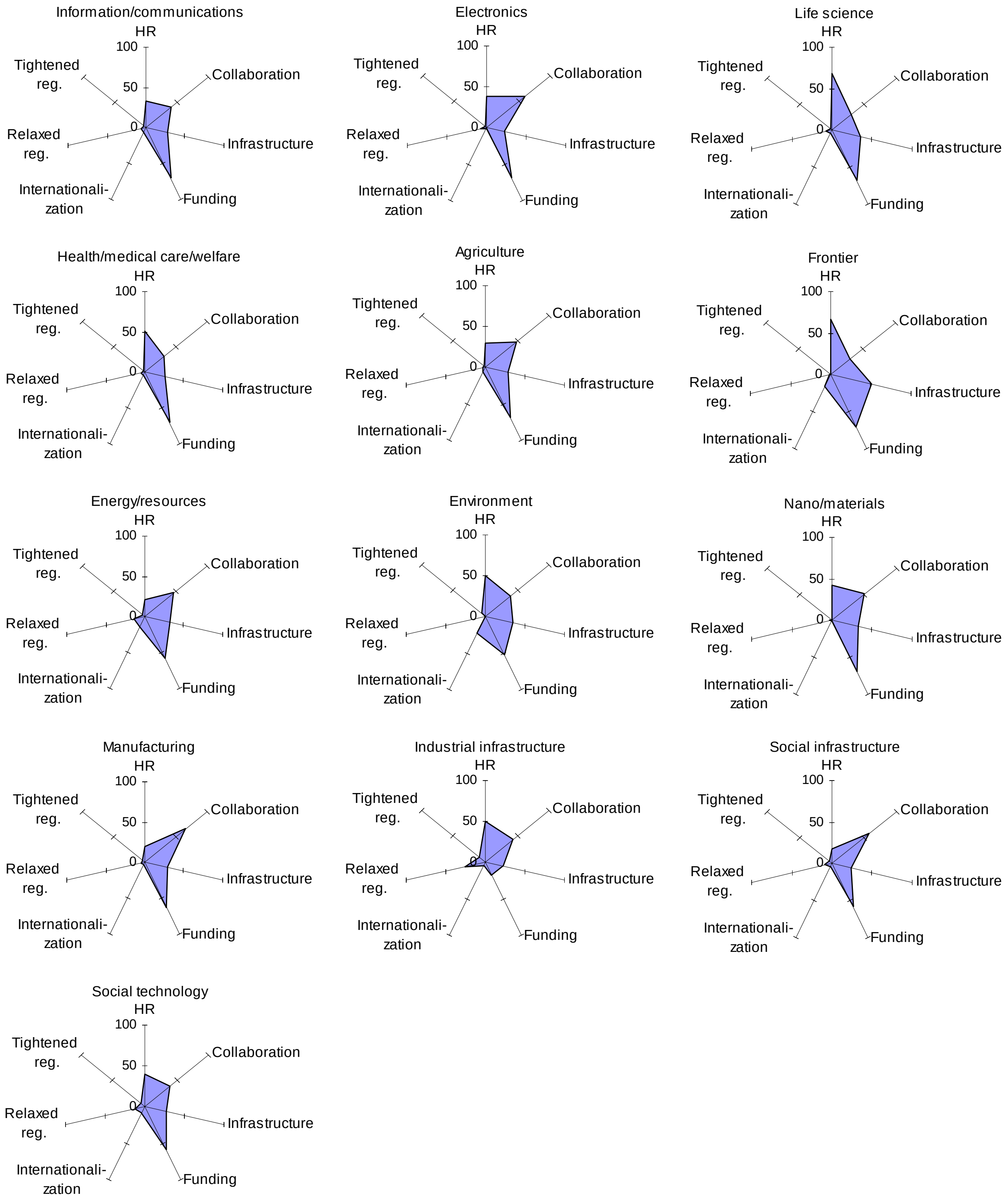
In addition, development of R&D infrastructure is emphasized in the frontier and energy and resources fields.

Chart 41 depicts effective measures that government should take towards social application.

- ○ Fields where strengthened industry-academia-government and interdisciplinary collaboration is emphasized
  Electronics; life science; agriculture, forestry, fisheries and foods; frontier; environment; nanotechnology and materials; manufacturing; and social infrastructure
- ○ Fields where taxation, subsidies, and procurement are emphasized
  Information and communications; electronics; health, medical care, and welfare; energy and resources; manufacturing; social infrastructure; and social technology
- ○ Fields where human resource development is emphasized
  Life science; health, medical care, and welfare; and frontier
- ○ Field where relaxation or elimination of relevant regulations is emphasized
  Industrial infrastructure

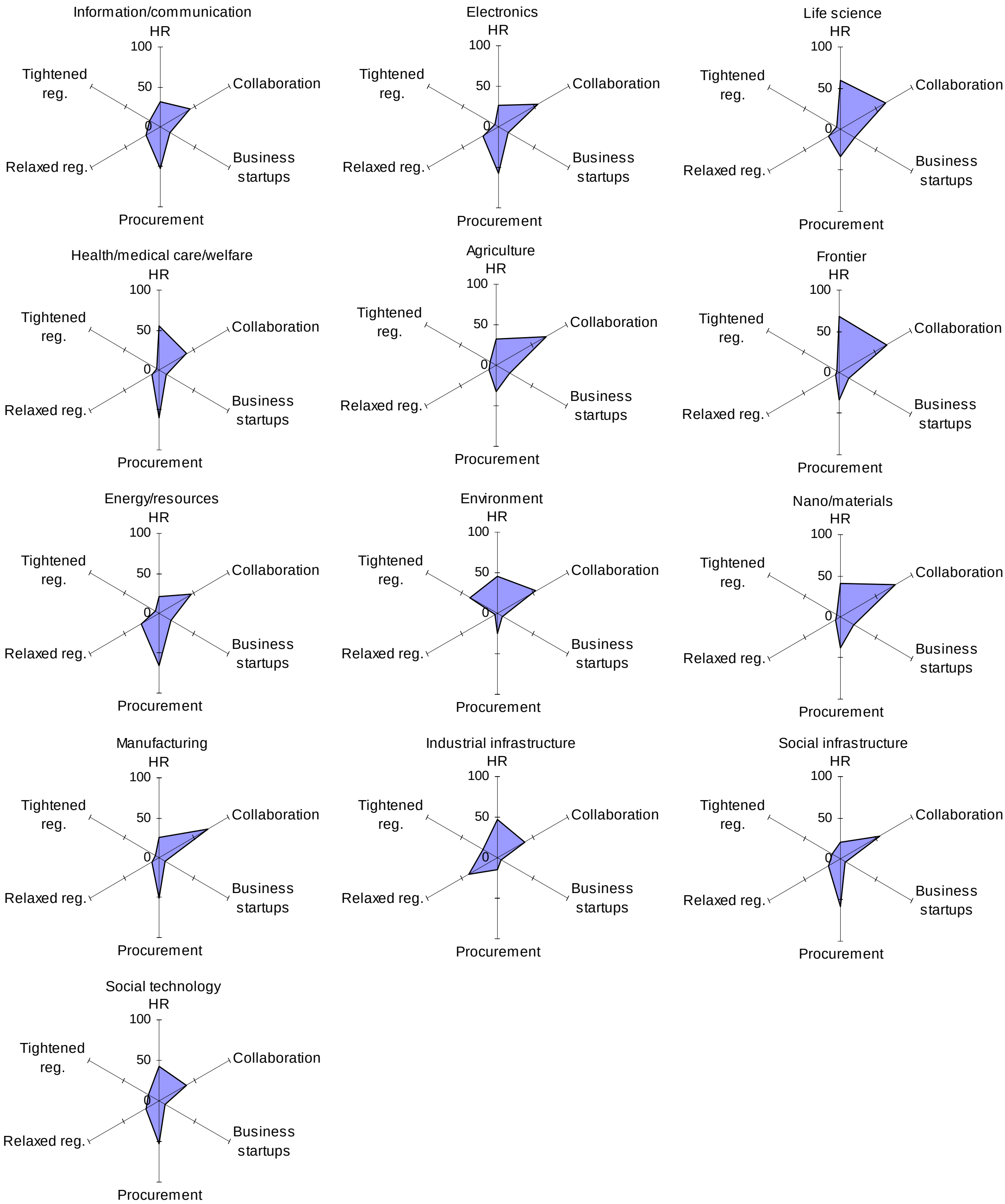
For example, areas in the social infrastructure field where support through taxation, subsidies, and procurement are strongly needed include environmental management in the transport sector and efficient and environmentally-friendly logistics systems technology, while those in the information and communications field include information security.

Chart 40 Effective measures that should be taken by government towards technological realization



(Note 1) HR: human resources development; Collaboration: strengthened industry-academia-government and interdisciplinary collaboration; Infrastructure: development of R&D infrastructure; Funding: expansion of R&D funding; Internationalization: internationalization of R&D activities; Relaxed reg.: relaxation or elimination of relevant regulations; Tightened reg. : tightened or new regulations
(Note 2) Multiple selections possible
(Note 3) Area averages used for field data

Chart 41 Effective measures that should be taken by government towards social application



(Note 1) HR: human resources development; Collaboration: strengthened industry-academia-government and interdisciplinary collaboration; Business startups: improvement of environment for business startups; Procurement: support through taxation, subsidies, and procurement; Relaxed reg.: relaxation or elimination of relevant regulations; Tightened reg.: tightened or new regulations

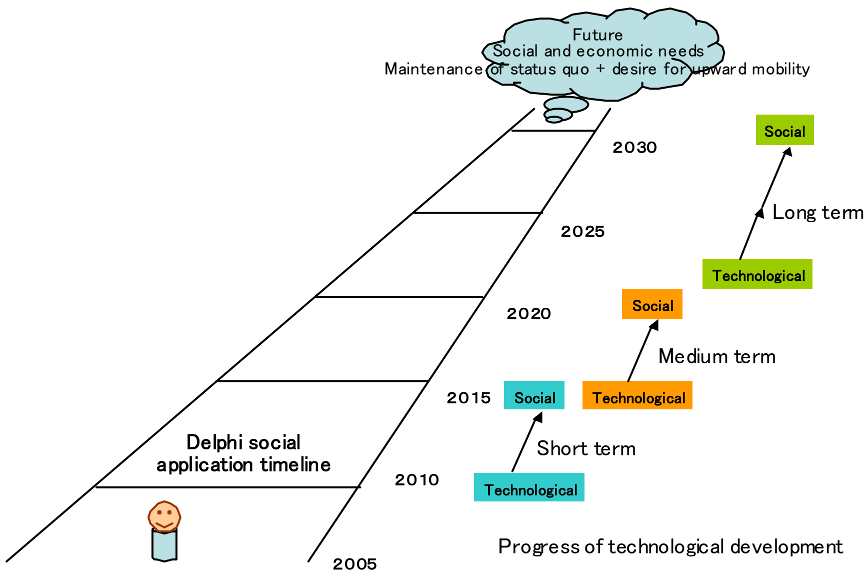
(Note 2) Multiple selections possible

(Note 3) Area averages used for field data

3.2.7. Characteristics of the 13 fields

Technological characteristics of the fields are summarized considering technological development. When the timeline created through the Delphi Analysis is used as the time axis and the time of technological realization and social application are examined, the following three categories result (see Chart 42).

Chart 42 Image of Delphi Analysis projected timeline



(Note) Short-term technologies with technological realization around 2010 and social application around 2015 (blue)
Medium-term technologies with technological realization around 2015 and social application around 2020 (orange)
Long-term technologies with technological realization around 2020 and social application around 2030 (green)

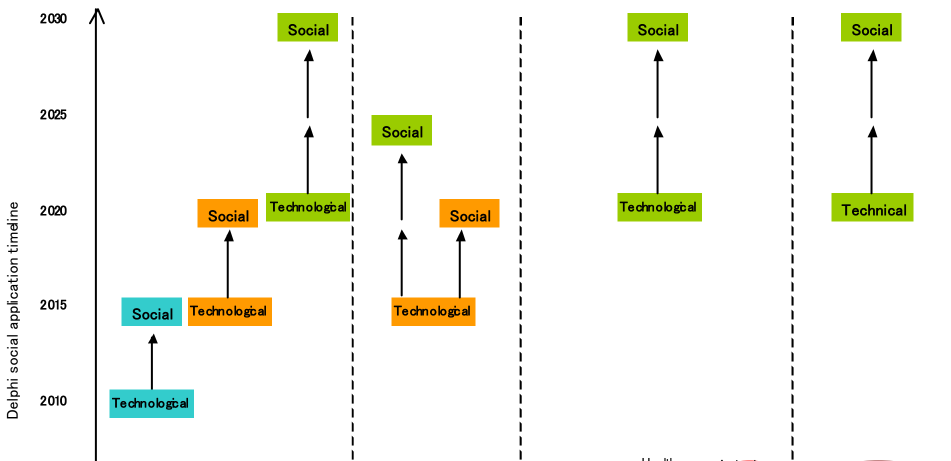
Based on this, characteristics of the 13 fields can be summarized as shown in Chart 43.

For example, in the information and communications and electronics fields, there are three patterns, short-term, medium-term, and long-term. The time lag between technological realization and social application is short compared with other fields. These fields appear to be led by the private sector, with less need for government involvement. Expanded research and development funding, strengthened industry-academia-government and interdisciplinary collaboration, and support through taxation, subsidies, and procurement are stressed as effective measures.

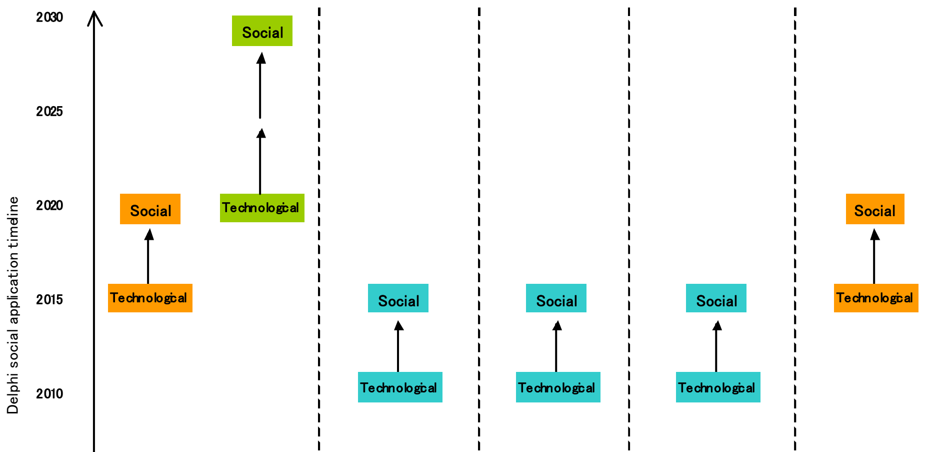
Life-related fields (life science, health, medical care, and welfare, agriculture, forestry, fisheries, and foods) and the frontier field include mainly long-term technologies. Their research and development levels are not necessarily high, and there is a strong need for government involvement. The fact that an effective measure is training and securing human resources also indicates the need for long-term policy.

The environment and energy fields are generally considered closely interrelated, but the Delphi Analysis indicates a high degree of independence. The environment field includes medium-term technologies, and its research and development level is moderate, while the energy field includes long-term technologies, and its research and development level is high. The reason for this gap is probably that there are many topics in the environment field involving environmental measurement, elucidation of mechanisms, social systems, and so on, while the energy field involves concrete countermeasure technologies and alternative energy technologies. Effective measures specific to the fields are strengthened industry-academia-government and interdisciplinary collaboration for the environment field, and support through taxation, subsidies, and procurement for the energy field.

Chart 43 Technical characteristics of the 13 fields



	Information and communications	Electronics	Nanotechnology and materials	Life science	Health, medical care, and welfare	Agriculture, forestry, fisheries, and food	Frontier
R&D level	Medium	High	High	Low	Low	Low	Low
Need for government involvement	Very low	Low	Medium	High	High	High	Very high
Technological realization	Funding	Funding, collaboration	Funding, collaboration	Funding, human	Funding, human	Funding, Collaboration	Funding, human, infrastructure
Social application	Procurement	Procurement, collaboration	Collaboration	Collaboration, human	Procurement, human	Collaboration	Human, collaboration



	Environment	Energy	Industrial infrastructure	Social infrastructure	Social technology	Manufacturing
R&D level	Medium	High	Low	Medium	Low	High
Need for government involvement	Very high	High	Very low	High	Medium	Medium
Technological realization	Funding	Funding	Human	Collaboration, funding	Funding	Collaboration, funding
Social application	Collaboration	Procurement	Relaxed	Procurement, collaboration	Procurement	Collaboration, procurement

Measures that should be taken by the government:

Human (human resources development), Collaboration (strengthened industry-academia-government and interdisciplinary collaboration), Infrastructure (development of R&D infrastructure), Funding (expansion of R&D funding), International (promotion of international development), Relaxed (relaxation or elimination of relevant regulations), Tightened (tightened or new regulations), Startup (improvement of environment for business startups), Procurement (support through taxation, subsidies, and procurement)

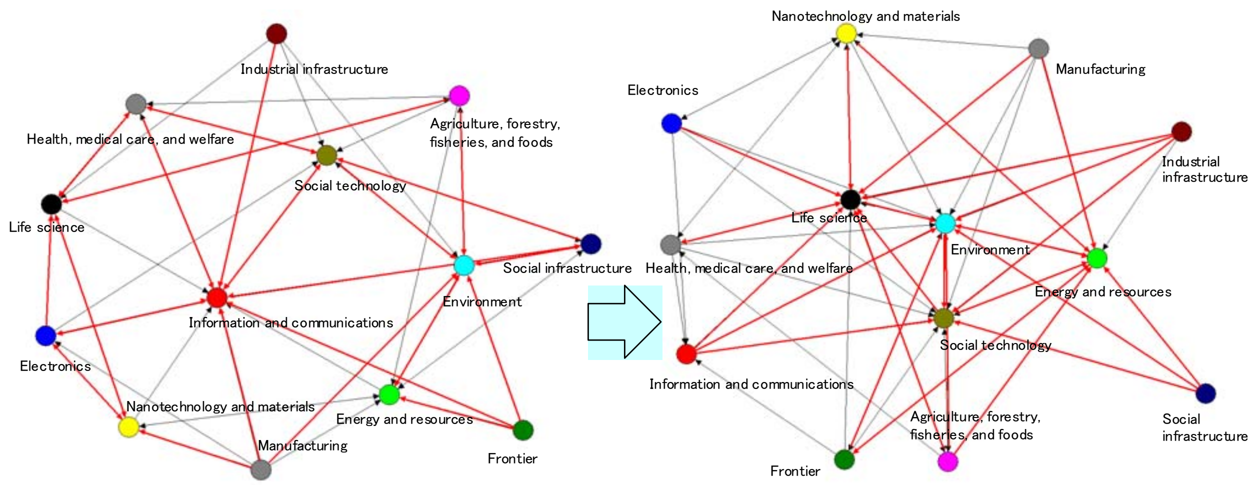
3.2.8. Integration and collaboration across fields

Developing integration and collaboration across fields is an important issue in science and technology policy. Respondents from each field were asked to select three fields that their own field should integrate and collaborate with over the coming 10 years and over the 10 years after that. The results are shown in Chart 44.

Over the 10 years through 2015, information and communications, environment, and social technology are likely to become the centers of integration and collaboration, with the environment, life science, social technology, and energy and resources fields filling this role over the subsequent 10 years.

Information and communications will cease to be a center of integration and collaboration after 2015, not because its importance will diminish, but rather because this field will need to aggressively pursue integration and collaboration with other fields over the subsequent 10 years. It is noteworthy that after 2015, life science will become a center of integration and collaboration, as will energy and resources. As Chart 43 illustrates, these fields are characterized by long-term technologies.

Chart 44 Integrated and collaborative relationships that should be actively pursued



Integrated and collaborative relationships that should be actively pursued until 2015

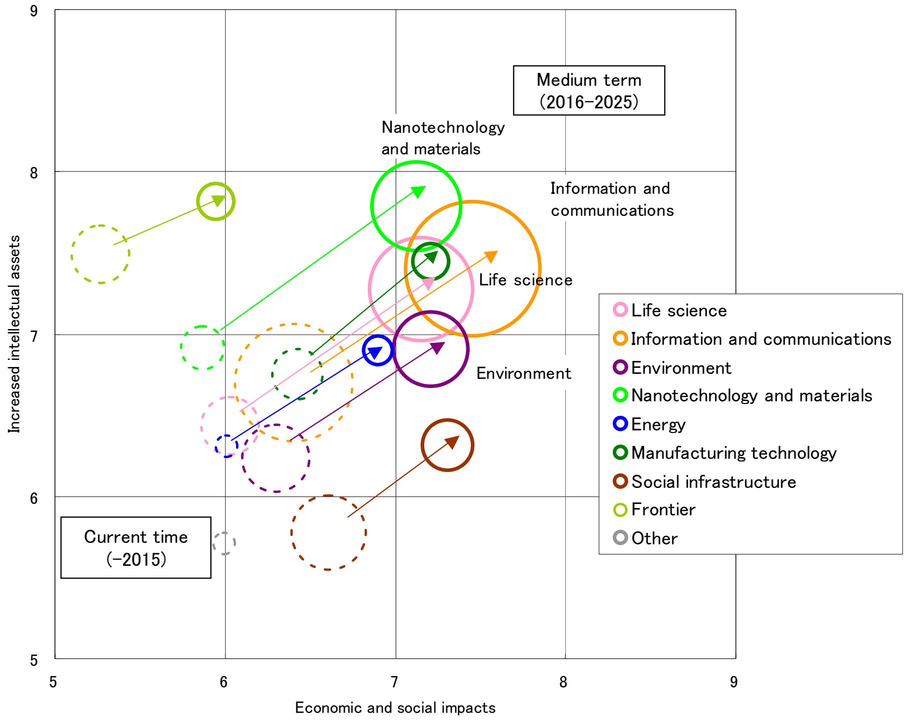
Integrated and collaborative relationships that should be actively pursued between 2016-2025

(Note 1) Up to three fields other than the respondent's field with which the respondent's field should seek integration and collaboration
(Note 2) Fields indicated for integration and collaboration by over 30 percent of a field's respondents are connected by an arrow. Mutual cases are indicated by a double-pointed arrow.
(Note 3) Red lines connect fields indicated by 50 percent or more of a field's respondents.

3.2.9. Examination based on the field classifications of the Science and Technology Basic Plan

We classified the 130 areas according to the eight fields described in the current Science and Technology Basic Plan (life science, information and communications, environment, nanotechnology and materials, energy, manufacturing, social infrastructure, frontier) and outside these fields and examined changes in their impacts between the present (now and 10 years into the future) and the medium term (2015–2025; see Chart 45).

Chart 45 Changes in the impacts of areas in the eight fields of the Basic Plan



Increased intellectual assets (vertical axis): increased intellectual assets (index)
Economic and social impacts (horizontal axis): average value of economic impacts (index) and social impacts (index)
Circle size: number of areas with overall impact*

* The number of areas with overall impact is the total of the 43 areas in the top one-third in terms of overall impact (see below) and the top 10 percent of areas (13 areas) in terms of individual impacts. This resulted in 51 areas for the present and 50 for the medium term. These were divided among the eight fields.

* Areas relevant to multiple fields were counted more than once, so values were calculated on the basis of 178 areas.

Arrows: Trends in impact over time

○ Overall impact

- The responses were indexed on a 10-point scale.

  Index=$\sqrt{\ }$ {(index of increased intellectual assets)^2 + (index of economic impacts)^2 + (index of social impacts)^2}

The values were rounded off to the nearest hundredth.

Four prioritized fields, i.e. information and communications, life science, nanotechnology and materials, and environment, include many areas with large overall impact in the medium term, and their impact is large both in terms of increased intellectual assets and in terms of economic and social impacts. The number of areas with overall impacts is increasing over time particularly in life science and nanotechnology and materials. In addition, the increasing impact likely to be brought by all four of these fields from the present to the medium term is remarkable.

Furthermore, as can be seen in Chart 46, there are many areas related to multiple fields, and many areas outside the four prioritized fields are connected to them.

Chart 46 Examples of areas spanning multiple fields

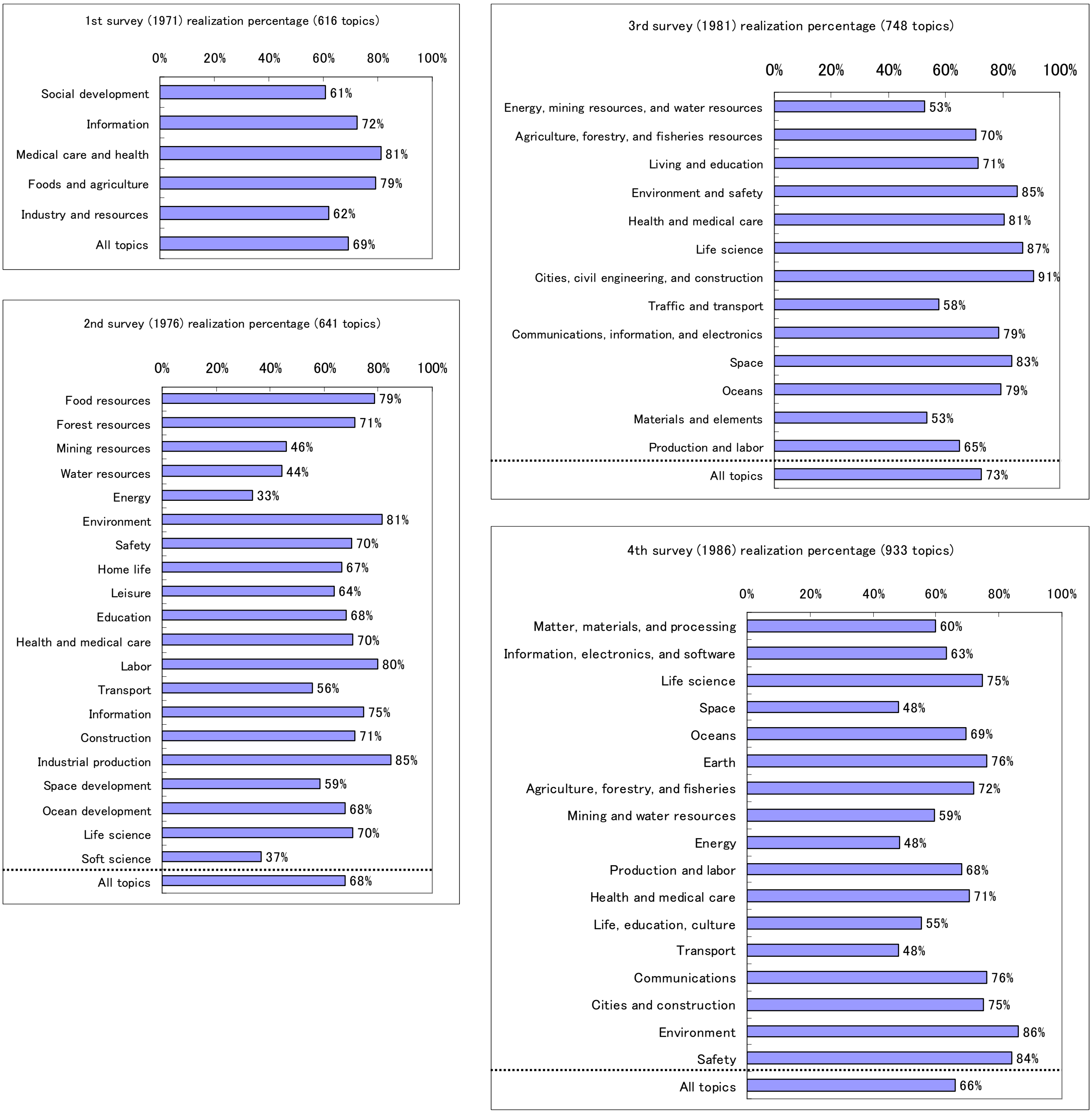
Area	Field
Bioligical solution to environmental problems and achievement of a sustainable society	Life science, environment, energy
Nanobiology	Life science, nanotechnology and materials
Nano devices and sensors	Information and communications, nanotechnology and materials
Manufacturing technology utilizing advanced information technology	Information and communications, manufacturing
Security electronics	Information and communications, social infrastructure
Recycling-oriented manufacturing technology with a low environmental load	Environment, manufacturing
Environmental management in the transport sector	Environment, social infrastructure
Technology for high precise observation of Earth environments and for prediction of change	Environment, frontier
Fuel cells	Environment, energy
Nano processing, molding, and manufacturing technology	Nanotechnology and materials, manufacturing

3.2.10. Evaluation and analysis of first, second, third, and fourth surveys

We evaluated the extent to which topics predicted in the first (1971), second (1976), third (1981), and fourth (1986) surveys for which at least 20 years have passed have been realized (see Chart 47). We calculated the percentage of the topics realized, including those that have been partially realized.

The percentage of topics from the first four surveys at least partially realized are, in chronological order, 69 percent, 68 percent, 73 percent, and 66 percent. Thus, about two-thirds of the topics were correctly predicted. Fields with high realization percentages include life science, health and medical care, agriculture, forestry, and fisheries, environment and safety, and cities, civil engineering, and construction. Those with low realization percentages include traffic and transportation and energy and resources.

Chart 47 Realization percentages for 1st, 2nd, 3rd, and 4th surveys



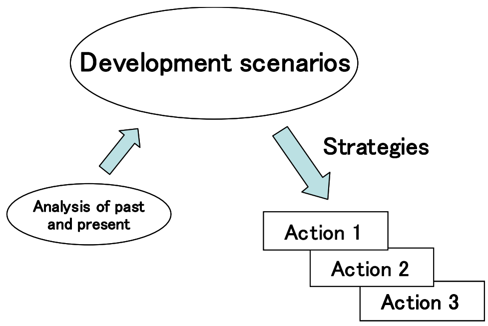
3.3. Scenario Analysis

For the Scenario Analysis, outstanding individuals (scenario writers) qualified to speak about the future were selected. Based on analysis of past and present conditions, they first sketched progressive scenarios and then described the actions that Japan should take to realize these scenarios. The addition of the progressive scenarios (images of the future) as another step is intended not merely to solve past problems but to draw out means of responding to problems that may occur in the future (see Chart 48).

Furthermore, in the Delphi Analysis, which has been continued as part of our foresight survey, opinions of forward-looking minority are not well reflected because of the formation of consensuses among groups of experts. The Scenario Analysis complements the Delphi Analysis in two ways.

1) It collects the unaveraged opinions of outstanding individuals.
2) Unlike the Delphi Analysis, the Scenario Analysis is not centered on technology, but handles themes in basic science and society.

Chart 48 Method of seeking images of future science and technology areas through the creation of progressive scenarios



3.3.1. Selection of progressive scenario themes and scenario writers

In the Scenario Analysis the themes used to create progressive scenarios are called “progressive scenario themes,” while those who use the themes to create scenarios are called “scenario writers.”

○ Selection of progressive scenario themes

A scenario analysis subcommittee was established. Based on the interim results of the Study on Rapidly Developing Research Areas and examination by the various Delphi Analysis subcommittees, it extracted draft progressive scenario themes. It examines science and technology areas with the potential to make major social and economic contributions or bring groundbreaking knowledge 10 to 30 years into the future. In addition, suggestions from other subcommittees and relevant government agencies were gathered, synthesized, divided, and otherwise arranged and adjusted. The selection schedule comprised two rounds of selection period. A time lag is placed in between in order to ensure certain amount of completeness in the areas. Finally, it was decided that scenarios would be created for 48 themes.

○ Selection of scenario writers

To select individuals with sufficiently advanced capability to create scenarios from the progressive scenario themes, a list of scenario writer candidates was first compiled. The first round of themes (29) was sent to 524 academic societies and other organizations relevant to the themes, and the second round (19 themes) was sent to 242 organizations with a request for recommendations for scenario writers. The results are shown in Chart 49.

Chart 49 Recommendation of scenario writer candidates

	Date of recommendations	No. sent (organizations)	Responses	No. of individual candidates recommended
First round of themes (29)	June 2004	254	105	391
Second round of themes (19)	September 2004	242	78	211

(Note) The Scenario Analysis subcommittee members were allowed to recommend candidates other than those in the above responses, and these recommendations are included in the number of candidates.

A candidate list is compiled. The recommended scenario writer candidates were arranged by theme in the list. This was sent to electors (comprising recommending organizations and fixed electors [independent administrative agencies, large academic societies, various organizations, mass media, etc.]), who in principle were asked to vote for one or two candidates from up to five themes from the first round and up to four from the second. If no appropriate candidate was recommended for a given theme, the voters were permitted to make up to two additional recommendations. The results are shown in Chart 50. Voting took place separately for the first and second rounds of themes to determine the order in which candidates would be requested to write. In the end, 96 people were asked to write scenarios.

Chart 50 Voting for candidates

	Period of voting	Number of ballots sent	Replies	Votes
First round of themes (29)	July-August 2004	501 organizations	180 organizations	701
Second round of themes (19)	October-November 2004	472 organizations	124 organizations	418

(Note) Scenario Analysis subcommittee members could vote for candidates other than those in the above ballots, and these votes are included in the number of candidates.

Chart 51 shows the final progressive scenario themes and the scenario writers who created them. Eighty-five scenarios for 47 progressive scenario themes were completed. Some themes have only one scenario because those asked to write a scenario did not complete it. Thirty-eight scenario themes include more than one scenario.

Chart 51 Submitters of scenarios

(The names of the scenario writers are listed in the order of the Japanese syllabary [honorifics omitted]; affiliations are as of March 2005)

No.	Area	Progressive scenario theme	Scenario writer	Affiliation
1	General science and technology topics	Reconstruction of science and technology evolution models	NAGAO Makoto HASEGAWA Mariko	President, National Institute of Information and Communications Technology Professor, School of Political Science & Economics, Waseda University
2		The principle and activities of academic societies	YOSHIKAWA Hiroyuki	President, National Institute of Advanced Industrial Science and Technology
3		Training and treatment of science and technology human resources		
4	Basic science	Mathematics research and education	HIRONAKA Heisuke Peter Frankl	Chairman, Japan Association for Mathematical Science Regent, Mathematical Olympiad Foundation
5		Position of basic science	KOBAYASHI Shinichi HIRASAWA Ryo	Director, Social Technology System Research Center, Japan Science and Technology Agency Professor Emeritus, University of Tokyo
6		Space science	KAIFU Norio MATSUMOTO Hiroshi	Director, National Astronomical Observatory of Japan, National Institutes of Natural Science Director, Research Institute for Sustainable Humanosphere, Kyoto University
7	Life science	Regenerative medicine for a long-living society	SAKURAI Yasuhisa MORISHITA Ryuichi	Professor Emeritus, Tokyo Women's Medical University Professor, Division of Clinical Gene Therapy, Osaka University Graduate School of Medicine
8		Drug development utilizing Nanobiology	HASHIBA Mitsuru BABA Yoshinobu	Professor, Graduate School of Pharmaceutical Sciences, Kyoto University Professor, Department of Chemical and Biological Engineering, Graduate School of Engineering, University of Nagoya
9		New healthcare for individual needs	ARAI Kenichi TANAKA Hiroshi	Director, Tokyo Metropolitan Institute of Medical Science Professor and Director of the Information Center for Medical Sciences, Tokyo Medical and Dental University
10		Minimally invasive bioinstrumentation technology and therapy	HASHIZUME Makoto MORIKAWA Yasuhide	Professor, Department of Advanced Medical Initiatives, Faculty of Medical Sciences, Kyushu University Professor, Department of Surgery (Pediatric), School of Medicine, Keio University
11		Integrated understanding of cognitive and emotional neuronic mechanisms based on brain science	AMARI Shunichi KATO Genichiro	Brain Science Institute, RIKEN Associate Professor, Department of Neuropsychiatry, School of Medicine, Keio University
12		Sensory prosthesis (technology)	AKAI Masami SHIMIZU Yutaka FUKUDA Atsushi	Department of Rehabilitation for Movement Functions, Research Institute, National Rehabilitation Center for Persons with Disabilities Professor, Department of Systems Engineering, Faculty of Electro-Communications, University of Electro-Communications Department of Information Transfer Medicine, Graduate School of Medicine, Osaka University
13		New healthcare system for emerging disease	IWAMOTO Aikichi HASEGAWA Toshihiko	Director, Advanced Clinical Research Center, Institute of Medical Science, University of Tokyo Director, Department of Policy Sciences, National Institute of Public Health
14		Preventative medicine in food science	ABE Keiko FUSHIKI Toru	Professor, Department of Applied Biological Chemistry, Graduate School of Agricultural and Life Sciences, University of Tokyo Professor, Division of Food Science and Biotechnology, Graduate School of Agriculture, Kyoto University
15		Development of life science as interdisciplinaryscience	USUI Shiro	Team Leader, Brain Science Institute, RIKEN
16	Informati on and communi cations	Communication utilizing the five senses	KASHINO Makio TACHI Susumu	NTT Communication Science Laboratories Professor, Graduate School of Information Science and Technology, University of Tokyo
17		Ultrahigh-capacity data processing devices	NEMOTO Yoshiaki	Director, Information Synergy Center, Tohoku University

No.	Area	Progressive scenario theme	Scenario writer	Affiliation
18		Ultralow power consumption in information and communications systems	NAKAMURA Toru MASTUSHIMA Yuichi	Professor, Department of Electronic Informatics, Faculty of Engineering, Hosei University Executive Director, Information and Network Systems Department, National Institute of Information and Communications Technology
19		Ultrafast high-capacity networks	INOUE Yuji	Senior Vice President and Manager of Department III, NTT Corp.
20		Life support robotics	KOSUGE Kazuhiro HAGITA Norihiro	Professor, Department of Bioengineering and Robotics, Graduate School of Engineering, Tohoku University Director, Intelligent Robotics and Communication Laboratories, Advanced Telecommunications Research Institute International
21		Humanoid robot technology	INOUE Hirochika DOI Toshitada	Inspector General, Japan Society for the Promotion of Science President, Sony Intelligence Dynamics Laboratories, Inc.
22		Information services with GPS technology	SHIBASAKI Ryosuke TAMAMA Tetsuo	Professor, Center for Spatial Information Science, University of Tokyo Member of Board of Directors, Defense Research Center (DRC)
23		Software engineering	TAMAI Tetsuo YAMAMOTO Shuichiro	Professor, Department of General Systems Studies, Graduate School/College of Arts and Sciences, University of Tokyo Technical Development Headquarters, NTT Data Corp.
24		Biomimetics through information technology	OMORI Takashi KAWATO Mitsuo	Professor, Division of Synergistic Information Science, Graduate School of Information Science and Technology, Hokkaido University Director, Computational Neuroscience Laboratories, Advanced Telecommunications Research Institute International
25		Quantum information technology	IMAI Hiroshi YAMAMOTO Yoshihisa	Professor, Department of Computer Science, Graduate School of Information Science and Technology, University of Tokyo Professor, National Institute of Informatics and Department of Electrical Engineering, Stanford University
26		Information and communications environments	SAKAMURA Ken DOI Miwako	Professor, Graduate School of Information Science and Technology, University of Tokyo Lead Researcher, HumanCentric Laboratory, Toshiba Corporate Research and Development Center
27	Environment	Low-emission cities	YASUI Itaru	Vice-Rector, United Nations University
28		Environmental measurement	AKIMOTO Hajime	Program Director, Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology
29		Science and technology indicators for solving environmental issues	TAIRA Keisuke YAMAMOTO Ryoichi	Controller, University of the Ryukyus Professor, Institute of Industrial Science, University of Tokyo
30		Environmental restoration technology	NISHIMURA Minoru WADA Eitaro	Center for the Strategy of Emergence, Japan Research Institute, Ltd. Program Director, Frontier Research center for Global Change, Japan Agency for Marine-Earth Science and Technology
31	Nanotechnology and materials	Materials design through computer simulation	DOI Masao MIYAMOTO Akira	Professor, Department of Applied Physics, School of Engineering, University of Tokyo Professor, Department of Applied Chemistry, Chemical Engineering and Biomolecular Engineering, Course of Applied Chemistry, Tohoku University
32		Measurement technology	GOSHI Yoichi	President, National Institute for Environmental Studies
33	Energy	The development of fuel cells and their dissemination into society	OTA Kenichiro HONMA Takuya	Professor, Graduate School of Engineering, Yokohama National University Executive Board Member, Fuel Cell Development Information Center
34		Energy conservation	TONOMURA Shigeaki MATSUI Kazuaki	Department Manager, Energy Conservation Technology Development Department, New Energy and Industrial Technology Development Organization Research Director, Institute of Applied Energy
35	Manufacturing technology	Design and manufacturing technology that cannot be easily imitated	AKAIKE Manabu ARAKI Hiromi	President, Universal Design Intelligence, Inc. President, Toyota Caelum Inc.
36		Automated production systems for small lots of very diversified products	CHUMA Hiroyuki HASHIMUKAI Hiroaki	Professor, Institute of Innovation Research, Hitotsubashi University Java Consortium, Control Devices Division, Fujisawa Factory, Yamatake Corp.

No.	Area	Progressive scenario theme	Scenario writer	Affiliation
37	Social infrastructure	Restoration and maintenance management for social infrastructure	UOMOTO Takehito NAKAMURA Hideo	Professor, International Center for Urban Safety Engineering Institute of Industrial Science, University of Tokyo Dean, Musashi Institute of Technology
38	Frontier	Deep Earth exploration	OKUBO Shuhei TAIRA Akihiko	Professor, Earthquake Research Institute, University of Tokyo Center for Deep Earth Exploration, Japan Agency for Marine-Earth Science and Technology
39		Satellite technology	SUMI Akimasa FUGONO Nobuyoshi	Professor, Center for Climate System Research, University of Tokyo President, Advanced Telecommunications Research Institute International
40	Technology for a safe and secure society	Stable supply of food	KAINUMA Keiji TAKAHASHI Masao	Chairman, Association for Advancement of Agricultural Science Professor, Graduate School, Kagawa Nutrition University
41		Post-disaster recovery	KAWATA Yoshiaki FUJIWARA Hiroyuki	Professor and Director, Research Center for Disaster Reduction Systems, Disaster Prevention Research Institute, Kyoto University National Research Institute for Earth Science and Disaster Prevention
42		The automobile oriented society	KOBAYASHI Toshio DAISHO Yasuhiro	Japan Automobile Research Institute Professor, Department of Mechanical Engineering, School of Science and Engineering, Waseda University
43	Industry and society	Risk management in finance	KON-NO Hiroshi	Professor, Department of Industrial and Systems Engineering, Faculty of Science and Engineering, Chuo University
44		Technology to forecast economic change	TAKAYASU Hideki NISHIMURA Kazuo	Senior Researcher, Sony Computer Science Laboratories Professor, Research Center for Economics of Complex Systems, Institute of Economic Research, Kyoto University
45		The sound mental and physical upbringing of "the next generation" in a society with a low birthrate	BESSHO Fumio	Professor, School of Medicine, Kyorin University
46		Efficiency improvement through information investment	AOKI Toshiharu HIRANO Masaaki	Representative Director and Advisor, NTT Data Corp. Professor, Waseda University Business School
47		Diversity and unity in Asian in science and technology	ISHII Takemochi	Professor Emeritus, University of Tokyo; Chairman, Tokyo Marine Research Institute
48		Science and technology for art, culture and recreation	NAKATSU Ryohei MATSUBARA Hitoshi	Professor, Department of Informatics, School of Science and Technology, Kwansei Gakuin University Professor, Department of Media Architecture, Future University - Hakodate

(Note 1) Area names were assigned for classification in the chart, but these names were not given to the scenario writers.

(Note 2) For each of the 48 themes, two people accepted the assignment to write the scenarios, but not everyone who accepted completed the scenario. As a result, there are some blanks in the chart.

Scenario theme 4: Mathematics research and education

Dr. Peter Frankl, Regent, Mathematical Olympiad Foundation

1. Analysis of current situation

In the past, mathematicians and physicists were very similar. Even now, many physicists have studied mathematics. One of the winners of the 2004 Nobel Prize in Physics has a doctorate in mathematics. Early in the 21st century, chemistry is another discipline making heavy use of advanced mathematics, and this trend is strengthening in biology as well. Through the Human Genome Project, even medical fields have become heavily involved with mathematics. Medical devices such as CT scanners and MRT developed over the past 20 years make very extensive use of higher-level mathematics called Fourier analysis. In addition, the weight of mathematics in economics has also increased. Furthermore, computers were developed by mathematicians. As can be seen from the above, mathematics is intimately connected with a number of scientific fields and has made important contributions to their development. This trend is likely to grow even stronger in the future.

2. Progressive scenario

"Discrete mathematics, probability theory, and the complete elucidation of the Riemann Hypothesis"

Attractive, interesting problems draw researchers into a field. When these problems are solved, the number of people researching in that field decreases. This has been repeated many times in the history of mathematics. Currently, the most interesting major problem is "P ≠ NP." This problem in discrete mathematics appeared through the development of computers. In simple terms, it is an attempt to prove that efficient, good methods of solving certain problems using computers do not exist. Over the coming 30 years, this problem and the theoretical computer science surrounding it will grow remarkably. Probability theory and its surrounding theories will grow in a similar fashion. In addition, the complete elucidation of the Riemann Hypothesis and related research will likely develop extensively.

3. Actions Japan should take

(1) It is difficult to grasp actual conditions without objective outside evaluation. Japan's leading universities and the mathematics field as a whole need outside (overseas) evaluation.

(2) Japan should actively invite foreign researchers to Japan.

(3) Japan should strengthen its sabbatical system, allowing researchers to join overseas research institutions every few years.

(4) An environment that allows outstanding foreign students to remain in Japan to continue their research should be created.

(5) Hierarchical societies should be eliminated and universities democratized for the sake of younger mathematicians.

(6) Japan should create a national institute of higher mathematics with an environment in which mathematicians can immerse themselves in research. Topics should be selected each year and personnel from all over the world with profound knowledge of the relevant fields invited for one year only to conduct research while they engage faculty members and students.

(7) Policies to encourage mathematically talented young people to enter a research career. 1) Mandate greater use of computers in high schools, 2) encourage the establishment of math departments equivalent to athletics departments, 3) gather selected students in one location for contests in creating and solving math problems as well as personal exchange, (overnight) summer camps with lectures from frontline researchers and so on, 4) unconditionally admit to universities outstanding performers in the International Mathematical Olympiad (IMO) and the Japanese version (JMO).

This summary was created by NISTEP from the main points of the scenario.

Scenario theme 9: New healthcare for individual needs

Professor TANAKA Hiroshi, Tokyo Medical and Dental University Graduate School

1. Analysis of the current situation

When we consider that even though Japanese healthcare accounts for 7–8 % of GDP, a low figure for a developed country, it has the world's longest life expectancy, national healthcare appears to operate efficiently. However, this long life expectancy is because of the high level of health awareness among the public and the efforts of those involved in healthcare. The institutions and systems around Japanese medicine actually face a number of problems. For example, correcting the gaps in the quality of healthcare provided by different medical facilities is a major issue. The highest standard of medical care today is not available to everyone at every facility.

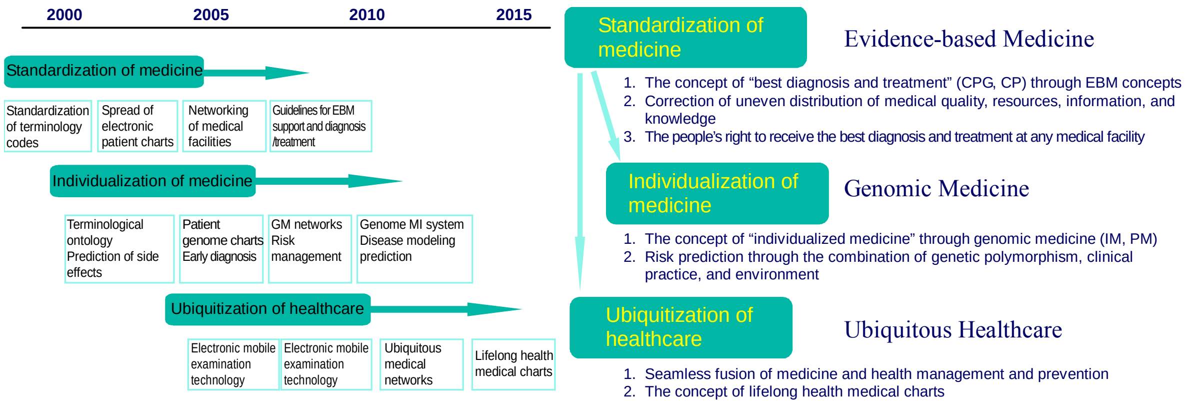
2. Progressive scenario

(1) Early realization (the coming 5 years or so): administration of individualized drugs such as anti-cancer agents

(2) Realization over the short to medium term (the coming 8 years or so): individualized healthcare through very early diagnosis, especially of cancer, by measurement of exhaustive biological data such as the genome and proteome

(3) Realization over the medium to long term (the coming 12 years or so): establishment of care in accordance with the condition of the individual to prevent the onset or worsening of disease

(4) Realization over the long term (the coming 15 years or so): individualized healthcare through ubiquitous health and medical information that seamlessly unites disease and health



3. Actions Japan should take

(1) Promotion of individualized medicine in medical development centered on pharmaceutical genomics

(2) Identification of individual genetic polymorphism that causes the onset, progress, and worsening of lifestyle-related disease, elucidation of the interaction between genes and environments, and individualized medicine based thereon

(3) Research and development of information systems to support individualized medicine

Stage 1: Establishment of basic IT technology for the realization of genomic medicine

Stage 2: Consortium-type collaboration on the test development of actual hospital and medical information networks

Stage 3: Proving test stage

(4) Towards the development of national information infrastructure for ubiquitous medical and healthcare management

This summary was created by NISTEP from the main points of the scenario.

Scenario theme 20: Life support robotics

Dr. HAGITA Norihiro, Intelligent Robotics and Communication Laboratories, Advanced Telecommunications Research Institute International

1. Analysis of the current situation

In the research and development of lifestyle support robotics, there are two trends, “mechanical robots” that perform mechanical acts in place of human beings and “communications robots” that emphasize communication functions. The latter element, communication with human beings, is particularly vital to lifestyle support robotics. The elements and ideas below are garnering attention.

* Physical contact: Unlike other types of communications media, only robots include physical contact as a form of communication. This is connected to friendly communications activities.
* Networked robots: The concept of “networked robots” -- generating services by networking robots rather than attempting to add functions to individual robots -- is Japan’s flagship technology.
* Present medium: The ability to respond and reply to speech can make robots a “present medium,” providing added companionship in Japan’s aging society.

2. Progressive scenario

The development of lifestyle support robotics will be at Stage 1 from now until about 2015, with technology for “mechanical robots” and “communications robots” developing separately. Beginning about 2016, Stage 2 will likely see the development of integrated technology.

Development during Stage 1 is likely to progress as follows.

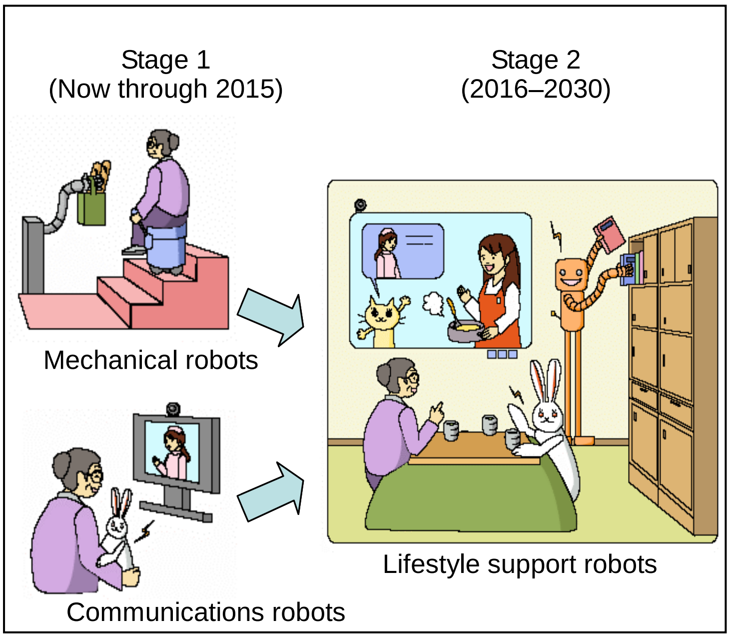
Single-function household robots

↓

Upgrading of functions through networks

↓

Coordinated service by networked robots



3. Actions Japan should take

Strategy 1: Connecting various robots to network information and communications infrastructure is the top priority.

Strategy 2: Power-assist technology should be given priority for advancement.

Strategy 3: Take initiatives on social intelligence (communication with human beings) rather than on individual intelligence.

In particular, Japan should establish initiatives to actively advance collaborative research in social science, cognitive science, brain science, and other research fields related to robot-human interaction (research on social intelligence-utilizing robots).

This summary was created by NISTEP from the main points of the scenario.

Comparative analysis: scenario theme 44: Technology to forecast economic change

Professor NISHIMURA Kazuo, Institute of Economic Research, Kyoto University
Dr. TAKAYASU Hideki, Sony Computer Science Laboratories

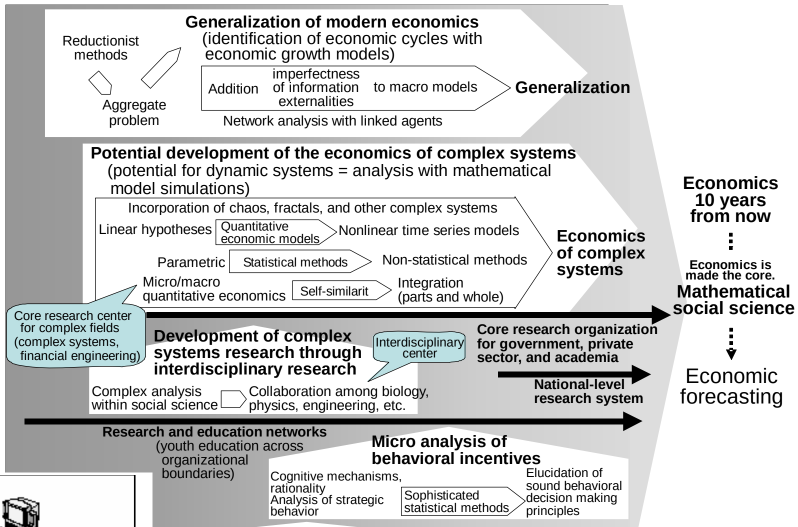
For this theme, economist and expert on the economics of complex systems, Professor NISHIMURA Kazuo and Dr. TAKAYASU Hideki, who is working in the new physics-based field of econophysics, were selected as scenario writers.

In the progressive scenario, Professor NISHIMURA presents an overview of economics over the coming 10 years as a whole. Current economics has become generalized, and with increased data volume and its accumulation, microanalysis of behavioral incentives, and interdisciplinary research with other science and technology fields contributing to the parallel development process of complex economic systems, economics as a whole is becoming a mathematical social science.

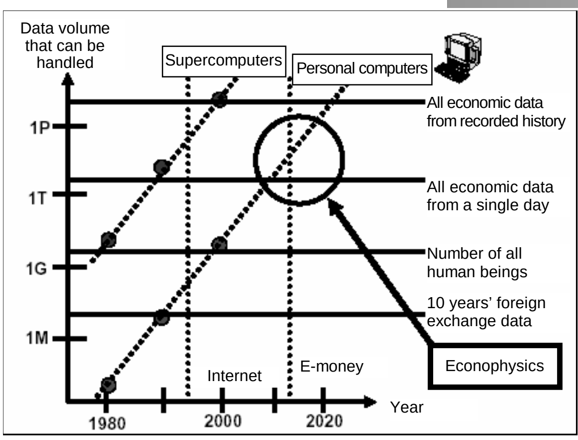
Meanwhile, Dr. TAKAYASU predicts that with the shift towards an environment in which anyone can obtain vast amounts of data in real time, 10 years from now, only countries that possess new data processing technologies and highly reliable computers systems will be able to dominate the financial world, and he hints at the potential contribution of the burgeoning field of econophysics.

Approaching the theme from completely different fields, the authors predict an almost identical future. Regarding actions that Japan should take, they propose establishing an interdisciplinary research institute as the academic core.

Changes in economics as a whole
(Prof. NISHIMURA Kazuo)



Targets of econophysics
(Dr. TAKAYASU Hideki)



Prof. NISHIMURA Kazuo's "actions Japan should take"

- Prioritized promotion of the economics of complex systems, in which Japan leads
- Establishment of a core academic center for advanced economic theory and interdisciplinary science
- Networking of graduate education

Dr. TAKAYASU Hideki's proposed "actions Japan should take"

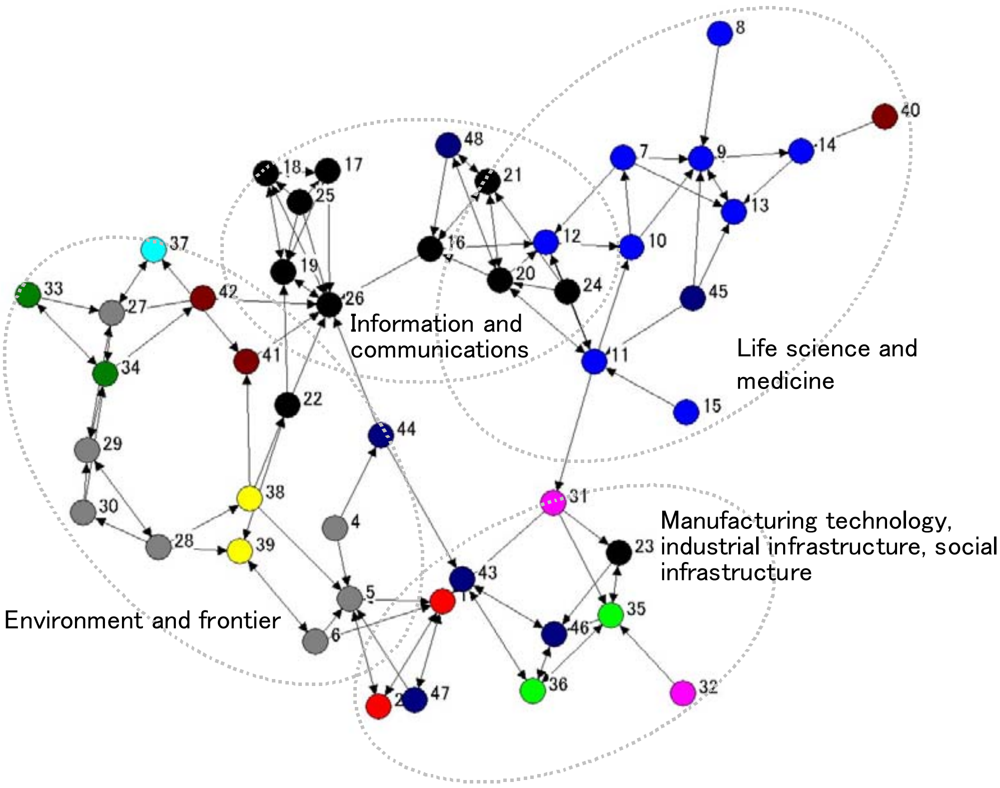
- Establishment of a public research institution to construct a completely new financial computer system

This summary was created by NISTEP from the main points of the scenario.

3.3.2. Relationships among progressive scenarios

Chart 52 is a map of the interrelationships among the scenario themes written in the progressive scenarios. Themes with strong relationships to other themes are “Information and communications environments (No. 26),” “New healthcare that meets individual needs (No. 9),” and “Position of basic science (No. 5).” In addition, as the dotted lines in the chart depict, there is a large overlap between “life science and medicine” and “information and communications.”

Chart 52 Interrelationships among the scenario themes



3.3.3. Future challenges indicated by progressive scenario writers

Some progressive scenario writers submitted, together with scenarios, opinions and proposals on science and technology in general or on the specific field, as summarized below. These are issues that cannot be obtained through a Delphi survey and should therefore be taken into consideration as Japan’s research activities move forward.

(Points indicated in several themes without reference to field)

- The necessity of integration with other fields, interdisciplinary research, breaking down institutional barriers, and so on is pointed out.
- The need for strategic planning at national level is asserted. In addition, establishment of research centers for special purposes and gathering human resources from multiple fields are proposed several times.

- The need to connect science and technology to society, and particularly to work to obtain public understanding, is pointed out.
- Many themes propose systemic improvements in response to the changing social environments facing Japanese scientists and researchers.
- Creation of a system for evaluation data development and sequential assessment is desirable to promptly assess policy proposals.
- Although in asking about actions Japan should take, the Scenario Analysis asserts the necessity (inevitability) of Japan working out its own research and development rather than following Europe and the USA, many cases from Europe and the USA are cited as models and examples.
- Although the scenario writers were asked to depict constructive future scenarios, some claimed that they cannot help but envision a negative future for the given theme.

(Points peculiar to specific fields and areas)

○ Areas in basic disciplines such as mathematics or themes in which research will be very difficult to realize
- Securing of human resources, especially the establishment of field-specific education systems, is proposed.

○ Themes related to life science
- The key concepts jointly raised in these nine themes are "utilization of computers and information science" and "constructing such systems." There seems to be a deficiency in this regard.

○ Themes related to information and communications
- The realization of a ubiquitously wired society is assumed, with 2015 being approximately when society as a whole will welcome the era of knowledge utilization. There are already attempts to coin words other than "ubiquitous" to describe the coming society.

○ Themes related to energy, social infrastructure, etc.
- In advance of natural science approaches, the particular necessity of resolving social problems and of clarifying social goals is suggested.

○ Themes related to industrial development
- It is pointed out that appropriate investment in and policies on information and communications technology are connected with a secure society and the maintenance of industrial competitiveness. In particular, it is indicated that the technical development of software is lagging behind that of hardware.

Summary 3:

Holistic overview of the development of fields and areas

The development of the expected four major fields and other fields can be summarized as follows.

○ <u>Areas related to information and communications</u>

The information and communications field includes three patterns, short-term, medium-term, and long-term technologies, depending on the area. The field is characterized by a shorter time lag between technological realization and social application compared to other fields. Because the need for government involvement is low, the private sector is likely to continue to lead development. Effective measures needed from the government are expansion of R&D funding, strengthened industry-academia-government and interdisciplinary collaboration, and support through taxation, subsidies, and procurement. The realization of a ubiquitously wired society is assumed, with 2015 marking the approximate time at which society as a whole will welcome the era of knowledge utilization. In addition, over the coming 10 years, the information and communications field is likely to become central to integration and collaboration among the fields, and steady development towards this end is needed. Mathematics and computer science, the basic research disciplines that support areas related to information and communications, are weak spots in Japan. Strengthening them is expected to lead to further leaps in technical progress.

○ <u>Life-related areas</u>

The life science field includes long-term technologies. From 2015, it will be central to the integration of fields. Training and securing human resources is strongly noted as an effective measure that can be taken by the government, further indicating the need for long-term policies. Looking at the field's future direction, "utilization of computer science or information science" is emphasized, and contact with these areas should be increased. Furthermore, the role of technology to meet needs for safety, security, and health will appear. To advance such technology, deepening basic research is mandatory. Compared with other developed countries' basic science portfolios, basic biology and clinical medicine have greatly expanded in Japan over the past 20 years, but the quantity of Japan's basic research activities remains insufficient and, in many fields, the quality lags behind the USA, the UK, and Germany. With top scientists and researchers from abroad having pointed out a "lack of depth," Japan must steadily accumulate basic research with clearly defined goals.

○ <u>Environment-related areas</u>

The areas identified in the field of environment through the Delphi Analysis are medium-term technologies. Most of these involve environmental measurement, elucidation of mechanisms, and social systems, and technologies meeting direct needs are often included in fields such as energy and resources, manufacturing, and social infrastructure. In contrast, the energy field comprises long-term technologies, and over the long term, it is expected to be among those central to the integration of fields. In environmental science, although Japan has a smaller share of article publications than in other fields, its applied and countermeasure technologies are highly regarded by leading scientists and researchers from overseas. In the Delphi Analysis as well, Japan's R&D level in fields centered on technologies to respond to environmental issues, such as energy and resources, manufacturing, and social infrastructure, was seen as high. These are fields where Japan should utilize its strength through promotion policies with clearly established "goals." On the other hand, to respond to needs such as actively contributing to solving global issues, in addition to elemental technologies and individual countermeasure technologies, it is essential to deepen understanding of the environment as a system. Fundamental to achieving this is expanding environmental science with a long-term perspective. The field requires extensive government involvement, with effective measures strengthened through industry-academia-government and interdisciplinary collaboration, support through taxation, subsidies, and procurement, and expanded R&D funding.

○ Areas related to nanotechnology

The areas identified in the field of nanotechnology and materials are characterized by relatively early technological realization coupled with time lags to social application that vary from short to long. The effective measure for government involvement is "collaboration," while promoting the integration of fields needed along with industry-academia-government collaboration. In the Delphi Analysis, the economic aspects of the field's expected impacts are very apparent, making it clear that the ambitions and goals of researchers in Japan are oriented towards application. Frameworks to realize concrete results should be strengthened.

These areas are based on the Japanese strong points of physics, material science, and chemistry, and nanoscience should be enhanced with a long-term perspective as the foundation for the pioneering of new nanotechnology. Five and ten years from now, the field must not be seen by overseas researchers as lacking in "depth." The recent rise of China and South Korea in material science especially has been eye opening. Japan should continue to utilize the store of knowledge it has accumulated and build a dynamic research environment that makes it easy to generate new areas by emphasizing interdisciplinary sectors and disciplines where rapid development is expected.

○ Other

In this Delphi Analysis as a whole, the rise in the importance of technologies related to security and safety is notable. This also accords with our Study on Social and Economic Needs, in which health and other needs related to security and safety have been emphasized.

The frontier field is one of those seen as important in the Delphi Analysis. Test matching of socio-economic needs with the 130 areas shows that this field makes a major indirect contribution to such needs. However, Japan's research and development level trails behind that of Europe and the USA, and the field requires government-led promotion.

In the Delphi Analysis, there are many areas that are relevant to multiple fields, and some areas from fields other than the four major fields are strongly related to these four. As can be seen from the number of interdisciplinary areas identified in our Study on Rapidly Developing Research Areas, it is difficult to remain inside traditional boundaries when solving problems. In addition, in the management and system technologies included in the field of industrial infrastructure, which are strongly characterized by the way they integrate the humanities and science, Japan's R&D level is considered low. To skillfully apply to social systems the elemental technologies that are Japan's strength, it is necessary to improve research on the aspects of such a system.

Reference Materials

Reference Materials 1: The case study in the impact survey

The purpose of this impact survey is to understand in detail the contribution of public research and development, and support to the impact or the impact realization process of technologies. For each of eight fields (life science, information and communications, environment, nanotechnology and materials, energy, manufacturing technology, social infrastructure, and frontier), two technologies that have already been realized and have generated impacts over the past 10 years (current technologies) and two technologies that are expected to be realized and bring impacts within the next 10 years (future technologies) were selected. These 32 cases were then analyzed. A summary of the case study is given below.

For the case study, interviews with experts and other relevant persons as well as literature reviews were conducted. An attempt was made to understand the technical trends, the role of public R&D and support, and impact on the economy, society, and people's lives of each technology. A perspective on the case study of current and future technologies is shown in Chart Reference 1-1.

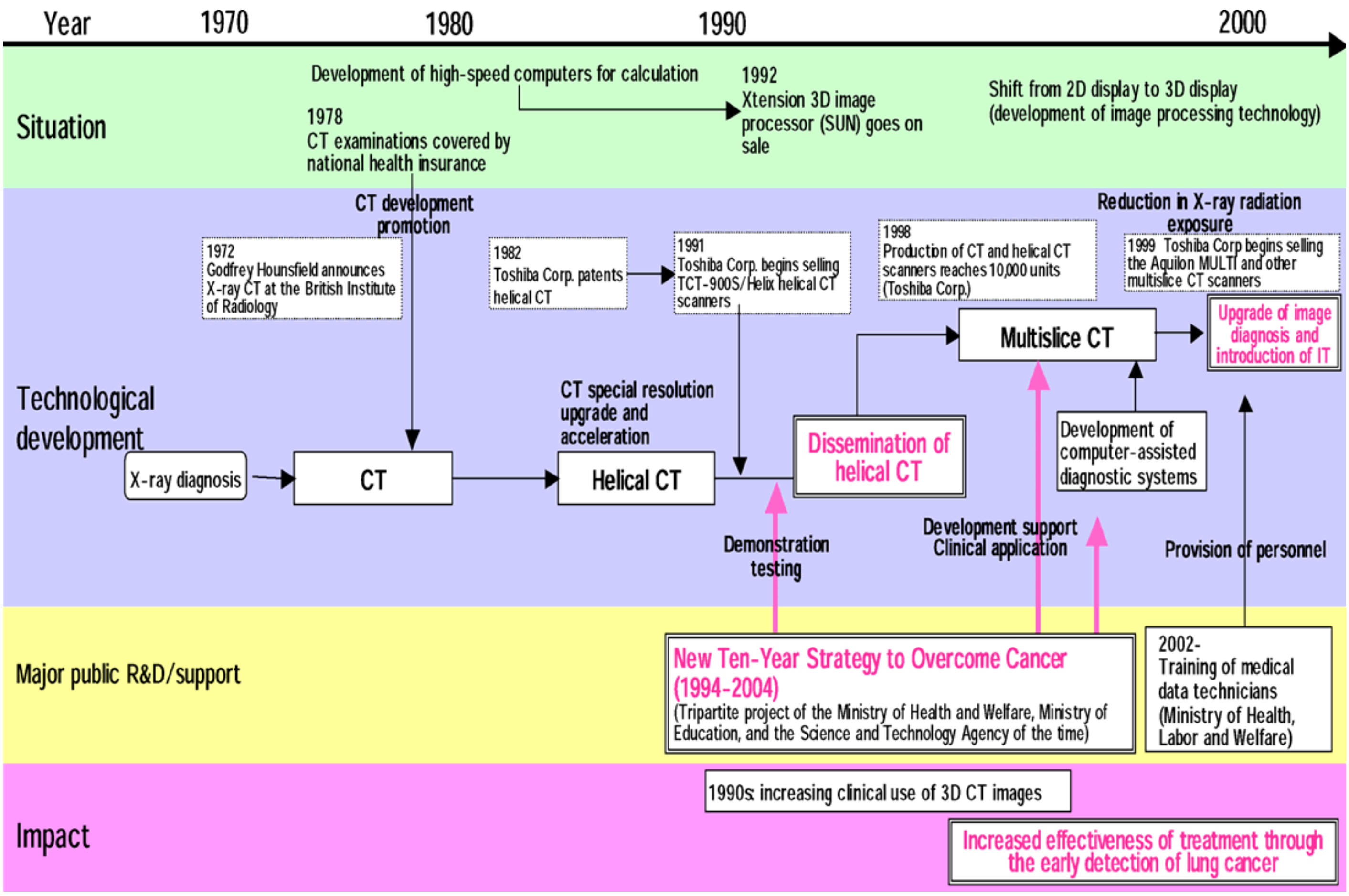
Chart Reference 1-1. Perspective on case study of current and future technologies

	Current technologies	Future technologies
Technical trends	● Technology type/details ● Background of technical development ● Changes in the relevant social environment ● Technical trends to the point at which impact was realized	● Technology type/details ● Background of technical development ● Changes in the relevant social environment ● Position to date in technical trends leading towards the realization of impact
Role of public R&D and support	● Relevant public R&D and support ● Contribution of public R&D and support	● Relevant public R&D and support ● Contribution of public R&D and support
Impact of technology on economy, society, and people's lives	● Types and details of impact realized ● Process by which impact was realized ● Discrepancies with the above application fields	● Type and details of expected impact ● Process by which impact will be realized ● Issues concerning and impediments to the realization of impact ● Discrepancies with the above application fields
Other	● Conditions surrounding the technologies ● Issues to date in public R&D and support ● Optimum future public R&D and support	● Conditions surrounding the technologies ● Issues to date in public R&D and support ● Optimum future public R&D and support

Helical CT technology (application to early diagnosis of lung cancer) (Life Science)

<Case study topics>

- Developing since the 1970s, the increasingly high performance of CT scanning has made an important contribution to the early detection of lung cancer. Japan leads the world in CT development. Helical CT, developed mainly by private sector corporations since the 1980s, enables the detection of very small tumors at the early stages. During the 1990s, helical CT technology continued steady progress via improved performance through the development of multislice CT by private sector firms.
- Helical CT was demonstrated in the New Ten-Year Strategy to Overcome Cancer, which was a tripartite project of the Ministry of Health and Welfare, Ministry of Education, and the Science and Technology Agency of the time. This demonstration led to the dissemination of helical CT in Japan.
- As examination technology that can detect lung cancer at the early stages, helical CT is having a broad impact on society (improving examination reliability, etc.) and people's lives (decreasing examination time, improving effectiveness of treatment through early detection, etc.).



<Economic impacts>

- Optimization of healthcare spending through the early detection of lung cancer
- Expanded markets for medical devices
  ¥49.6 billion in 2001. The market share leaders were Toshiba (47.3%), GE Yokogawa Medical Systems (32.5%), and Siemens-Asahi Medical Technologies (10.5%).
- Cost reductions through accelerated and automated examinations

<Social impacts>

- Increased reliability of examinations

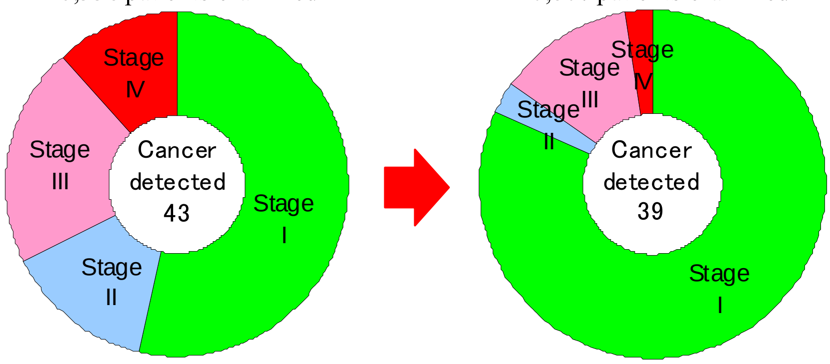
<Impacts on people's lives>

- Decreased examination time
- Improved effectiveness of treatment through the early detection of lung cancer
  Before the introduction of helical CT, 163 cases were detected per 100,000 people. After its introduction, the rate more than doubled to 361 per 100,000.
- Improved post-operative quality of life

Lung cancer detection before and after the introduction of helical CT

Before (9/1975 through 8/1993) 26,338 patients examined

After (9/1993 through 8/1998) 10,807 patients examined



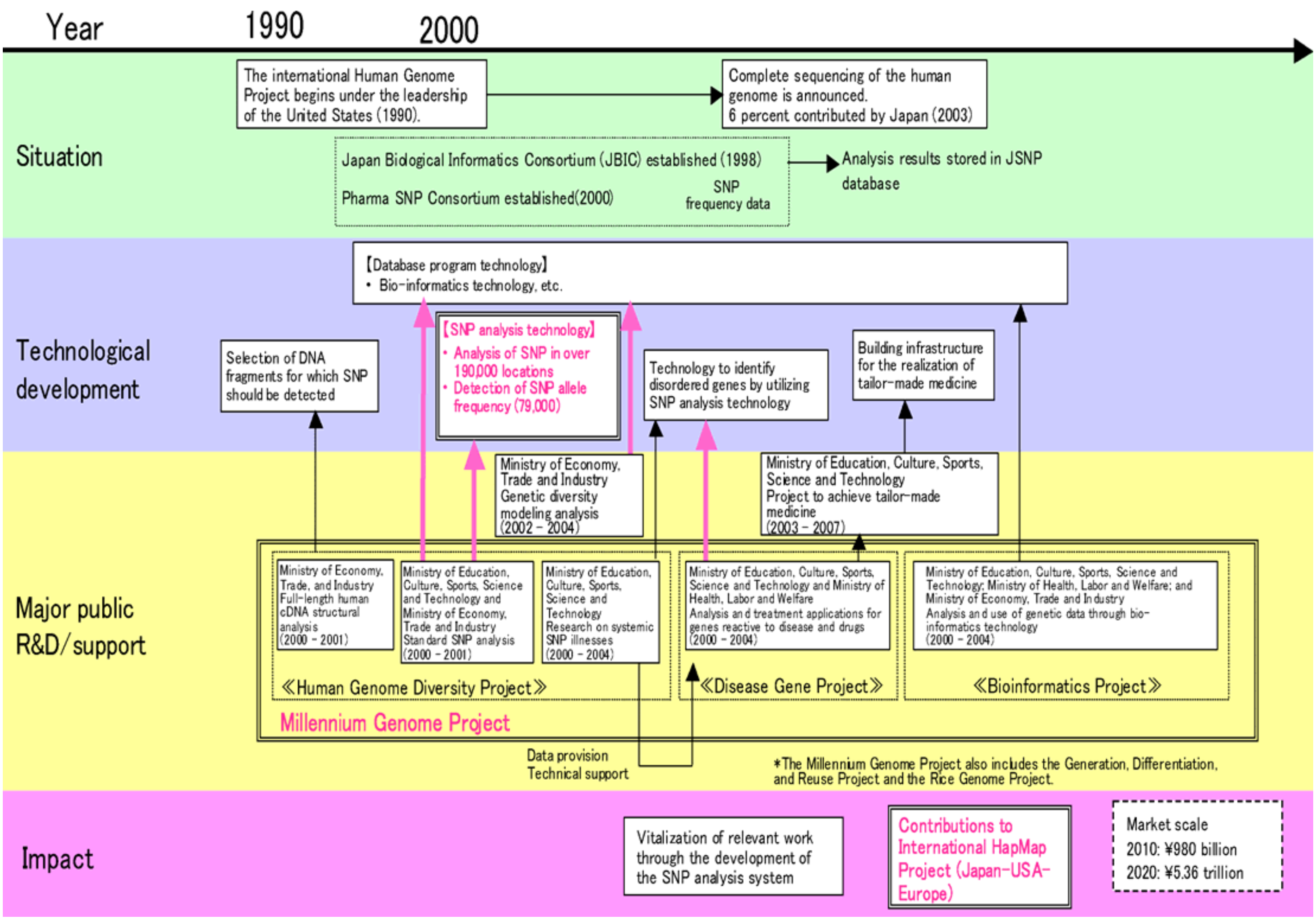
Source: Anti Lung Cancer Association (ALCA)

- The above data come from 37,145 ALCA members (90% male, average age 60) who received examinations (chest X-rays and sputum cytological exam through August 1993; chest X-rays, sputum cytological exam and helical CT scan after September 1993) through August 1999. Eighty-two cases of lung cancer were found.
- It is noteworthy that after the introduction of helical CT, more cases were detected at stage I.
- Stage I cancers (those in which cancer remains confined to a primary tumor) can often be resolved by surgery, and during the very early stages in which cancer cells are present only on the surface of alveoli, a 100-percent resolution rate is possible. Cancer advances through stages II through IV. At stage IV, cancer metastasizes beyond the primary tumor to other locations and organs. The five-year postoperative survival rates are 80% at stage I, 60% at stage II, 40% at stage III, and less than 10% at stage IV.

High throughput detection of single nucleotide polymorphisms and its application for diagnosis and personalized medication (Life Science)

<Case study topics>

- Through the Millennium Genome Project, the provision of R&D funding by universities and the private sector and collaborative academia-business R&D contributed to technical progress. In addition, SNP data useful for the gene region of the Japanese were also accumulated.
- These data are also being used in the International HapMap Project. Since the data began to be made publicly available, the RIKEN SNP Research Center has made the largest contribution to the project of the eight research institutions in the five nations involved.
- In addition to affecting people's lives by realizing tailor-made medicine, reducing pharmaceutical side effects, and curing refractory illnesses, economic impacts such as reduced healthcare costs (2020 market scale of ¥5.36 trillion) are also expected.
- Database maintenance and operating costs, the creation of rules for information disclosure, and R&D for basic infrastructure for the functional and structural analysis of proteins are necessary now and into the future.



<Economic impacts>

- Vitalization of relevant work through development of the SNP analysis system
- Potential reduction in healthcare costs through realization of tailor-made medicine and reduction in drug side effects
  - Market scale for genome-based drugs (tailor-made medicine): ¥980 billion in 2010, ¥5.36 trillion in 2020
- Potential reduction in social welfare costs
- Potential vitalization of pharmaceutical and medical diagnosis firms
- Potential vitalization of the medical devices industry through the fusion of IT and medical fields

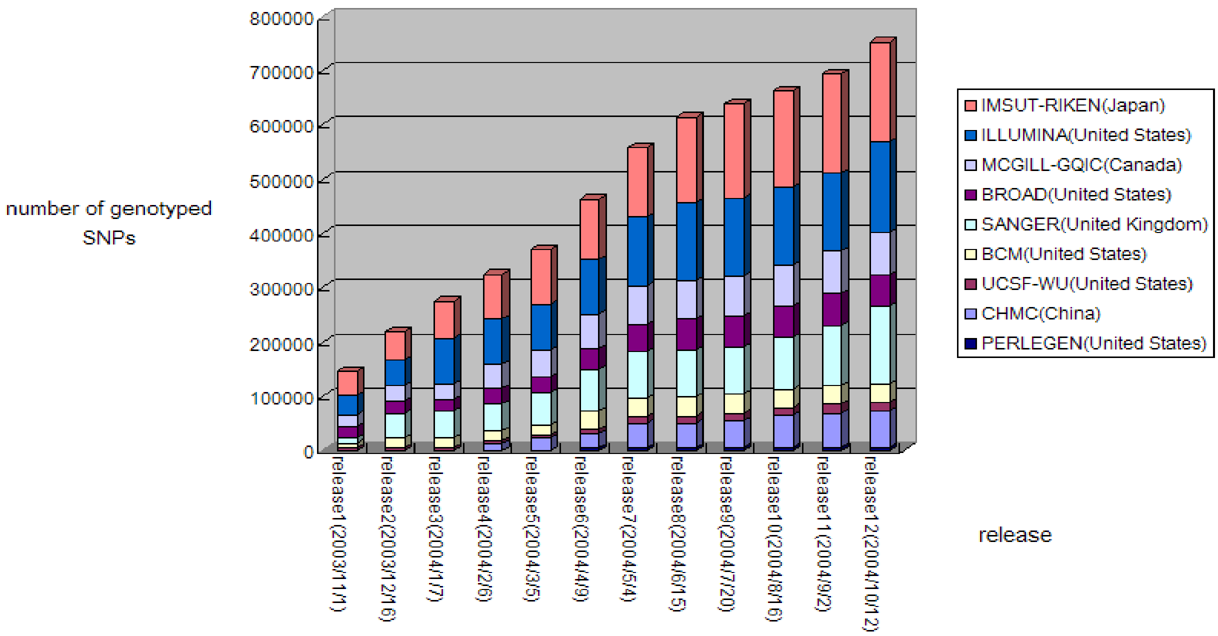
<Social impacts>

- Securing of intellectual property rights
  - Improvement of Japan's standing in relevant fields through contributions to the International HapMap Project
- Potential improvement of healthcare quality
- Potential achievement of a healthy, long-living society

<Impacts on people's lives>

- Potential prevention of cancer metastasis and treatment for Alzheimer's disease
- Potential provision of optimal medical care for each patient
- Potential avoidance of side effects
- Potential maintenance and improvement of national health

Progress of genotyping in International HapMap Project

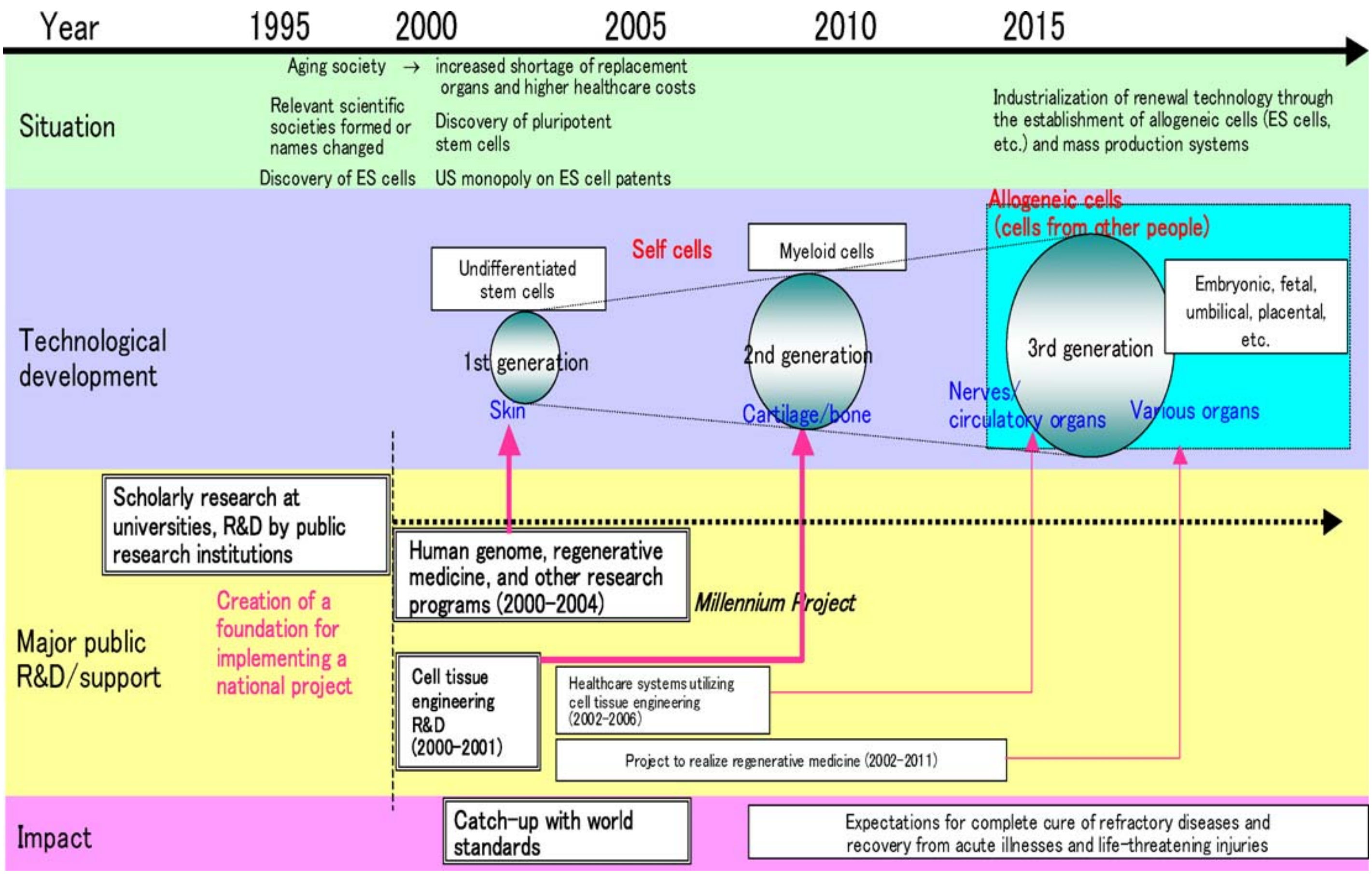


Source: International HapMap Project website

Technologies for utilizing tissues cultured from stem cells as material for artificial organs and tissues (Life Science)

<Case study topics>

- Accumulated basic research by universities and public research institutes laid the foundation for the implementation of a national project.
- Relevant scientific societies began to organize around 1998, and with research funding concentrated on the Millennium Project that began in 2000, Japanese research caught up with world standards. While Japan now leads in some fields, it has yet to overtake the United States, the world leader.
- A complete cure for some illnesses is expected. Social impact is expected in terms of the response to our aging society.
- Now and into the future, implementation and strengthening practical application with a view to public acceptance are necessary. This can be accomplished through enhanced R&D, an increased number of clinical cases, and industrialization.



<Economic impacts>

- Potential creation of new businesses
  - Predicted market scale in 2010 is ¥45 billion
  - Potential effects of the diffusion of stem cells in medicine as a whole are valued at ¥5–10 trillion
- Potential reduction in healthcare costs
- Potential creation of venture companies and development of patent businesses

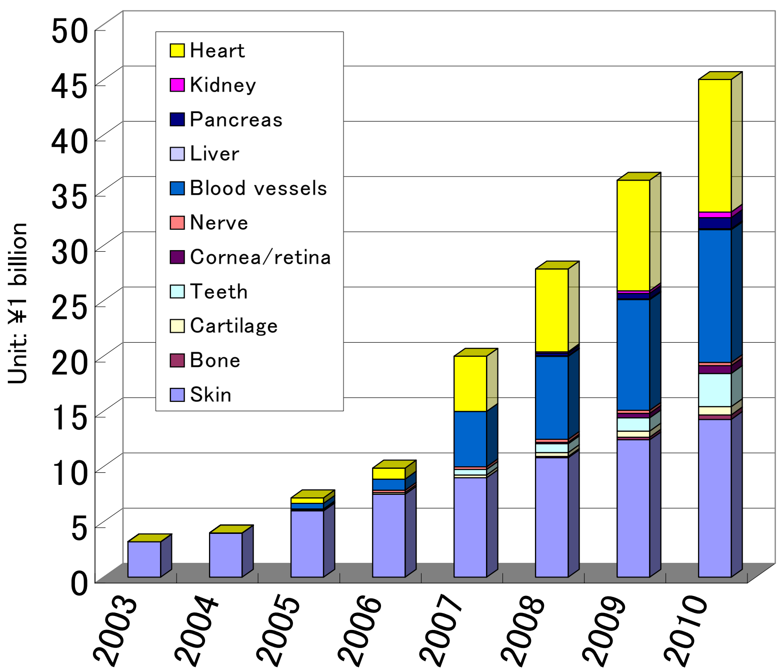
<Social impacts>

- Potential elimination of donor shortages
- Potential easing of the burden of caring for elderly people
- Potential increase in the vitality of the aging society

<Impacts on people's lives>

- Potential possibility of complete cure for refractory illnesses
- Potential recovery from acute illnesses and life-threatening injuries
- Potential radical improvement of patient quality of life

Predicted markets for regenerative medicine businesses by sector

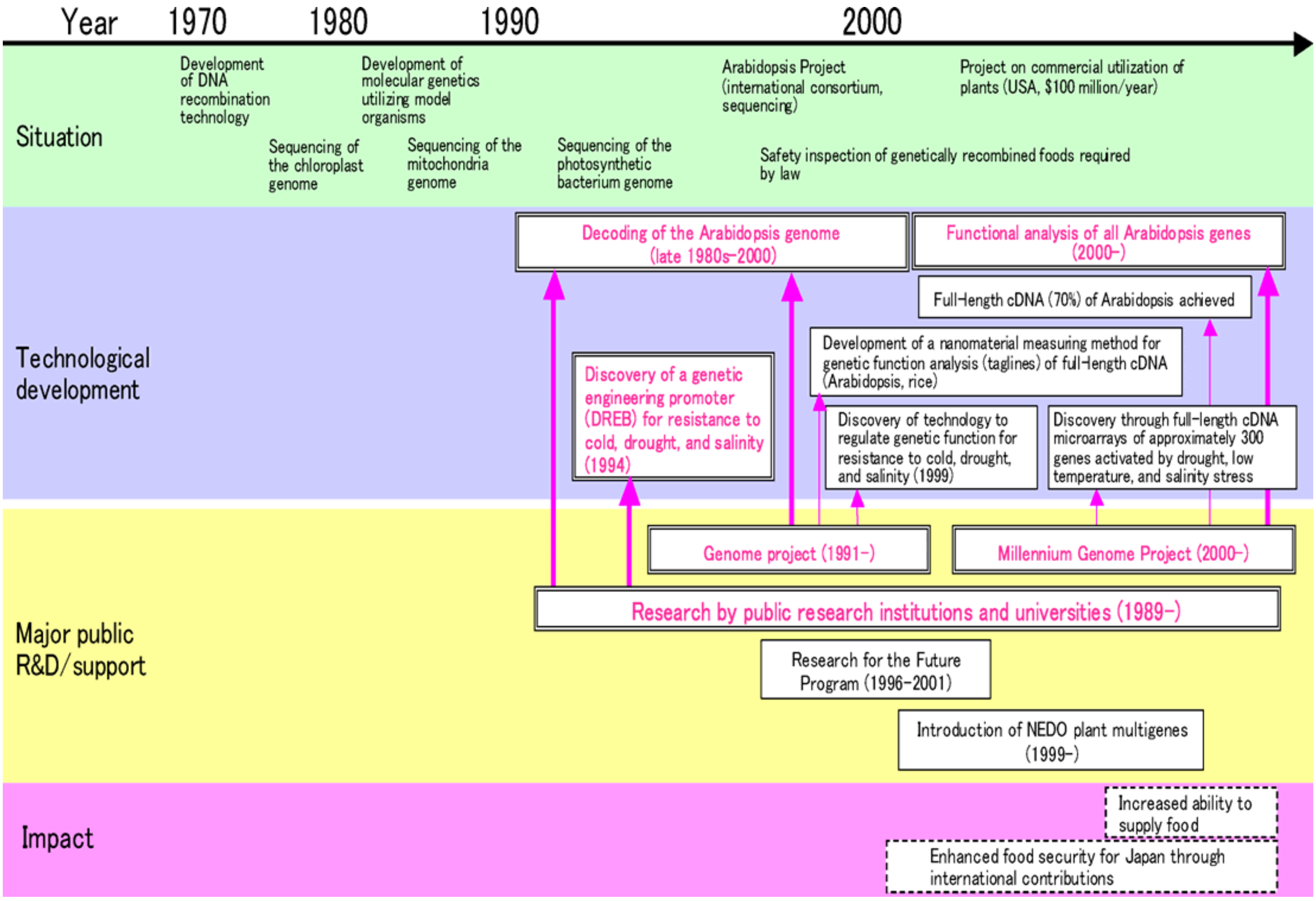


Source: Created by the Mitsubishi Research Institute based on data in Saisei Iryou Business 2003 ("Regenerative medicine business 2003, Fuji-keizai Co.)

Technology to produce crops resistant to cold, drought, and salinity through gene manipulation (Life Science)

<Case study topics>

- Japanese public research institutions led the world in using the Arabidopsis model plant to discover and develop function control technology and genes related to resistance to cold, drought, and salinity.
- Basic research and the establishment of fundamental technology and research infrastructure by universities and public research institutions such as RIKEN and the National Agriculture and Bio-oriented Research Organization were the primary public contributions.
- The technology has potential to make an international contribution (social impact) to resolving the world food crisis by raising agricultural productivity.
- Although the technology is entering the application phase, public receptivity of genetically engineered crops in Japan is low, and most companies have withdrawn from R&D.



<Economic impacts>

- Potential expansion of export of technology for the creation of genetically recombined crops
  - Export of technology for the creation of genetically recombined crops for countries and territories where salinity and desertification are advancing
- Potential creation and sales of genetically recombined crops overseas
  - The impact from rice plants will be realized decades into the future.

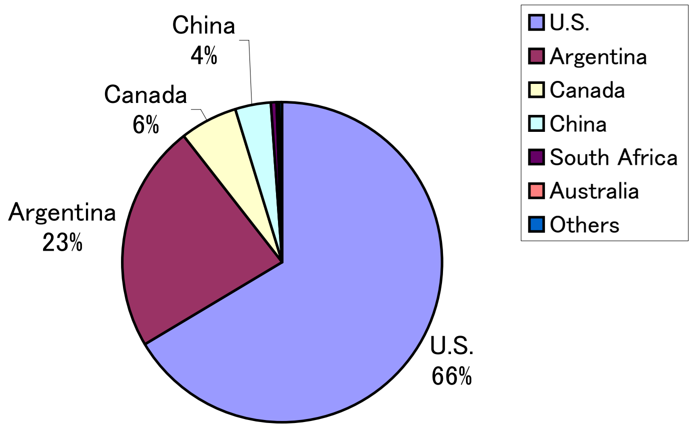
<Social impacts>

- Potential enhancement of ability to supply food during world food shortages
  - Export of drought-resistance technology to arid areas in Africa, China, and elsewhere can be an international contribution. Export of salinity-resistance technology can be an international contribution to Africa, China, Australia, and other areas suffering salinity damage.
- Potential maintenance of Japan's food security
  - Through international contributions to various countries in the form of technology, Japan can maintain food imports and build relationships to secure alternative crops during periods of cold damage due to bad weather.

<Impacts on people’s lives>

- Potential easing of anxiety over predicted future food crises
- Potential securing of a stable diet

Areas in various countries planted with genetically recombined crops (58.7 million ha, 2002)

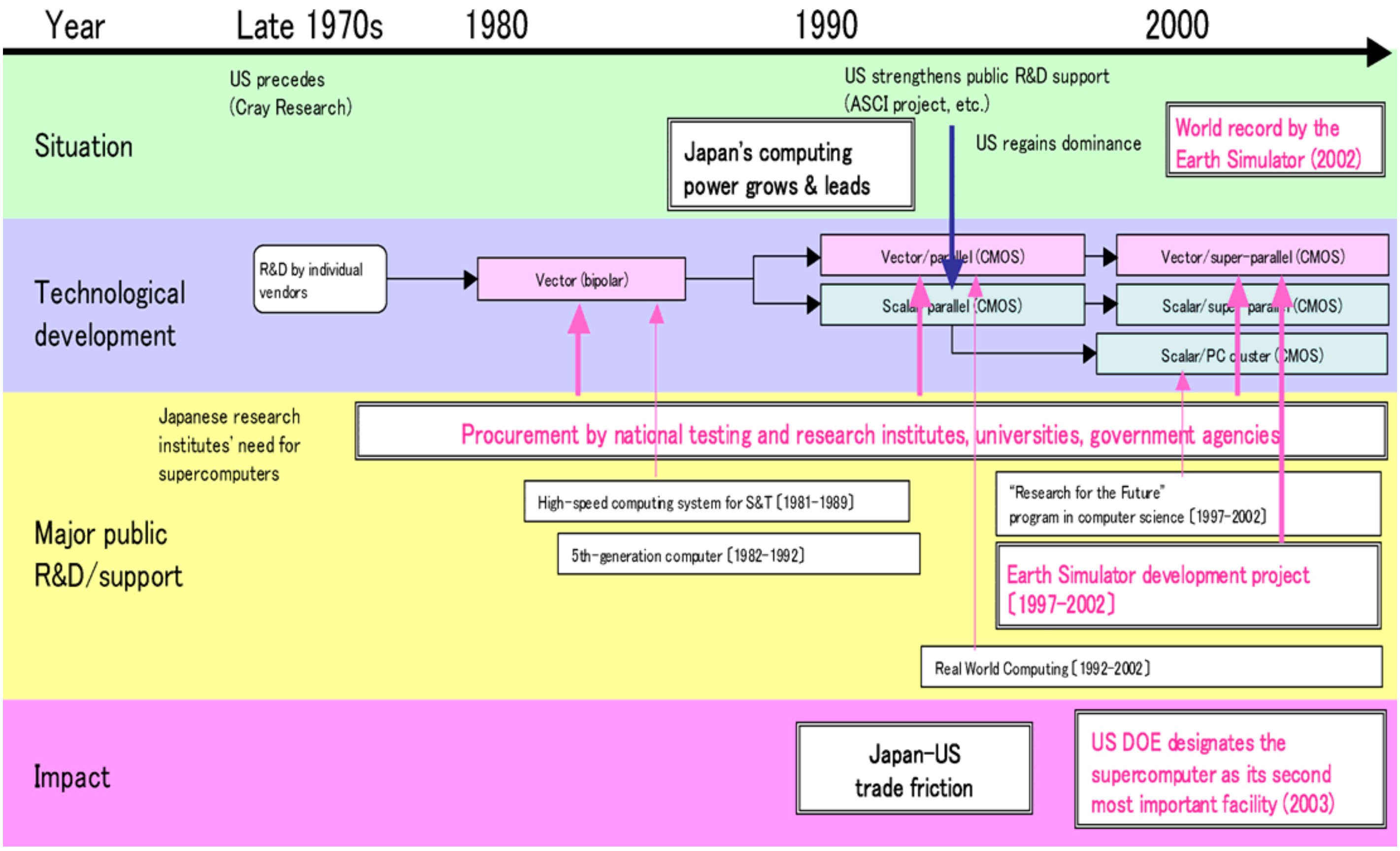


Source: Created by the Mitsubishi Research Institute based on materials of the Ministry of Agriculture, Forestry and Fisheries

Parallel supercomputers with high processing speed (Information and Communications)

<Case study topics>

- Around the 1970s, procurement by universities and public research institutes encouraged R&D in the private sector, helping Japan lead the world between the late 1980s and the early 1990s. As the U.S. government strengthened investment in the following years, scalar supercomputers, rather than vector-type computers, have become dominant.
- In response, Japan launched several public projects. Among them is the Earth Simulator, which demonstrated Japan's technological capacity in vector computers and became the world's fastest computer in 2002-2004. This posed a threat to the U.S.
- Applications are growing mainly in industry but can be expected even in the non-industrial sector, where long-term prediction projects on the impact of global warming and other issues are ongoing. There is potential for disaster prevention research based on simulations.



<Economic impacts>

- Supercomputer sales (Japanese market)
  Systems priced ¥30 mil or more: approx. ¥100 bil/year
  Systems priced ¥100 mil or more: approx. ¥50 bil/year
  (Public procurement accounts for over half of the above.)
- Potential venture business creation (software/PC cluster vendors, etc.)

<Social impacts>

- More accurate prediction of global environmental changes and weather
- Improved reliability and safety in urban, traffic, and other infrastructures
  (Earthquake resistance in high-rise buildings, aircraft safety, etc.)

<Impacts on people's lives>

- Improved car safety and comfort
- Potential prevention of disasters such as earthquakes, typhoons, and tsunamis

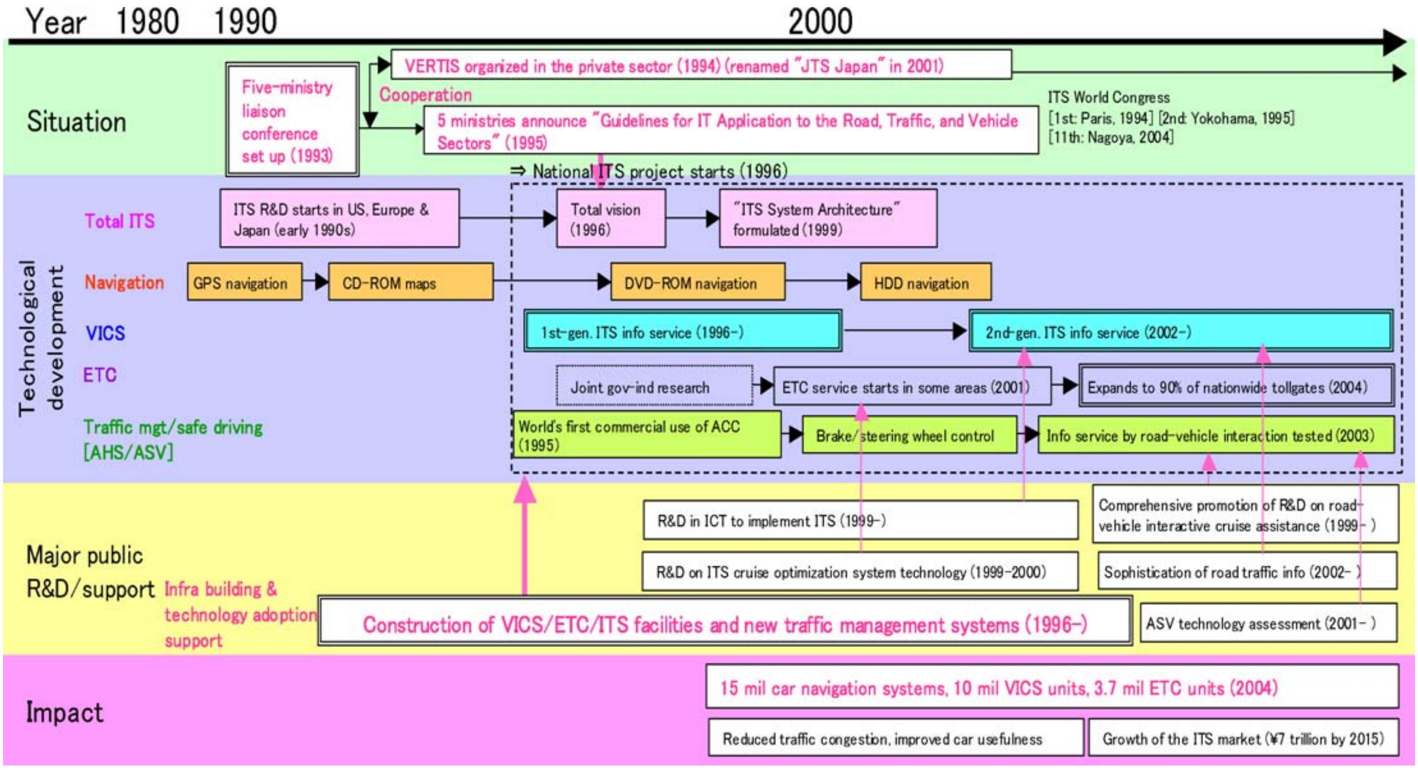
<Other (global impacts)>

- Motivated by the achievements of the Earth Simulator, the US DOE designated the supercomputer as its second most important facility after ITER.

ITS (car navigation, VICS, ETC, traffic management, etc.) (Information and Communications)

<Case study topics>

- Japan is leading the world in constituent technologies such as car navigation, VICS, ETC, and traffic management systems (AHS, ASV, etc.). The implementation of ITS has had a broad impact.
- R&D was conducted at ministerial level until the 1990s, successfully leading to the development of fundamental constituent technologies. Since the mid-1990s, collaboration among relevant ministries and agencies has been fostered so that R&D can be promoted according to national plans.
- Potential impacts are expected on the economy (e.g. growth of the ITS market to about ¥7 trillion by 2015), society (e.g. mitigated traffic congestion, reduced traffic accidents, reduced environmental burden, energy conservation), and even people's lives in a future ITS society (e.g. changes in lifestyles, in patterns of behavior).
- To integrate the outcomes of individual R&D projects and to make the whole vision of ITS a reality, it is necessary that relevant ministries cooperate to promote R&D and public relations to facilitate the smooth transformation of social systems and people's patterns of behavior.



<Economic impacts>

- Growth of the ITS market driven by widespread use of car navigation systems (15 mil), VICS units (10 mil), and ETC units (3.7 mil) (as of 2004)
- Cost reduction and increased product/service competitiveness in industries using ITS technologies
- ITS-related information and communications markets
  - ¥881.4 bil (in 2000), ¥7,361.6 bil (in 2015), ¥60, 315.4 bil (cumulative total by 2015)
- Employment creation (for 1.07 mil people for 2015)
- Effects on traffic congestion mitigation (worth ¥1.2 trillion annually (2015))

<Social impacts>

- Mitigation and elimination of traffic congestion
- Reduction in traffic accidents (a 50% reduction in fatal traffic accidents by 2025)
- Reduction in environmental burden (a 15% reduction in fuel consumption and CO_2 emissions; a 30% reduction in urban-area NO_x emissions by 2025)
- Energy conservation
- Higher efficiency and advancement in the logistics sector

<Impacts on people's lives>

- Improved convenience for car drivers for a more comfortable life
- Transformation of people's lifestyles and behavioral patterns by creating an ITS society

Size of the ITS-related information and communications markets

(in ¥100 millions)

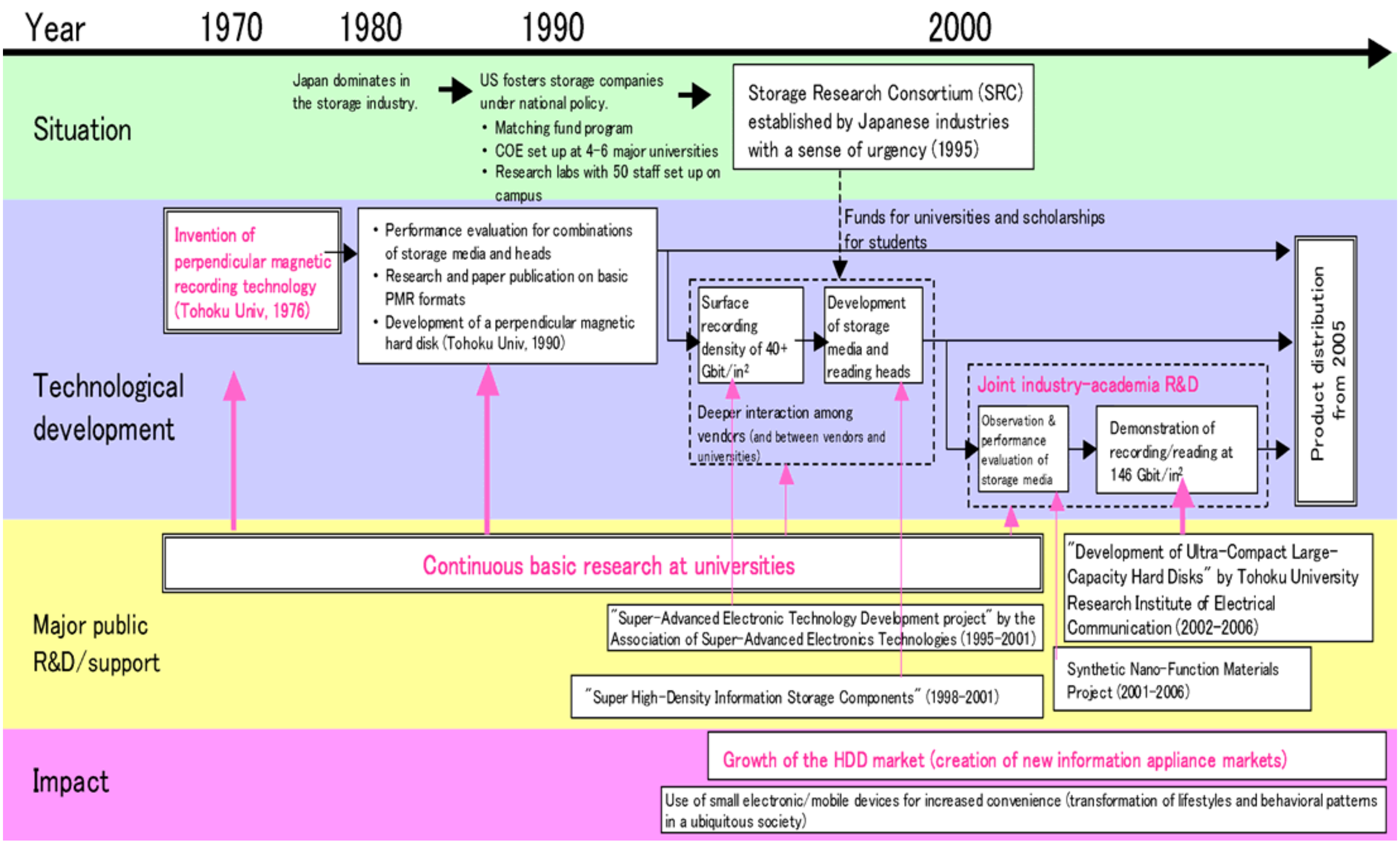
Market sector	2000	2005	2010	2015	Cumulative total by 2015
ITS-related I&C services	768	9,449	24,950	47,729	309,903
In-car and other terminals	4,452	10,182	15,068	17,417	186,705
ITS-related I&C systems (infra)	3,594	6,500	7,470	8,470	106,546
Total	8,814	26,131	47,488	73,616	603,154

Source: Created by the Mitsubishi Research Institute based on the reports by the ITS Info-Communications Systems Committee to the Telecommunications Technology Council

Perpendicular magnetic recording technology (for hard disk drives)
(Information and Communications)

<Case study topics>

- Japan currently has a strong position in the 2.5″ and 1.8″ hard disk drive (HDD) markets.
- Technologies are being commercialized, with continuous basic research at universities (invention of perpendicular magnetic recording, etc.) serving as the seedbeds. However, it has taken some time to implement full-scale national projects.
- Technology has significant economic impacts such as growth of the HDD market (e.g. through the creation of a new market for information appliances).
- Since HDD technologies are becoming increasingly complex, public R&D and support programs should focus on long-term projects, rather than short-term projects, so as to lead to technological seeds in the next generation.



<Economic impacts>

- Potential growth of the HDD market through the development of smaller-sized larger-capacity electronic devices based on this technology (creation of new information appliance markets)

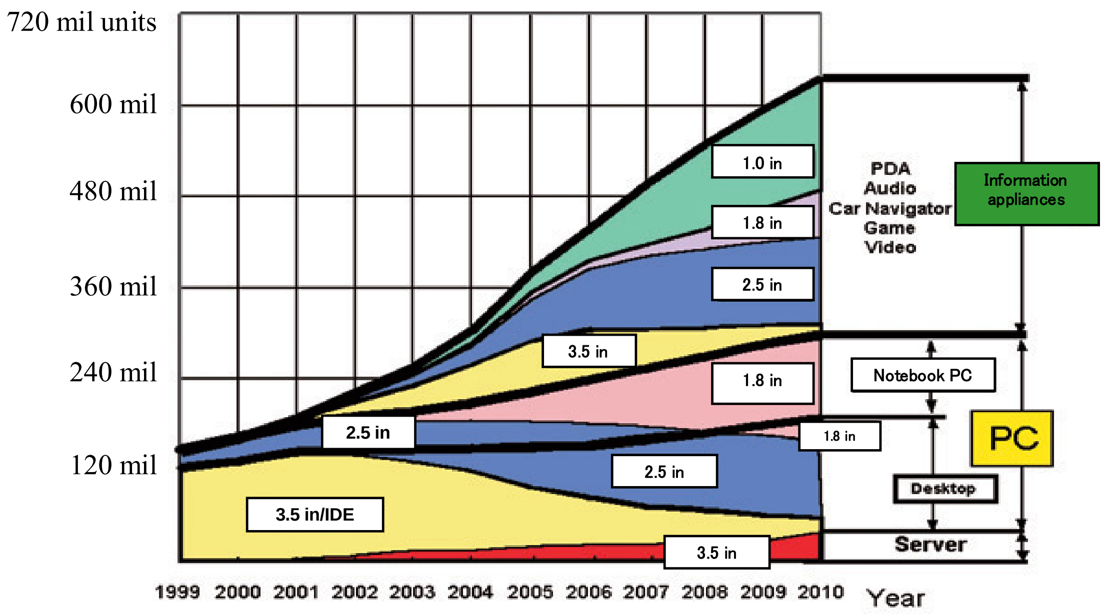
<Social impacts>

- Potential reduction in power consumption as a result of downsizing
- Potential construction of mobile infrastructure (practical use of network-ready, ultra-compact, large-capacity mobile storage systems for personal use)
- Potential creation of a healthy longevity society as a result of advances in medical technology

<Impacts on people's lives>

- Potential improvements in convenience through the use of small electronic devices and mobile devices
- Potential transformation of people's lifestyles and behavioral patterns through the construction of a ubiquitous society (changes in the perception of time and place)

Projected demand for HDD

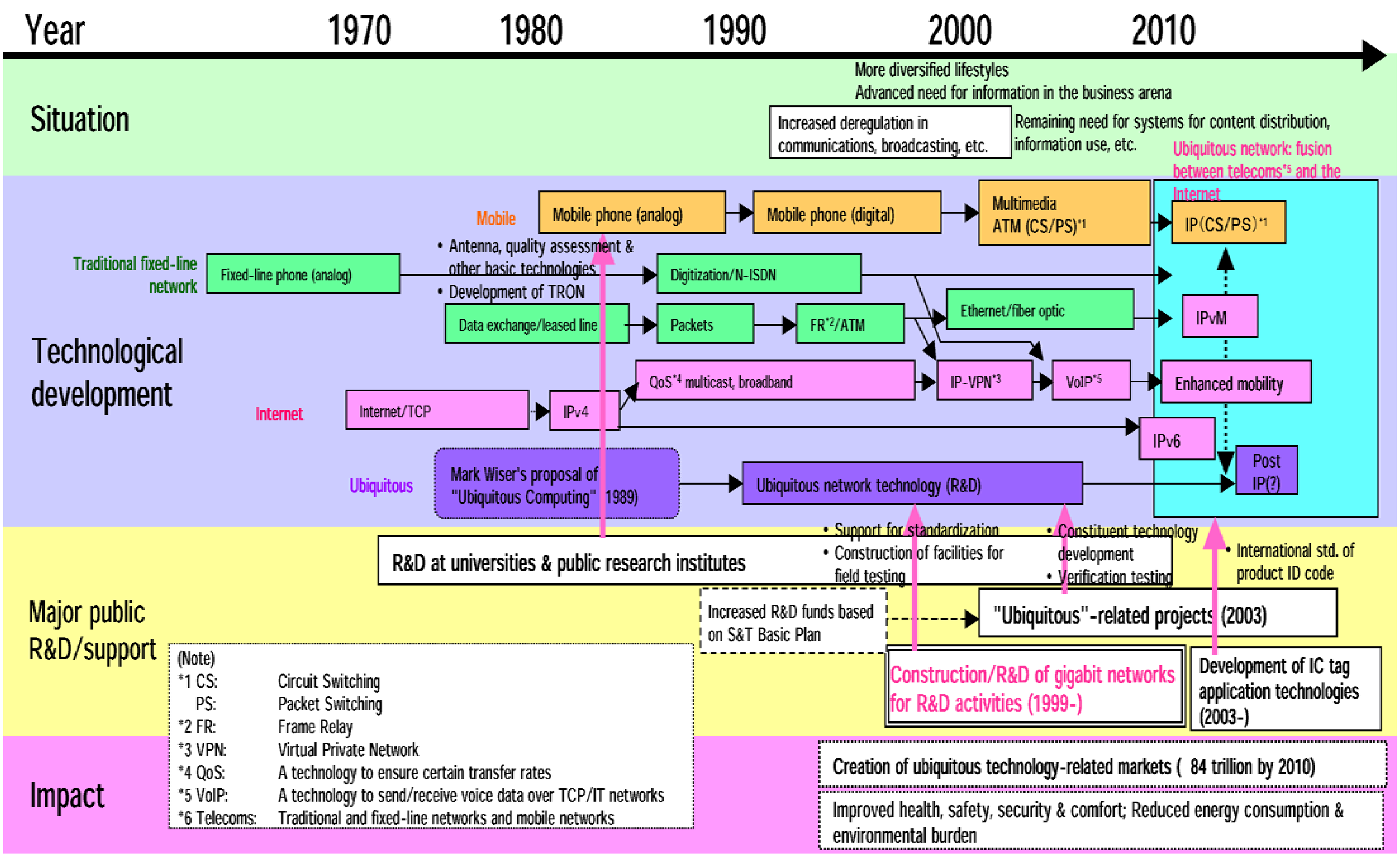


Source: Website of Hitachi Global Storage Technologies as partially modified

Ubiquitous networks (Information and Communications)

<Case study topics>

- Universities and public research institutes have contributed to overall R&D in mobile communications technology. For basic technologies (antenna technology, quality evaluation, etc.) and standardization of wireless communications, they have provided academic advice. In addition, TRON, an operating system developed mainly by university researchers, has been used in mobile phones and applied to ubiquitous networks.
- In the area of IC tag application technology development, product identification codes have been internationally standardized to allow the practical use of IC tags. Funds provided to manufacturers have helped them develop technologies for cost reduction and to perform field tests for individual user industries.
- Applications are expected in diverse fields. Economic impacts (the combined size of the related markets will reach ¥84 trillion by 2010) as well as social impacts and impacts on people's lives should be significant.



<Economic impacts>

- Potential creation of ubiquitous technology-related markets (¥84 trillion by 2010)
- Potential strengthening of Japan’s international competitiveness as a result of improved productivity and efficiency across industries
- Potential expansion of employment and vitalization of regional economies

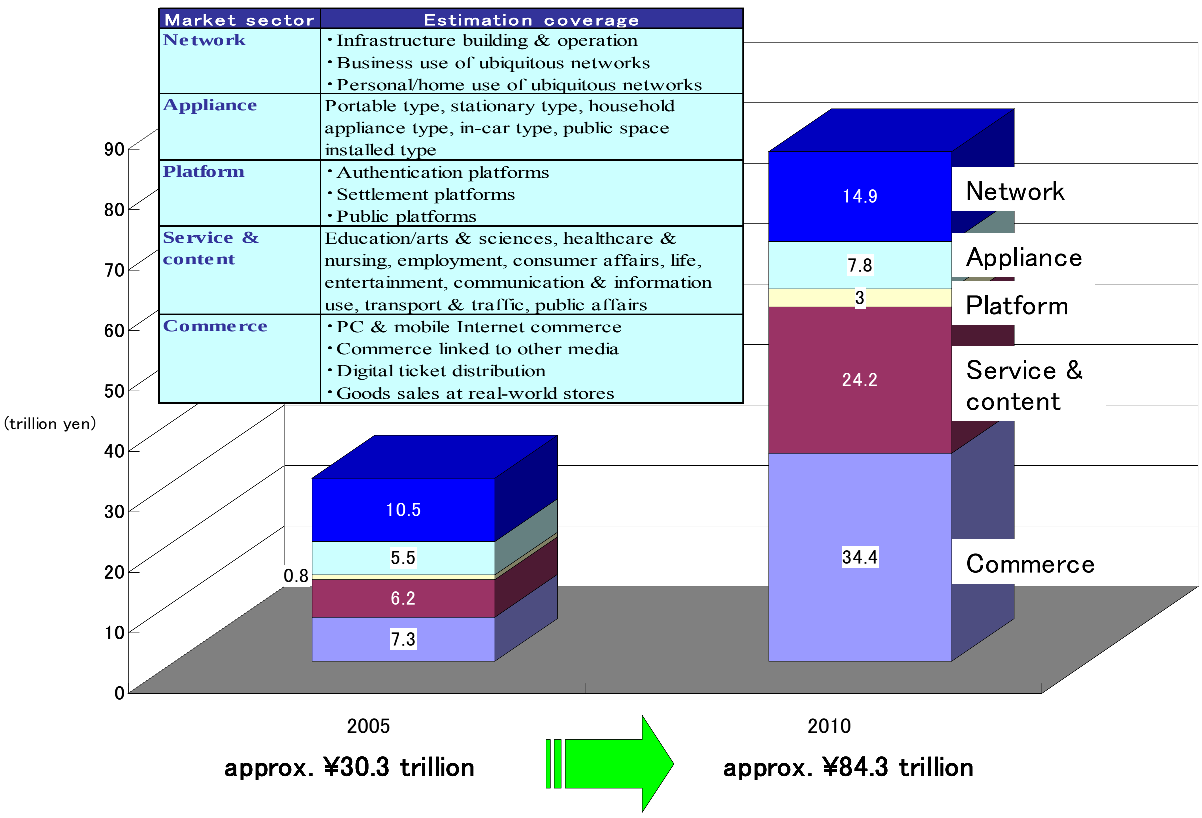
<Social impacts>

- Potential solutions to energy and environmental problems
  - Reduction in energy consumption and environmental burden as a result of improved efficiency
- Potential promotion of social participation by those with disabilities and elderly people
  - An environment friendly to those with disabilities and elderly people by making the urban infrastructure barrier-free and providing information in accessible ways
- Potential tools to address an aged society by improving worker productivity and reducing workload

<Impacts on people’s lives>

- Potential improvement of public health through better healthcare, food quality management, etc.
- Potential improvement of home and work life in comfort and convenience by eliminating waste
- Potential improvement of safety and peace of mind as a result of increased security
- Potential improvement of the comfort and enjoyment of life and leisure
- Potential increase in purposefulness in life through participation in creative activities

Size of the ubiquitous network-derived markets (sample estimation)



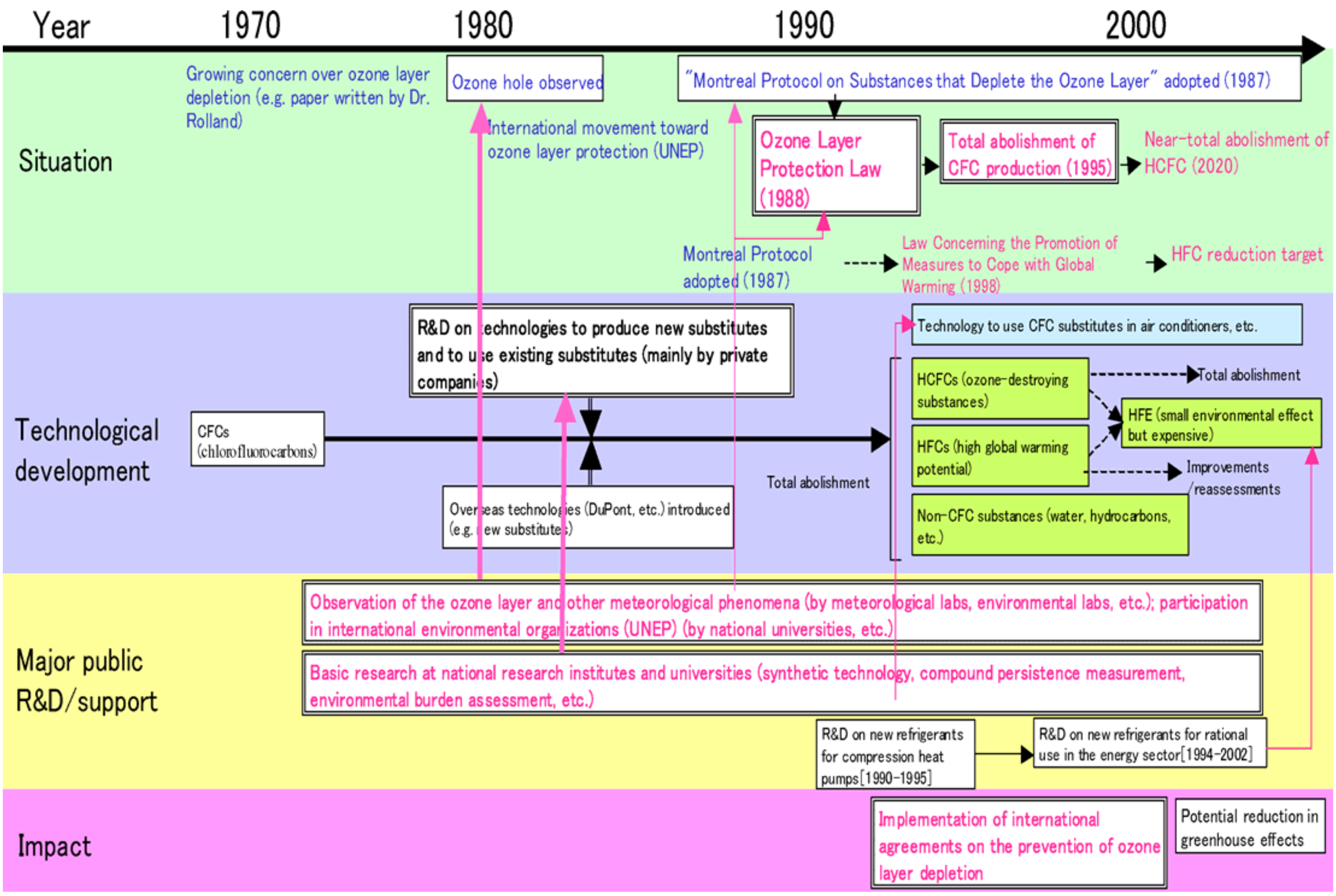
Market sector	Estimation coverage
Network	・Infrastructure building & operation ・Business use of ubiquitous networks ・Personal/home use of ubiquitous networks
Appliance	Portable type, stationary type, household appliance type, in-car type, public space installed type
Platform	・Authentication platforms ・Settlement platforms ・Public platforms
Service & content	Education/arts & sciences, healthcare & nursing, employment, consumer affairs, life, entertainment, communication & information use, transport & traffic, public affairs
Commerce	・PC & mobile Internet commerce ・Commerce linked to other media ・Digital ticket distribution ・Goods sales at real-world stores

Source: Created by the Mitsubishi Research Institute based on reports by the Ministry of Internal Affairs and Communications

Fluorocarbon and halon substitutes that neither damage the ozone layer nor cause global warming problems (Environment)

<Case study topics>

- Observations at Japan's Showa Base in Antarctica led to the discovery of the ozone hole, which spurred the international movement toward ozone layer protection
- Regulations have facilitated the development and application of technologies to manufacture and use substitutes, resulting in virtually total abolishment of CFCs that have high ozone depletion potential
- While R&D is led by the private sector, legal regulations as well as fundamental technical development support (e.g. assessing global warming potential and other environmental burdens, measuring the persistence of chemical compounds) have proven effective.
- Noteworthy impacts have been exerted on preventing ozone layer depletion through a major reduction in ozone-destroying substances (social impact) and increased international competitiveness in the CFC/halon substitute markets and in conforming to environmental regulations ahead of companies in other countries (economic impact).
- A future challenge is to rationally formulate regulations and other policies based on comprehensive scientific knowledge such as measurement of environmental impacts of alternative substances.



<Economic impacts>

- Encouraging industry to widely move toward replacing CFCs and halons with alternatives (enhanced environmental technologies, improved environmental R&D capacity, and better environmental image of companies)
- Strengthened international competitiveness
  - Japan's air conditioner industry is ahead of the U.S. in meeting European environmental regulations.
- Alternatives to the CFC and halon markets
  - The combined market size for HCFCs and HFCs is ¥36 billion. The CFC market has not retained its peak size of about ¥60 billion.

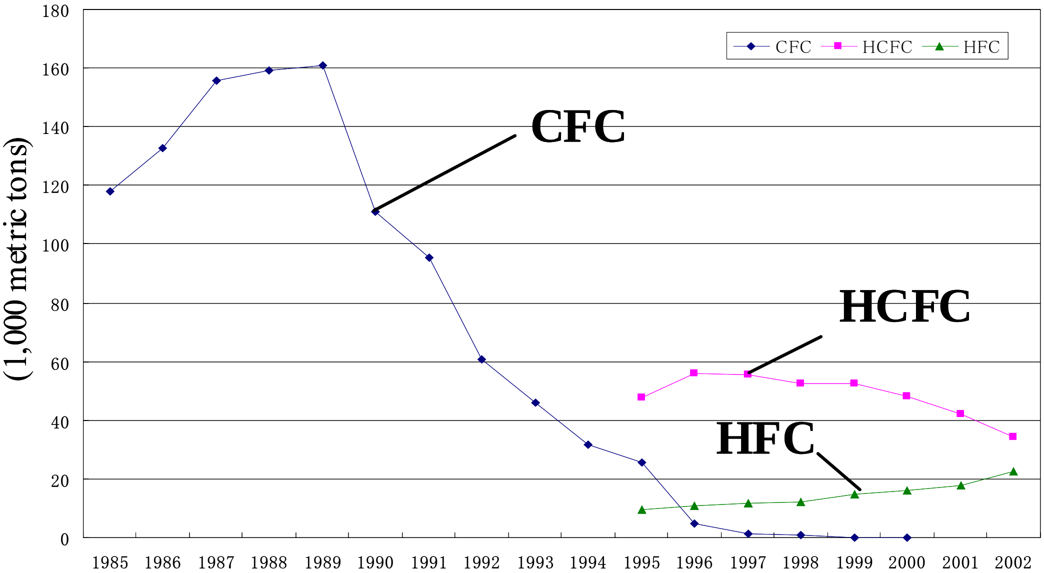
<Social impacts>

- Prevention and mitigation of ozone layer depletion
  - CFCs totally abolished; HCFCs to be near-totally abolished by 2020; halons near-totally abolished
- Reduction in greenhouse gases (HFCs)
  - HFC accounts for about 2% of the total greenhouse gases in terms of CO_2.
- Compliance with international regulations (Montreal Protocol)

<Impacts on people's lives>

- Prevention of ozone layer depletion and mitigation of health damage from UV rays (skin cancer, etc.)
- Reduction in the effects of global warming and abnormal weather on people's lives

CFC transition: Trends in CFC abolishment and substitution
(volume of shipments)

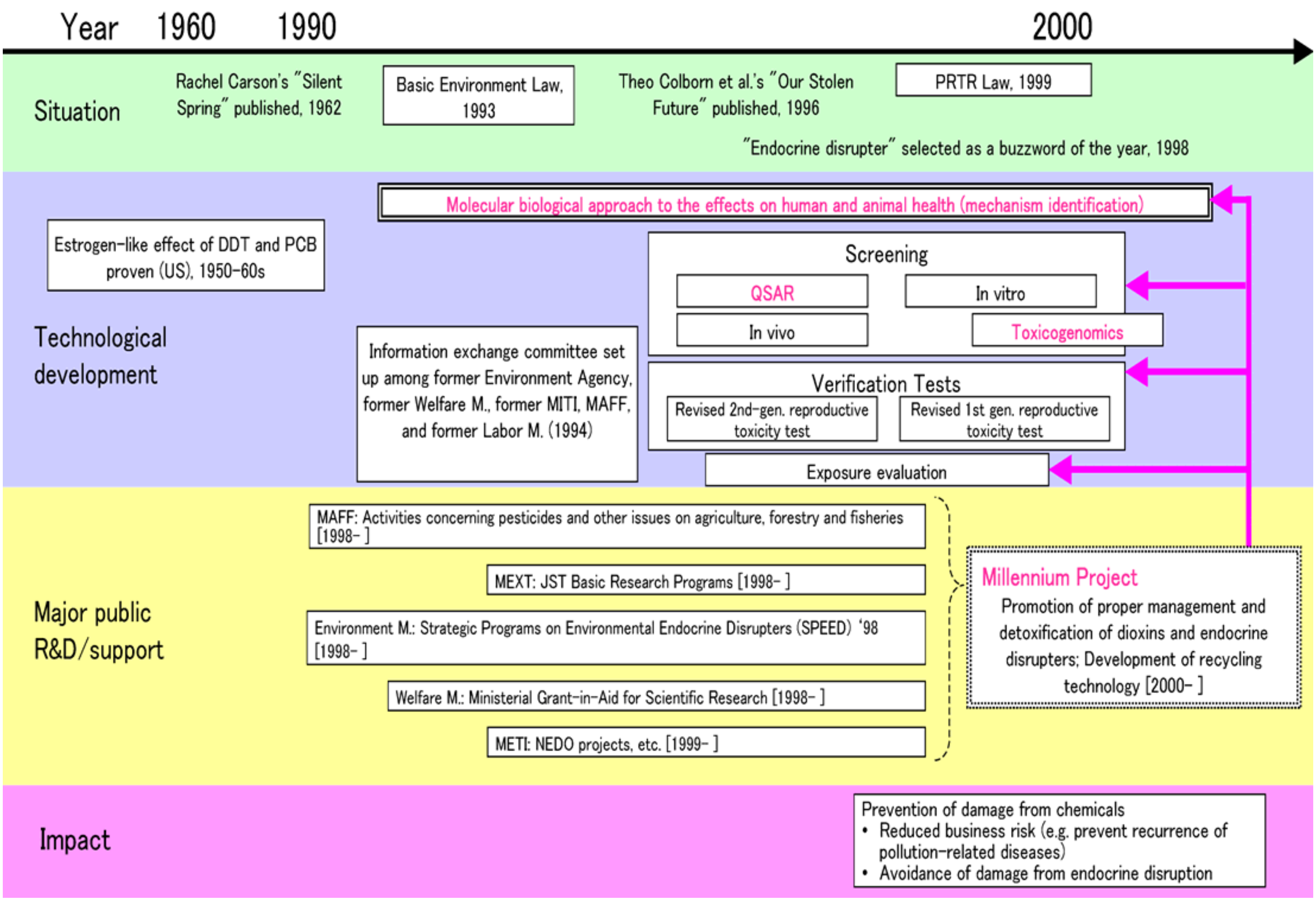


Source: Created by the Mitsubishi Research Institute based on the annual report on the ozone layer monitoring results for FY 2002 (Ministry of Environment, August 2003)

Technology to elucidate the effects of endocrine disrupters on human and wildlife health (Environment)

<Case study topics>

- How to perform the screening and risk assessment of over 20,000 existing chemical substances promptly and at reasonable cost poses a major challenge, and R&D has been conducted to find solutions.
- The knowledge in molecular biology accumulated by universities and public research institutes has significantly contributed to the establishment of effective elucidation techniques.
- The construction of databases regarding the endocrine disruption effects of chemicals, combined with appropriate regulations, will bring benefits such as reduced corporate economic risk and ensured safety in people's lives.
- In the future, more attention should be paid to cooperation among ministries and knowledge sharing among projects.



<Economic impacts>

- Reduced cost of toxicity assessment tests
- Lower business risk arising from chemical damage

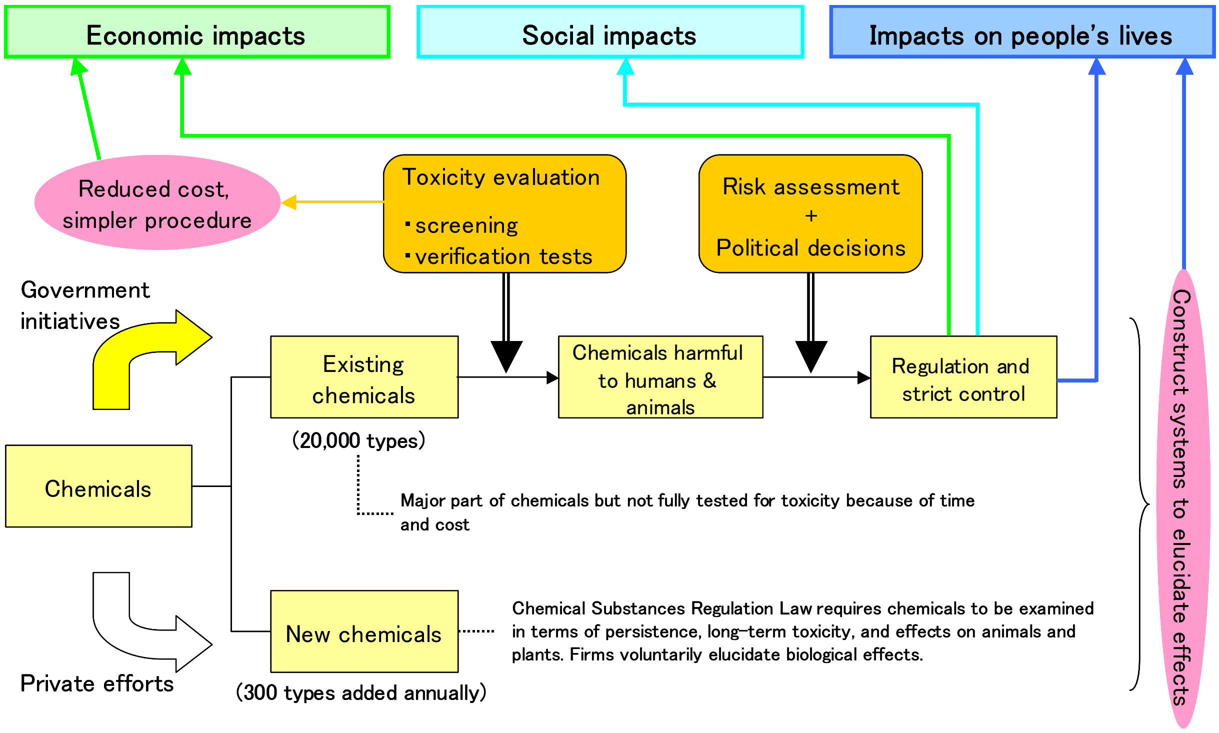
<Social impacts>

- Avoidance of environmental contamination with endocrine disrupters
- Avoidance of damage to the wildlife endocrine system

<Impacts on people's lives>

- Improved safety and security regarding chemicals
- Avoidance of irreversible damage to the endocrine system of newborn babies and fetuses

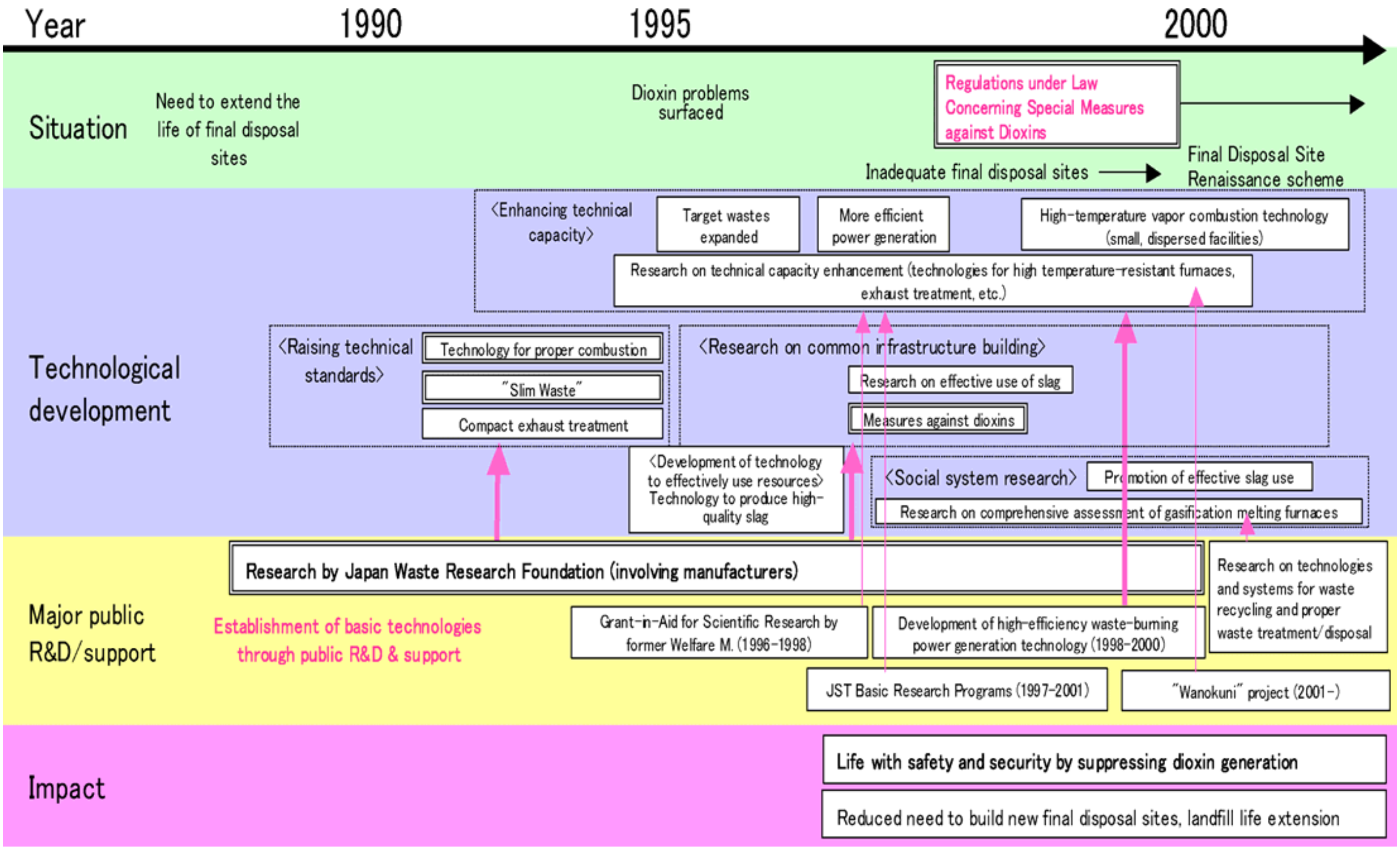
Process for generating impacts by elucidating the effects of endocrine disrupters on human and animal health



Gasification melting furnace and ash melting furnace technologies for waste disposal (Environment)

<Case study topics>

- Although most melting technologies originate overseas, Japan has seen unique development in this area because of its inherent problem: shortage of landfill space.
- R&D is mainly led by the private sector, but a combination of legal regulations and subsidies to municipal governments is working effectively, generating positive impacts. In addition, common basic technologies have been developed through joint research by private companies and public research institutes.
- Expected impacts are social impacts such as extending the useful life of final disposal sites and preventing leachate contamination of groundwater, economic impacts such as expanded markets for gasification melting furnaces and ash melting furnaces and a reduced need to build new final disposal sites, and impacts on people’s lives such as raised public awareness of waste disposal and recycling technology.
- Gasification melting furnaces and ash melting furnaces are technologies that have just fully developed and become commercially available. Future challenges in this area are research on technology for stable operation and reduction in the lifecycle cost of these furnaces, including the cost of running and maintaining them.



<Economic impacts>

- Potential expansion of markets for gasification melting furnaces and ash melting facilities
- Potential overseas export of technologies and resulting royalty income
- Potential reduction in the need to build new final disposal sites
- Potential income from sales of metal and slag products
- Potential reduction in electricity costs
- Potential for cost reduction through heat utilization and industry creation

<Social impacts>

- Potential prevention of leachate contamination of groundwater and soil
- Potential extension of the useful life of landfills
- Potential prevention of illegal dumping
- Potential for enabling metal resource recycling
- Potential for suppression of dioxin generation and dioxin collection/treatment
- Potential reduction in CO_2 emissions as a result of diminished fossil fuel use

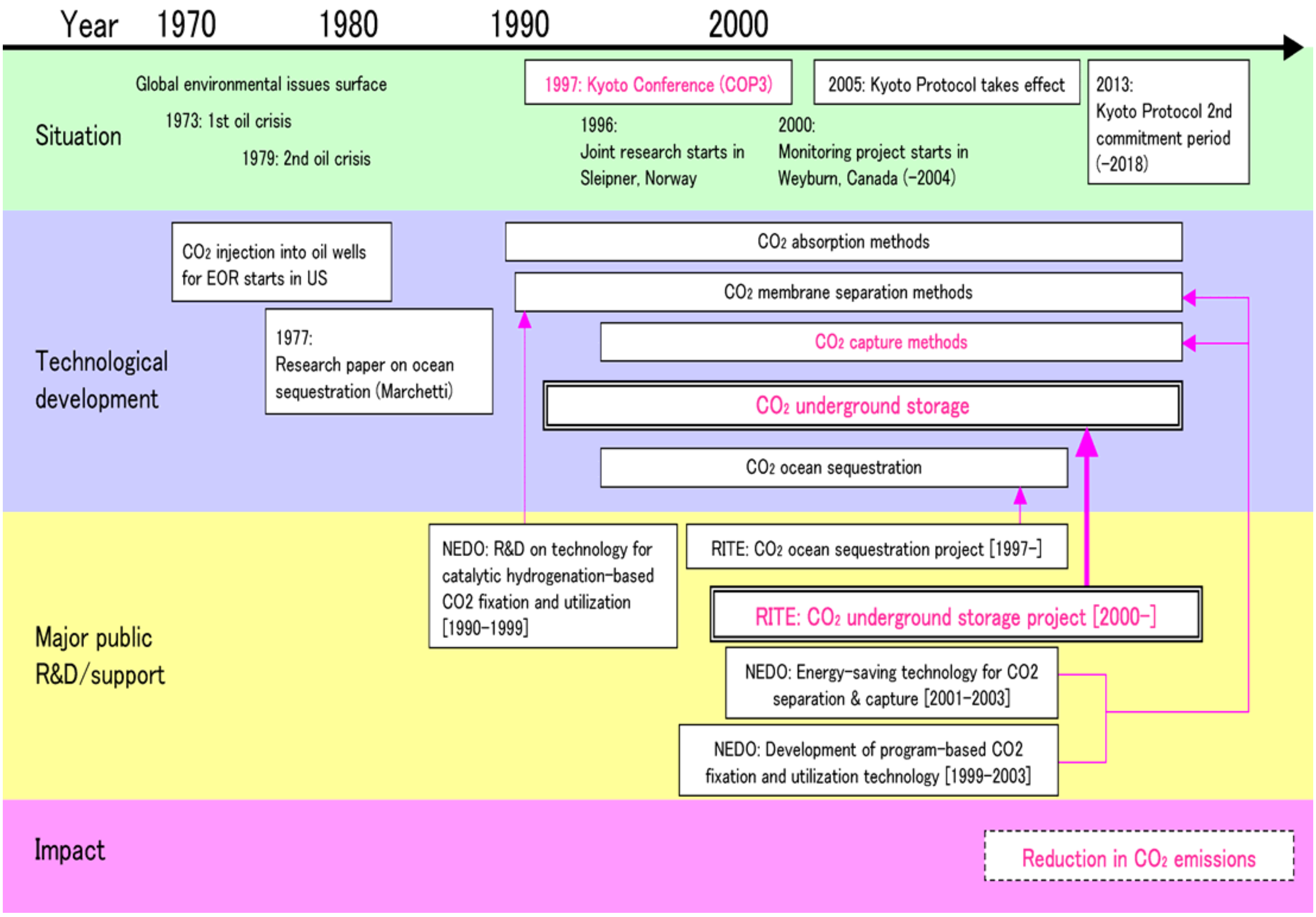
<Impacts on people's lives>

- Potential for making life safer and more secure
- Potential improvement of public welfare
- Potential improvement of comfort and convenience for people
- Potential growth in public environmental awareness concerning waste disposal and recycling technology
- Potential for solving health problems and reducing medical expenses

Technology for carbon dioxide separation, capture, and sequestration (Environment)

<Case study topics>

- The U.S. and Europe have been leading research on carbon dioxide capture and sequestration. In Japan, R&D on capture technology (especially absorption methods) has been mainly conducted in the private sector, while R&D on sequestration technology has been supported by the government.
- As social activities to prevent global warming become widespread, the government has launched a project for the field testing of underground storage, entering a phase of verifying the potential of the technology.
- Although this technology has a large potential impact—CO_2 emission reduction—, no derivative benefits can be expected from its application. This makes the private sector reluctant to address this area, suggesting that public R&D and support are essential for advancement.
- To generate such impacts, it is essential to reduce the cost of the technology as well as to improve its social acceptance by collecting geological data on possible sequestration/storage sites and by ensuring safety.



<Economic impacts>

- Potential creation of the CO_2 separation business
  - Annual separation of 10 mil t- CO_2 of a value of about ¥10-100 bil
- Potential reduction in the cost of CO_2 treatment
- Potential increase in oil production and methane extraction (mainly overseas)

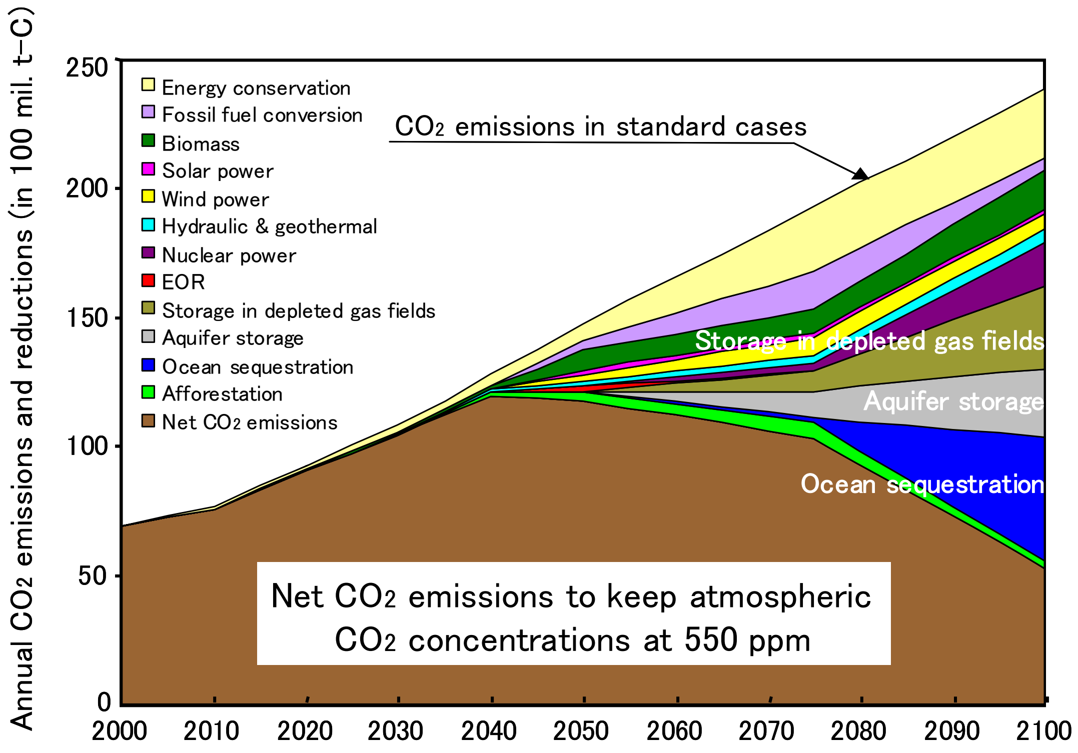
<Social impacts>

- Potential reduction in CO_2
  - Annual separation of 10 mil t-CO_2 by 2015 (at a scale of 1 mil t-CO_2 per site)
- Potential compliance with the Kyoto Protocol

<Impacts on people's lives>

- Potential increase in environmental awareness in the storage regions
- Potential prevention of global warming

Predicted CO_2 emissions (countermeasures and their effects)

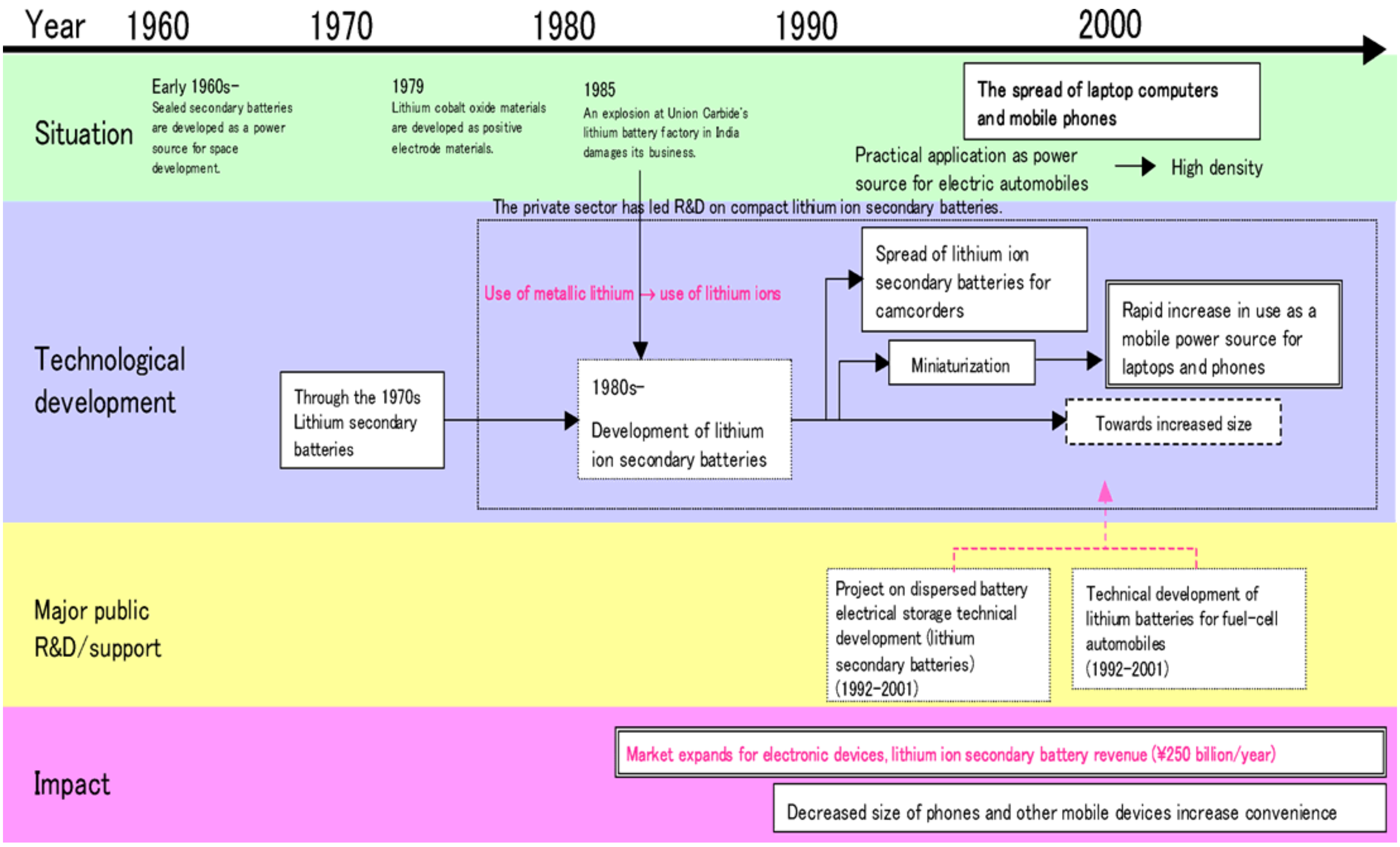


Source: Reports presented to the "14th Trend Review Meeting on Innovative Technology for the Earth" by the Research Institute of Innovative Technology for the Earth (RITE)

High-density, long-life technology for lithium batteries (Nanotechnology and Materials)

<Case study topics>

- Japanese manufacturers were the first to commercialize lithium batteries for mobile phones, and their technical standards lead the world.
- The private sector led research and development, and public R&D and support were not significant. However, support for the development of battery materials, utilization of laser processing technology for lightweight aluminum housing materials, and so forth made an indirect contribution to basic research.
- The batteries have made a major contribution to making phones and other mobile devices smaller and lighter, broadly affecting the economy, society, and people's lives as basic technology for electronic devices.
- Support for basic battery technology is needed. (R&D in basic technologies such as materials and processing technology and electrolyte development are essential to battery development.)



<Economic impacts>

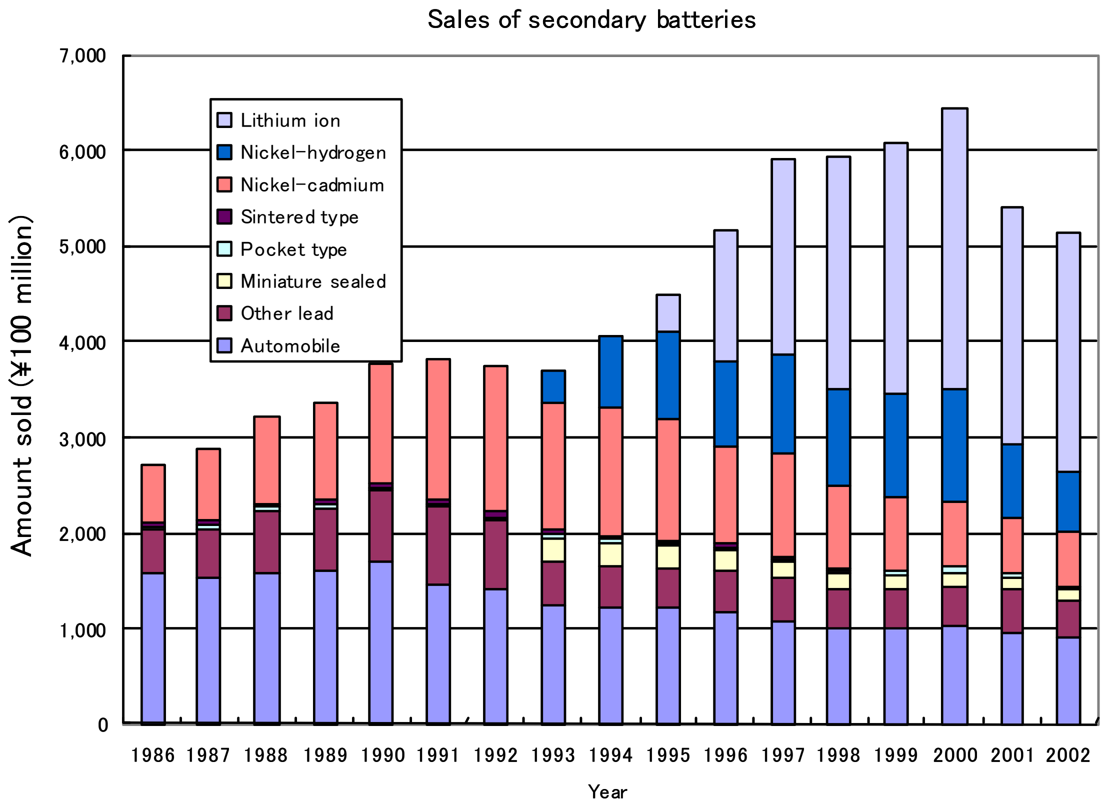
- Market expansion for electronic devices through decreased size and weight
- Lithium ion secondary battery revenue (approx. ¥250 billion/year)
- Japan led in market share in 2002.

<Social impacts>

- Decreased soil contamination (by eliminating the use of lead, mercury, and cadmium found in previous secondary batteries)
- Improved stability and reliability of power supplies
- Potential promotional use of new energy sources (solar power, etc.)
- Establishment of emergency power in case of earthquake, typhoon, tsunami, or other disaster

<Impacts on people's lives>

- Benefits of using compact telephones and mobile devices
- Lifestyle changes due to ubiquitous Internet connections

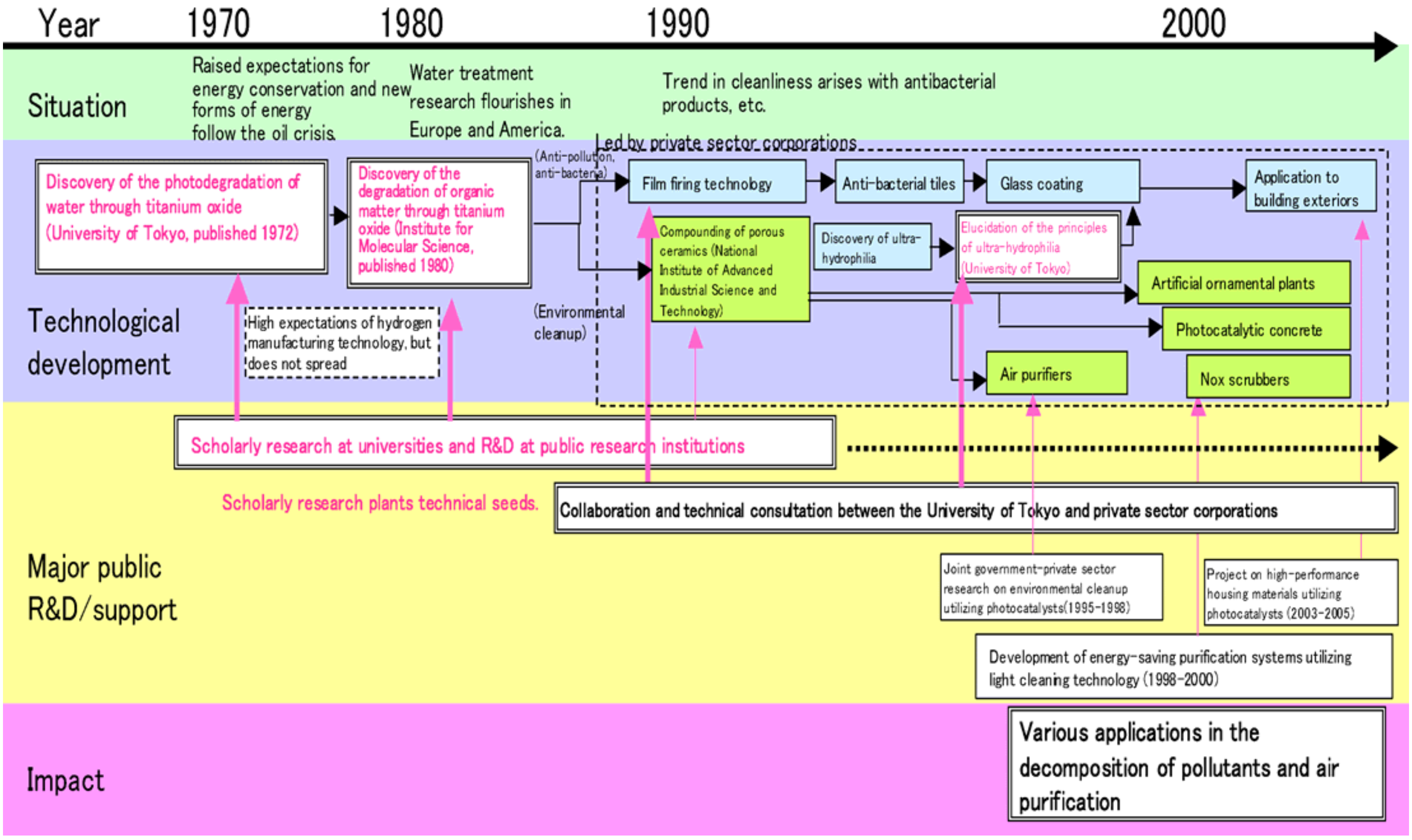


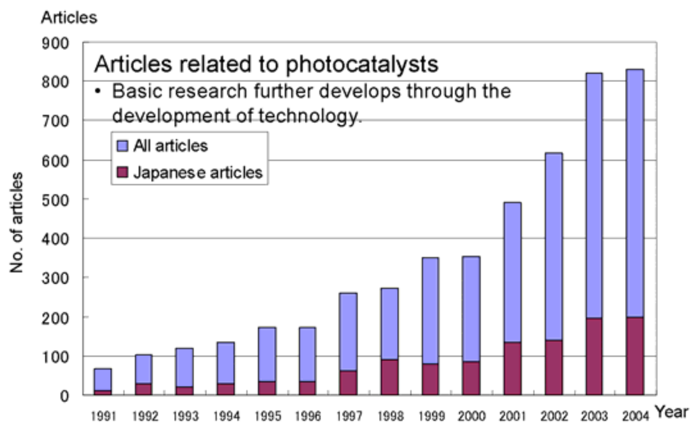
Source: Battery Association of Japan

Photocatalytic materials (Nanotechnology and Materials)

<Case study topics>

- Scholarly research at the University of Tokyo and public research institutions led the early stages of development. The discovery of the photodegradation of water at the end of the 1960s, followed by the discovery of the degradation of organic matter, planted technical seeds.
- Basic research at the University of Tokyo did more than plant technical seeds. It provided ongoing contributions to the process of technical development through technical guidance on titanium-oxide films by private sector corporations, elucidation of the principles of ultra-hydrophilia through industry-academia collaboration, and so forth. Recently, basic research has further developed through technical development (chain model).
- The advance of thinning technology has had an impact through applications such as self-cleaning tiles and air purification.





Note: search string used for title, keyword, and abstract is "(photocatal* AND (Tio2 OR rutile OR anatase OR titanium dioxide*))."
Data: Created using the Thomson Scientific Web of Science database

<Economic impacts>

- An approximately ¥40 billion market for adding value to or replacing existing products such as exterior walls, air purifiers, and deodorizers has emerged (¥25 billion for members of the industry group, the Japanese Association of Photo-catalyst Products, alone).

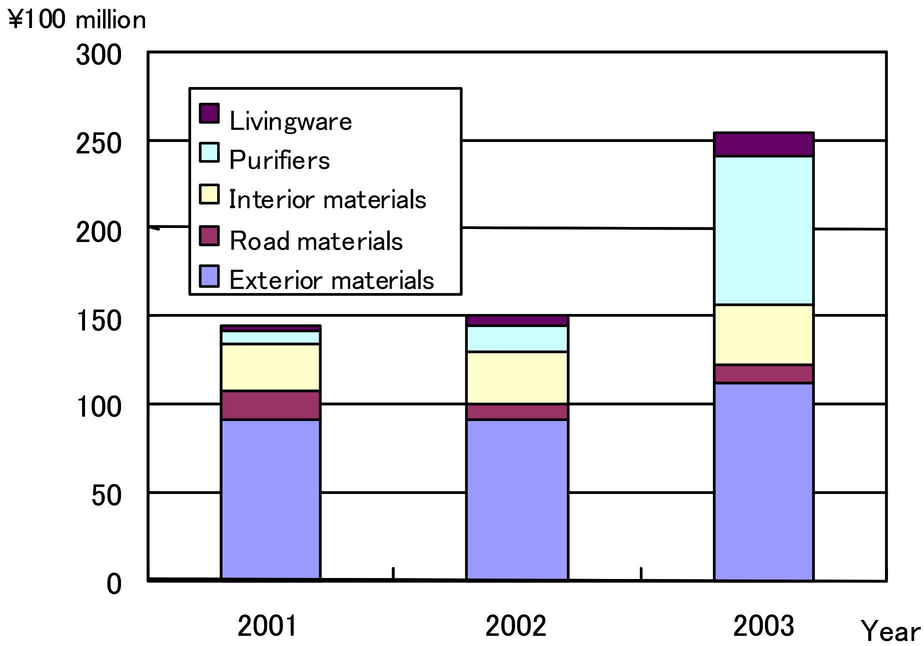
<Social impacts>

- Reduction in cleaning costs for buildings and around roads (sound-insulated walls, guardrails, etc.)
- Cleaning agricultural (greenhouse) runoff
- Potential removal of NO_x from around roads
- Potential cuts in energy needed for summer air-conditioning

<Impacts on people's lives>

- Reduction in effort needed to clean home interior and exterior walls
- Beautification of cities and roads

Market scale for products using photocatalysts

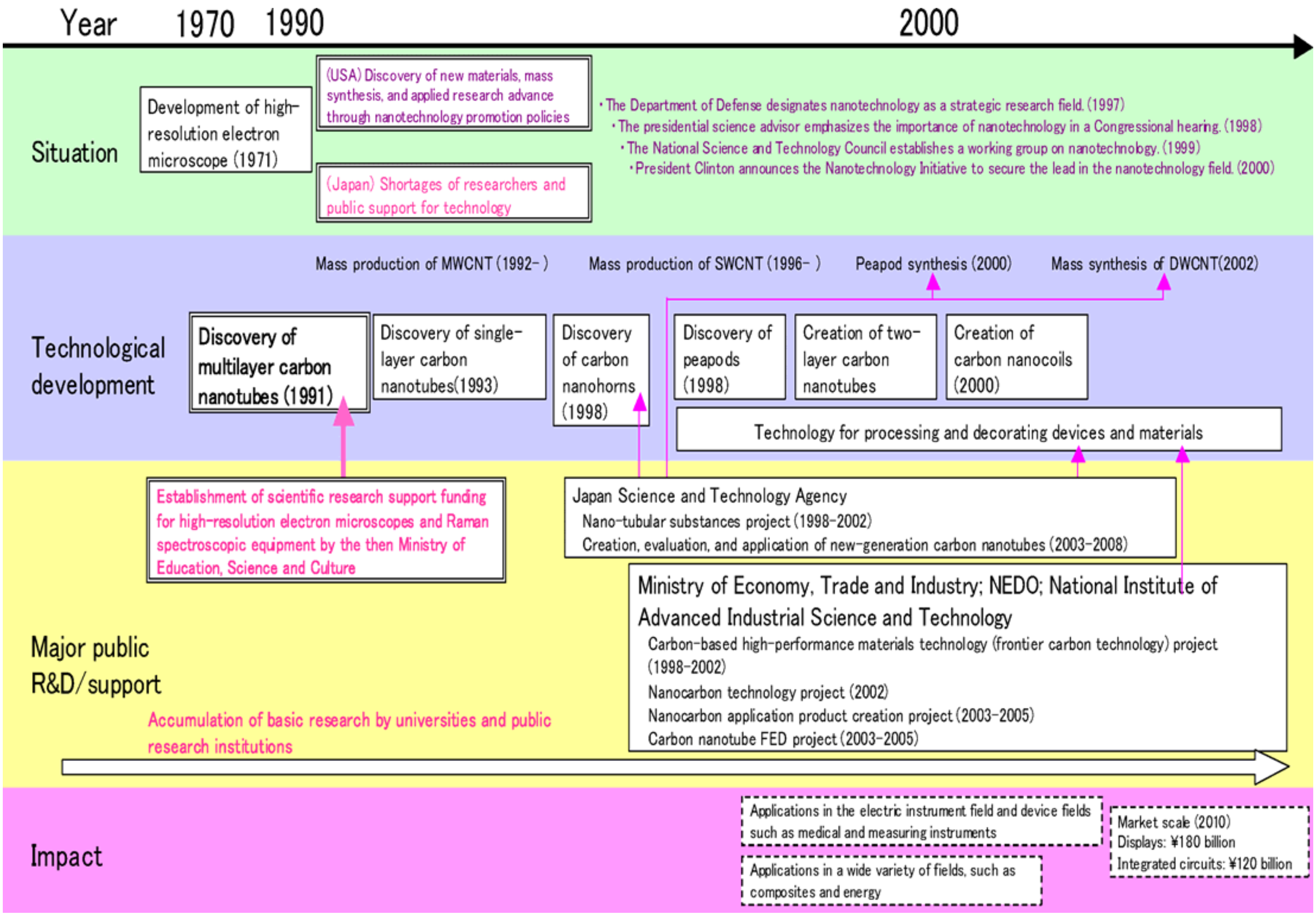


Note: The sudden increase in revenue in 2003 is due to a change in the method of calculation. (Previously, only the filter portion was counted; beginning in 2003, the value of the entire product was included.)
Source: Japanese Association of Photo-catalyst Products

Carbon nanotube devices (Nanotechnology and Materials)

<Case study topics>

- Carbon nanotubes (CNT) were discovered in Japan in 1991. Ongoing research and development of high-resolution electron microscopes from the 1970s on and the accumulation of basic research at universities and public research institutions contributed to the discovery. However, until the latter half of the 1990s, Japan did not conduct large-scale public R&D or support regarding carbon nanotubes, and during this period, the United States synthesized mass quantities and took the lead in applied research.
- Public R&D and support regarding relevant technology did not begin in earnest until the latter half of the 1990s. Provision of research and development funding to universities and the private sector and joint government-academia R&D have contributed to the advancement of the relevant technology.
- Impact is remarkable in terms of creating new business and expanding employment (economic impact) in the markets for displays, integrated circuits, healthcare, and so forth, and in terms of people’s lives through improved convenience via compact electronic devices and health maintenance and improvement.
- Now and into the future, public R&D and support will take on themes that are likely to have early application and practical use. However, continued support of themes that will take more time for application or practical use is required so that basic research is not interrupted.



<Economic impacts>

- Potential economic effects through new markets and the creation of new businesses
  - Display market of approximately ¥180 billion and integrated circuit market of approximately ¥120 billion in 2010
- In the industries utilizing these technologies, potential for reductions in costs and time to development, and improved competitiveness
- Potential expansion of employment in the industries utilizing these technologies

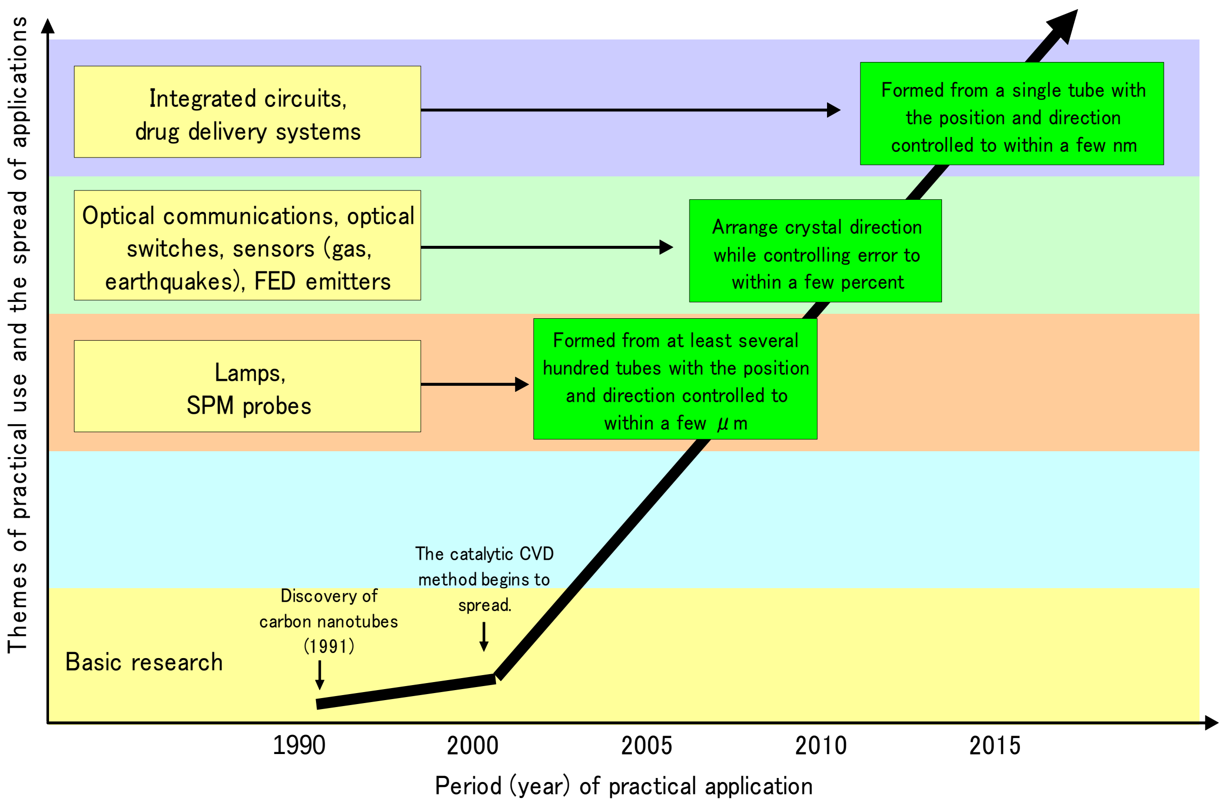
<Social impacts>

- Potential reduction in the burden on the global environment through prevention of global warming (CO_2 emission reduction)
- Potential major reduction in energy consumption (energy conservation)
- Potential achievement of a healthy, long-living society through improved medical technology

<Impacts on people's lives>

- Potential improvements in convenience through compact electronic devices
- Potential lifestyle changes through ubiquitous Internet connections
- Potential maintenance and improvement of national health

The dissemination of carbon nanotubes in various application fields

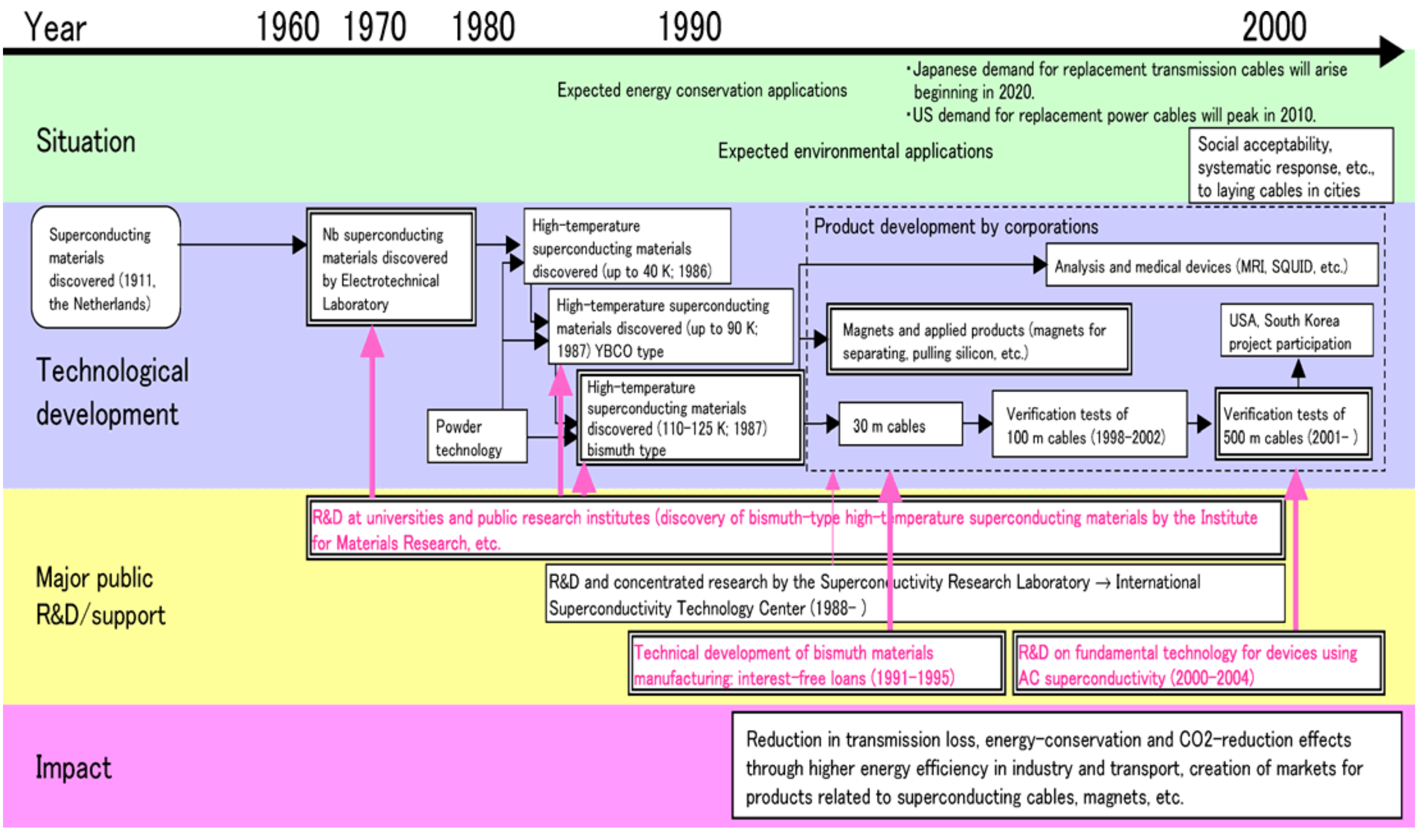


Source: Created by the Mitsubishi Research Institute from various materials and from interviews

High-temperature superconducting materials (Nanotechnology and Materials)

<Case study topics>

- Japan leads in scholarly and basic research. At the application level, however, American and European venture firms are ahead in securing capital for R&D and may overtake Japan.
- Superconducting materials in the form of lanthanum oxides were discovered by the faculty of Engineering of the University of Tokyo. High-temperature superconducting materials in the form of bismuth oxides were discovered by the Institute for Materials Research. In addition, public R&D and support even contributed to high-risk product development and verification tests.
- The use of products applying superconducting cables (for power transmission), superconducting magnets, and motors is expected to have economic impacts such as the creation of new markets along with social impacts such as energy conservation and reduced CO_2 emissions.
- Although R&D on superconducting cables (for power transmission) has reached the application phase, a number of issues must be resolved before they can be put into use. Furthermore, because markets will not arise during the early stages, it may be necessary to use public R&D and support, including verification testing and procurement, to maintain and improve the advanced technologies that have been accumulated and to link them to market creation.



<Economic impacts>

- Potential market for superconducting cables
  - The US market will remain promising for some time to come. The United States will spend approximately ¥10 trillion on replacement power cables over the coming 10 years, and the use of superconducting cables is possible. Japan's cable replacement is expected to begin about 20 years from now.
- Potential energy cost savings through reduction in electrical transmission loss
  - If all of Japan were laid with superconducting cables, annual savings would be about ¥370 billion.
- Potential creation of markets for superconducting magnets, applied products, and superconducting wire products
  - The domestic market for bismuth wire products is forecast to be ¥50 billion, with the worldwide market at ¥60 billion.
- Potential cost reductions through greater energy efficiency for railroads, industrial plants, etc.
- Potential added value for semiconductors due to improved silicon quality

<Social impacts>

- Potential energy-conservation and CO_2-reduction effects through reduced transmission loss and greater energy efficiency in industry and transport
  - Stringing all of Japan with superconducting cable would enable an annual reduction of about 1,570 tons of CO2.
- Potential for efficient use of space and reduction in electromagnetic waves in densely populated urban areas
- Environmental improvement through elimination of water pollution

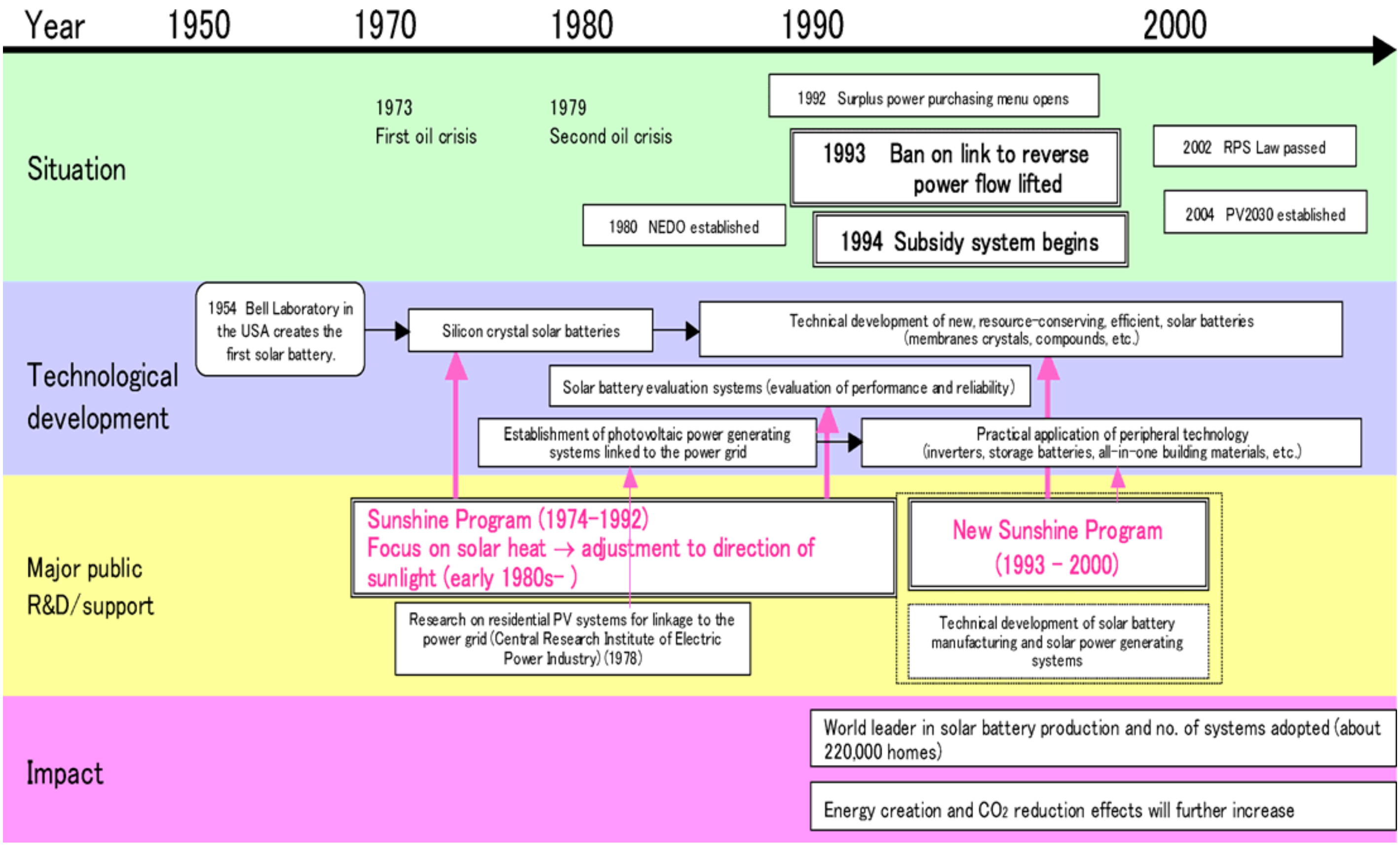
<Impacts on people’s lives>

- Potential reduction in electricity bills through reduced transmission loss
- Potential improvement of health through advanced imaging diagnosis (already partly realized)

Residential photovoltaic power generation systems (Energy)

<Case study topics>

- The advancement of long-term national R&D with a 30-year vision into the future has played a major role in its success.
- At first, the major goal was solar heat, but public R&D and support shifted to the orientation of sunlight as technology developed.
- Deregulation ended the ban on linking reverse power flow[Note 1] to the system, and subsidies for its adoption formed the early market. Through the virtuous circle of market expansion and decreasing costs, Japan is currently Number One in the world in both the production of solar batteries and the adoption of solar generating systems.



Note 1: Reverse power flow is active flow into the power grid from those who have established generating systems.

<Economic impacts>

- Market creation
  - Over ¥150 billion in 2003; ¥400 billion in 2010
- Enhanced international competitiveness
  - Japan accounts for almost 50% of solar battery production
- Direct and induced job creation effects from manufacturing, installation, and operation/maintenance
  - Estimated 30,000 jobs in 2003

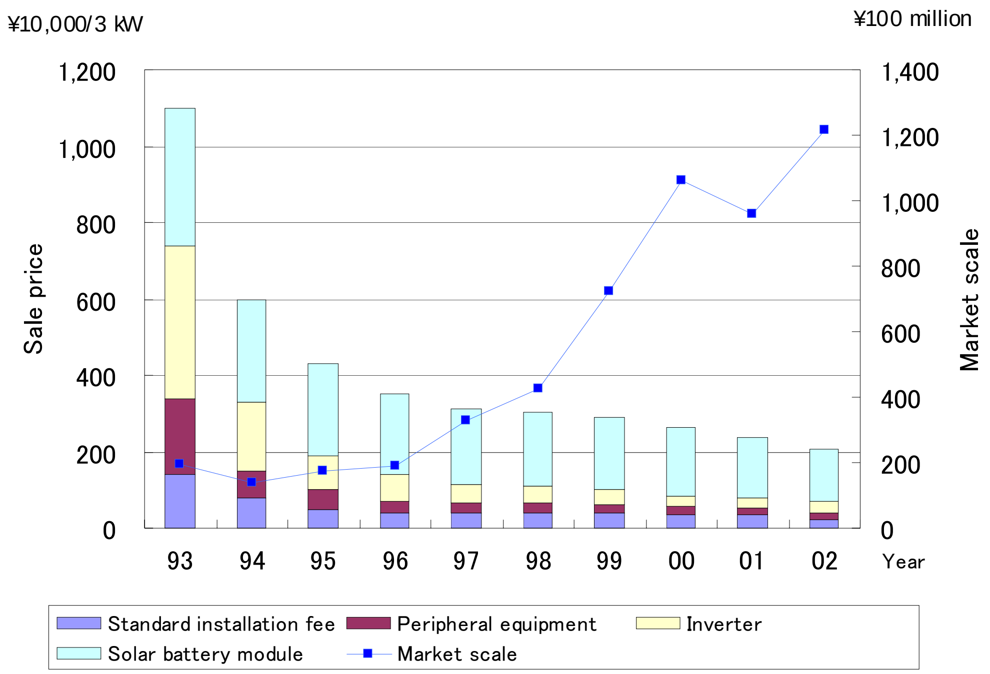
<Social impacts>

- Penetration to about 220,000 homes (2004)
  - From 0.02% share of power generation in 2002 to 10% in 2030
- CO_2 reduction effect
  - About 230,000 tons of CO_2 in 2002, about 1,700,000 tons in 2010

<Impacts on people's lives>

- Lower electric bills through use and sale of electricity generated

Market scale and solar generating system prices

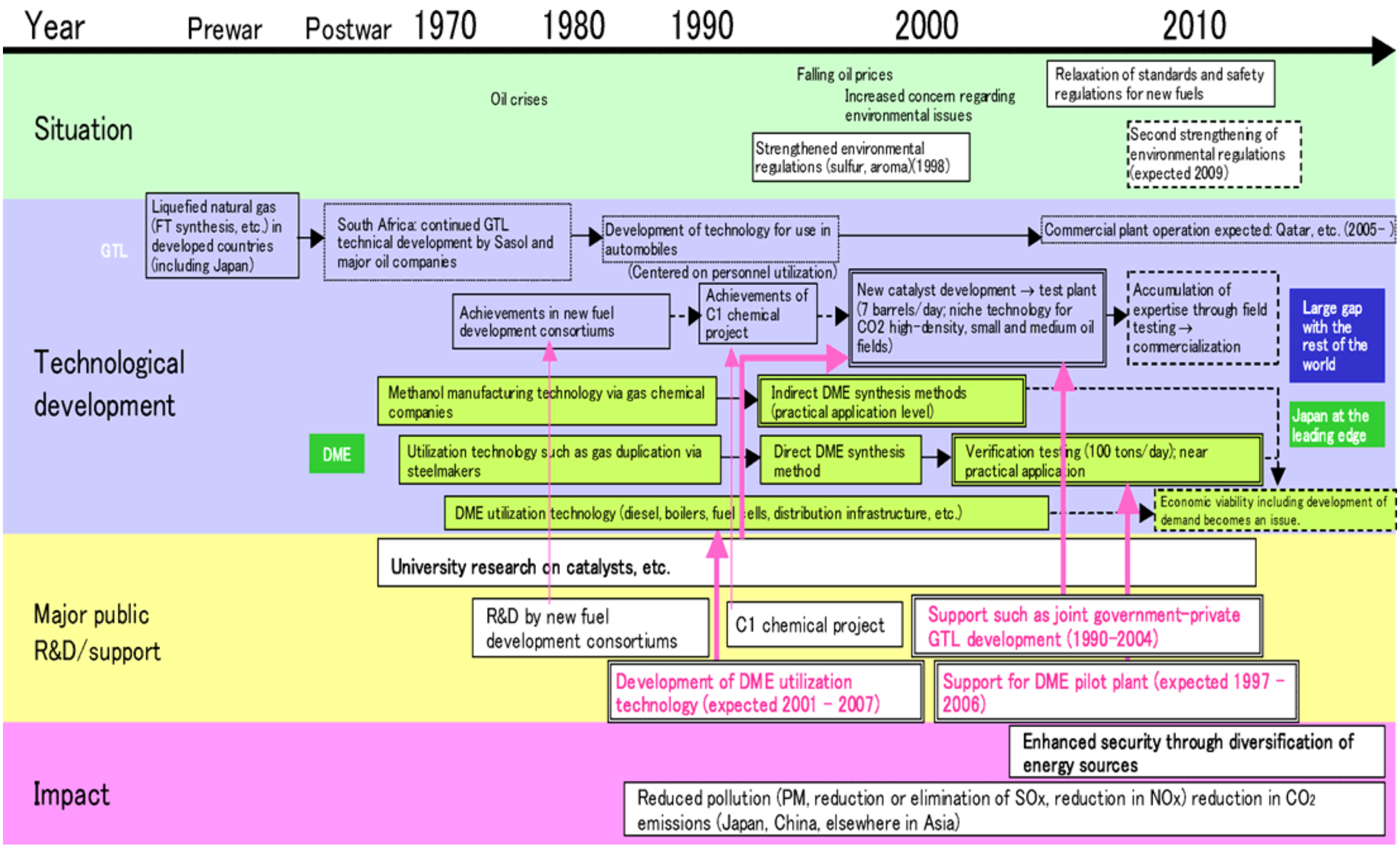


Source: Created by the Mitsubishi Research Institute from NEDO's "H14-nen shin-energy data-shuu" (2002 New Energy Data Collection) and "PV Roadmap Toward 2030"

Liquid fuel production from natural gas and other gas sources and its application (GTL and DME; Energy)

<Case study topics>

- GTL is expected to be used in a mix with existing forms of diesel and kerosene. Although its commercialization overseas is projected for 2005, in Japan, only small test plants utilize it. DME is a new fuel, and development of utilization technology has reached the level of practical application. Japan is the leader in the field.
- Commercialization of GTL and DME technology carries high risk. The contributions of public R&D and support are particularly essential for verification testing, which requires large-scale investment.
- In light of the projected future crunch in the supply and demand of petroleum, the use of natural gas and other carbide resources to obtain synthetic liquid fuels that can be used in applications such as power generation, heating, and transport is expected to have the social impact of increased security through diversification of energy sources.
- To realize this impact, long-term public R&D and support based on a national energy strategy and linkage with policies other than science and technology policy are needed.



<Economic impacts>

- Potential creation of a market for new fuel (DME)
  - Estimated at about 2 million tons (about ¥30 billion) in 2010 and about 28 million tons in 2020 (about ¥420 billion)
- Potential alternatives to markets for diesel, kerosene, and naphtha through GTL
  - Example of commercialization scenario: operation of a 20,000–40,000-barrel plant in 2015–2010, approximately 0.5–1% of the domestic petroleum market, followed by phased expansion
- Potential creation of market for GTL/DME plant businesses
- Potential price reduction effect as alternative to LPG (DME)
- Potential creation of internal demand and employment in rural areas through synthesis of GTL and DME from forest and agricultural biomass
- Potential development of the petrochemical industry into the natural gas chemical industry

<Social impacts>

- Potential for enhanced security through diversification of energy sources
  - Securing of cost-competitive energy through unique Japanese technology and resources in response to the expected crunch in petroleum supply and demand and control by the USA and major oil companies
  - GTL/DME production will account for an estimated 4% of the domestic primary energy supply in 2020
- Potential reduction in pollution
  - Reduction or elimination of PM and SO_x, reduction in NO_x
- Potential reduction in CO_2 emissions
- Potential increase in fuel efficiency through elimination of post-combustion processing equipment for diesel engines

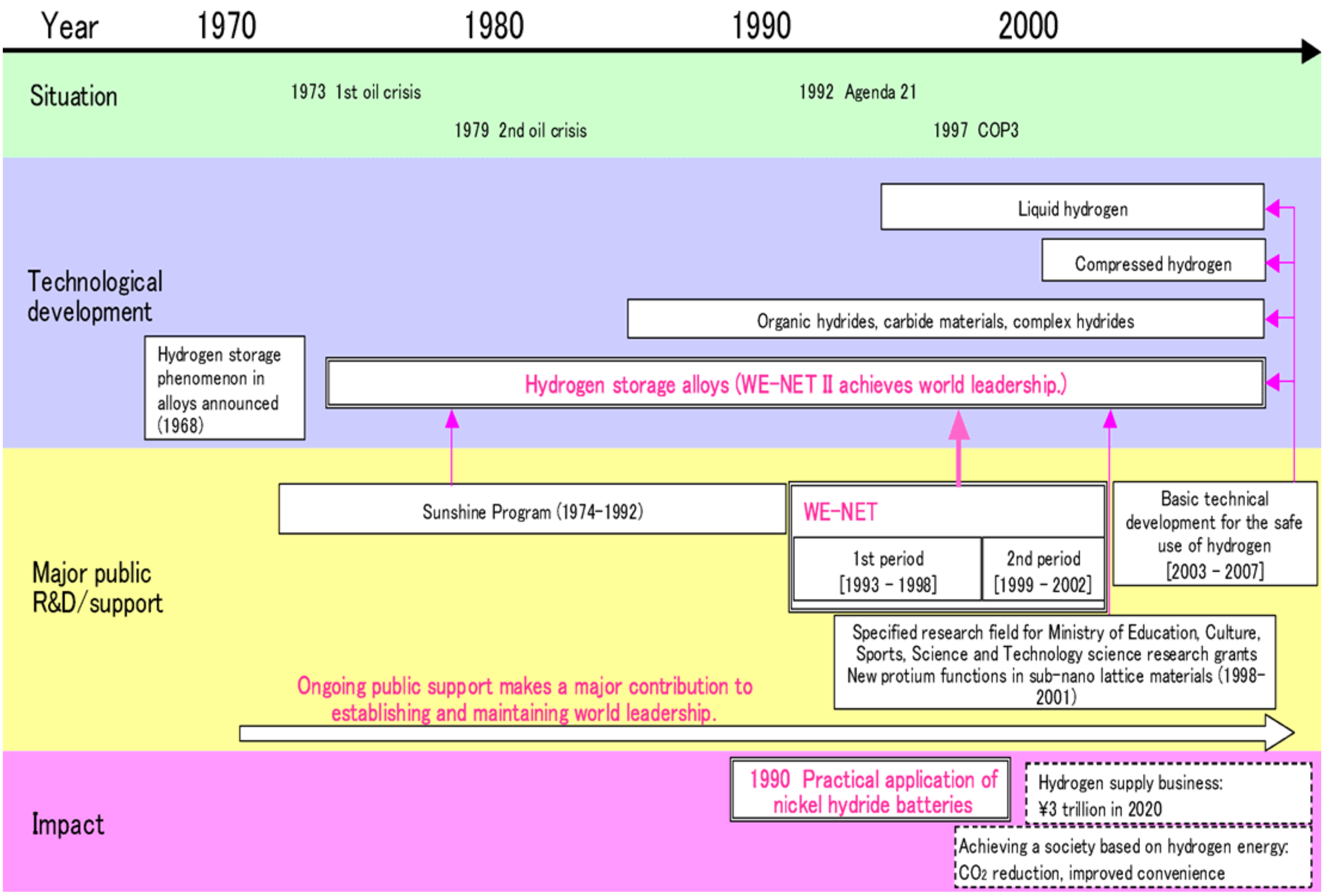
<Impacts on people’s lives>

- Potential increases in comfort and health due to a cleaner environment
- Potential maintenance of traditional rural ways of life through the revitalization of forestry and agriculture for biomass harvest
- Potential stability in overall prices spreading due to stability in the prices of diesel, kerosene, and alternatives

Hydrogen storage alloys (Energy)

<Case study topics>

- Japan is among the world leaders in hydrogen storage alloys. The USA leads in the high-pressure gas cylinders that are closest to practical application.
- Since the 1970s, public R&D and support has been continuously implemented, centered on basic research such as materials development. In particular, WE-NET has positioned itself among the world leaders by setting high R&D goals and conducting development in accordance with them.
- Achieving a society based on hydrogen energy is expected to have major impacts on the economy, society (energy security, reduction in CO_2 emissions, etc.), and people's lives (a better environment, etc.).
- Because R&D that explores materials and so forth is expensive and risky, it is difficult for the private sector to conduct. Public R&D and support into the future are essential.



<Economic impacts>

- Potential creation of hydrogen supply business
  - In 2020, 40 billion m^3 annually, ¥3 trillion
- Potential creation of distributed energy supply business
- Potential creation of a hydrogen automobile industry
- Potential creation of a hydrogen energy machinery industry

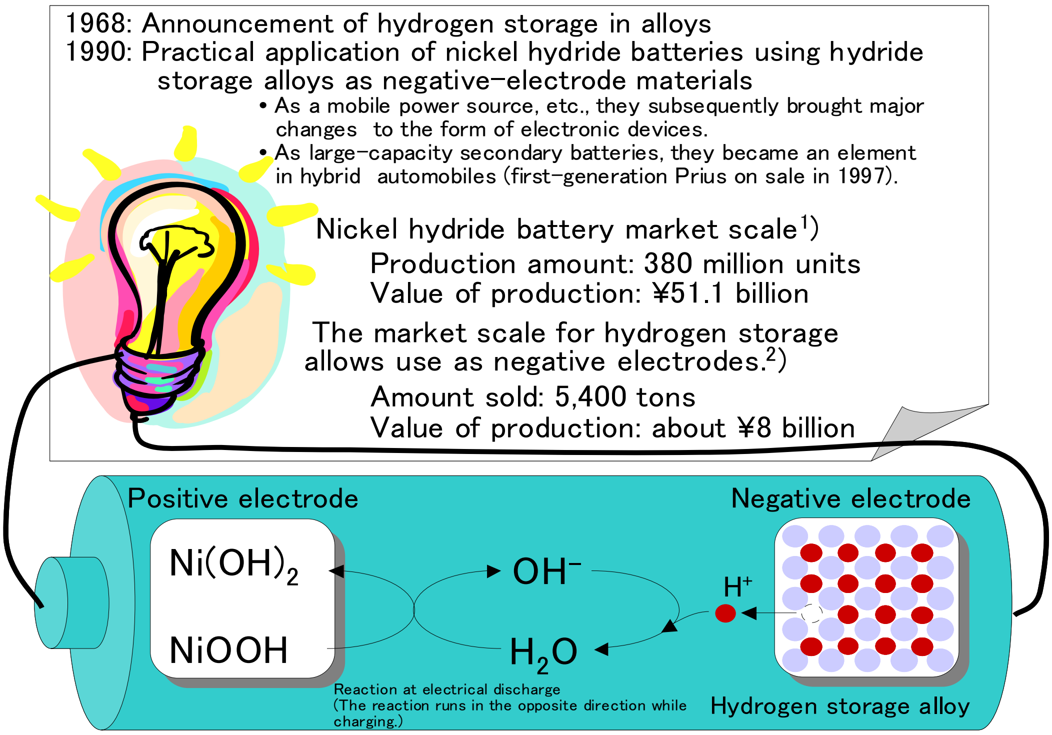
<Social impacts>

- Potential prevention of global warming through reduction in CO_2 emissions
- Potential contribution to energy security
- Potential spread of fuel-cell automobiles
  - Five million vehicles in 2020, 15 million in 2030
- Potential spread of fixed batteries
  - Ten million kW in 2020, 12.5 million in 2030
- Potential reduction in large power plants

<Impacts on people's lives>

- Potential supply of safe fuel
- Potential for life without air pollution, or engine noise and vibration

Already-realized impacts of hydrogen storage alloys

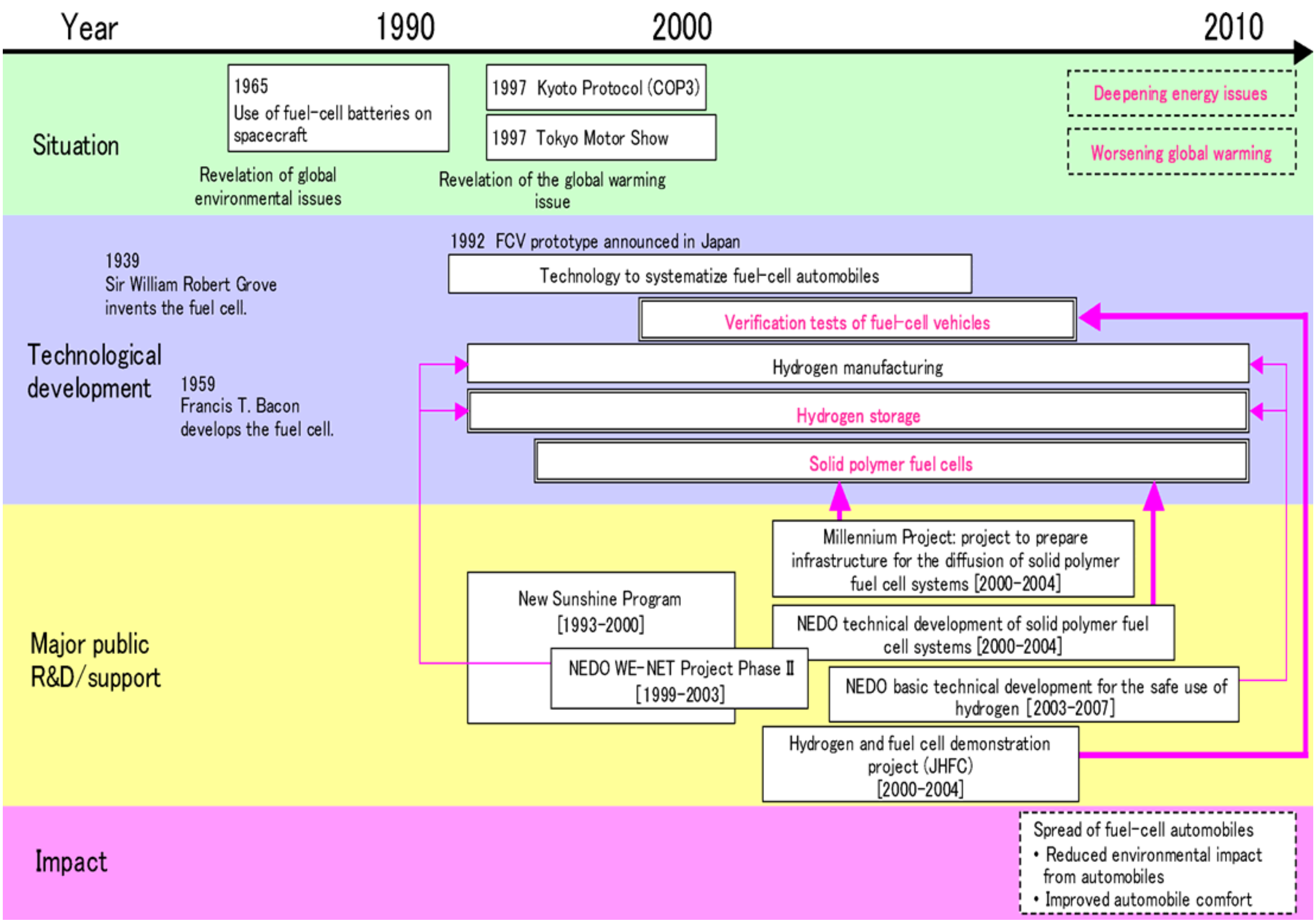


Note 1) 2003, Battery Association of Japan
Note 2) 2002, based on "Denchi to kouzouzairyou no shijo 2004" (Battery and Structural Materials Market 2004), CMC Publishing

Fuel-cell vehicles (Energy)

<Case study topics>

- Most automakers are conducting R&D related to fuel-cell automobiles
- Public R&D and support has contributed to basic aspects such as personnel and demonstration and safety testing.
- Numerous social impacts, such as reduction in carbon dioxide emissions, improved energy efficiency, and solution of noise problems are expected. The expected economic impact is the creation of a market for fuel-cell automobiles. The expected impact on people's lives is improved automotive performance.
- To realize these impacts, social momentum on energy and environmental issues must increase. In addition, fuel cells require technical breakthroughs in the technology of hydrogen storage. Basic research at universities and so forth is needed.



<Economic impacts>

- Potential creation of a market for fuel-cell automobiles
  - Scenario and goal of 50,000 vehicles in the 2005–2010 introductory phase and 5 million in 2020
- Potential building of new hydrogen infrastructure
- Potential creation of industry through promotion of utilization of new fuels (biomass, etc.)

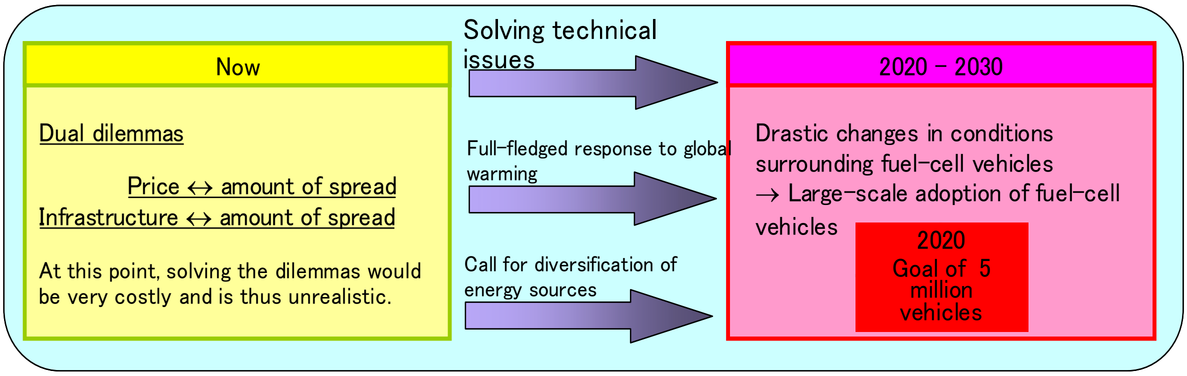
<Social impacts>

- Potential carbon dioxide reduction effect
  - Forty percent of the CO_2 emissions of gasoline engines; 50,000 vehicles in 2010 would reduce CO_2 by an estimated 60,000 tons.
- Potential reduction in air pollutants (NO_x, HC, CO, PM, etc.)
- Potential increase in national fuel security through diversification of fuel sources
- Potential improvement of well-to-wheel energy efficiency
  - Fuel-cell vehicles are three times as efficient as gasoline vehicles, with double the overall efficiency.
- Potential improvement of noise pollution from roads

<Impacts on people's lives>

- Potential improvement of living environment (reduction in air and noise pollution)
- Potential improvement of automobile comfort (improved quiet, more space, diversified design)
- Potential increase in environmental awareness

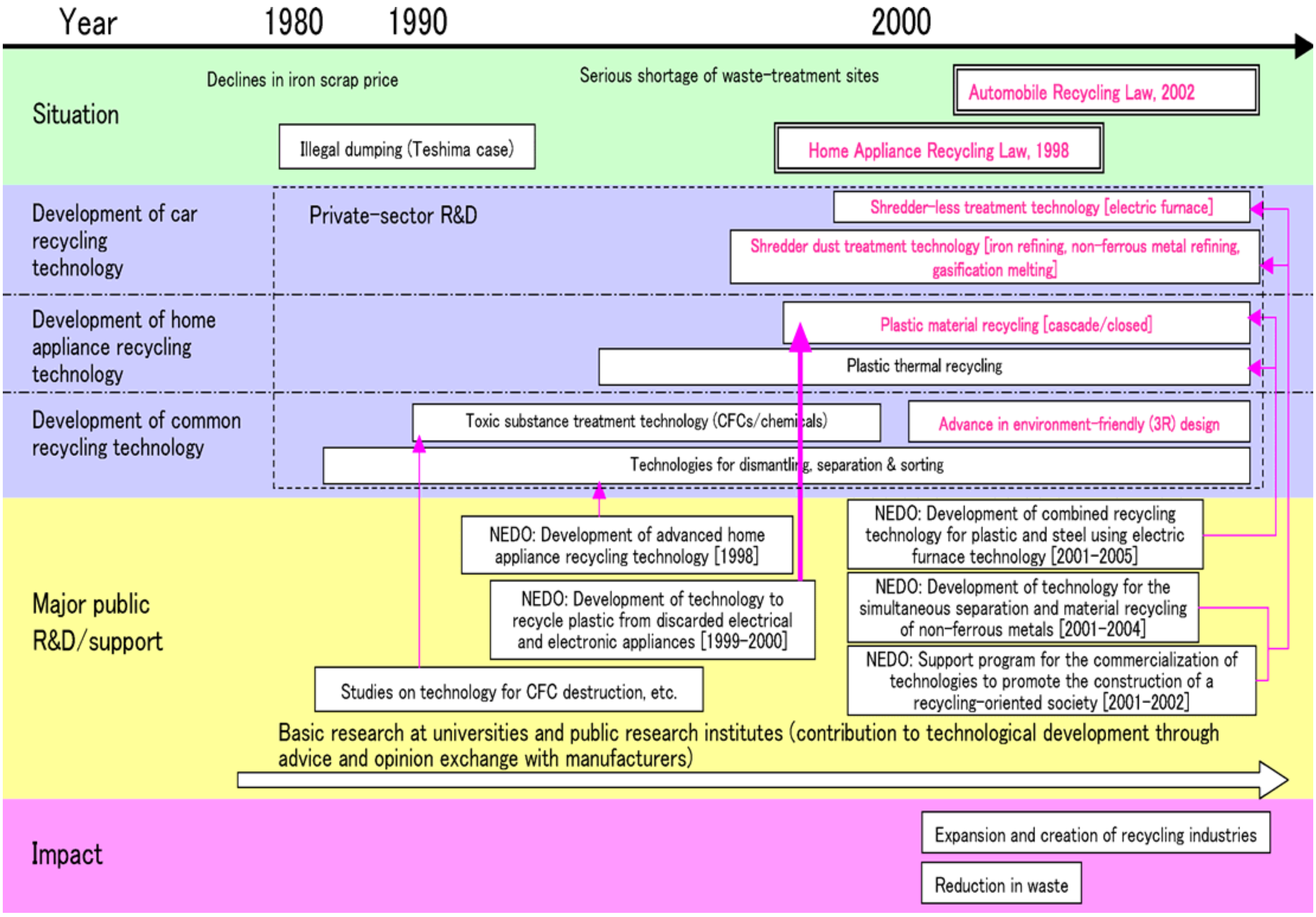
Scenario for the spread of fuel-cell automobiles



Technology for recycling end-of-life vehicles and electronic waste (Manufacturing)

<Case study topics>

- The recycling of cars and home appliances has been enabled mainly through R&D in industry.
- A combination of legal regulations, technological development, verification testing, NEDO's R&D projects on plant manufacturing, and subsidies has proven effective.
- The impact of technology is the largest on society since it reduces waste as a result of improved recycling rates for cars and home appliances. There are also major impacts on the economy, such as the creation of new recycling-related industries and markets and reduced recycling costs paid by consumers with technologies to simplify car recycling.
- To continue producing and enhancing these impacts, the government should formulate policies that address declines in iron scrap price and the outflow of scrapped cars to China and other countries (for car disposal) and improvement of the competitiveness of recycled materials by e.g. obliging manufacturers to use recycled plastic (for home appliance disposal).



<Economic impacts>

- Expansion and creation of recycling industries
  - Home appliances: ¥100 bil in value (estimation for 2005)
  - Automobiles: ¥300 bil in value (before Automobile Recycling Law)
    + ¥40-48 bil (after Automobile Recycling Law)
- Employment creation in recycling-related industries
  - About 1,600 workers for home appliance recycling plants
- Reduced recycling costs
  - Automobiles: around ¥20 bil
- Reduced spending by municipal governments for collecting electronic waste

<Social impacts>

- Reduced waste as a result of improved recycling rates
  - Home appliances: about 280,000 t/year
  - Automobiles: about 480,000 t/year (ASR only)
- Partial creation of a recycling-oriented society
- Prevention of global warming and protection of the ozone layer

<Impacts on people's lives>

- Raised awareness of recycling because of the cost to be shared
- Lighter burden as a result of reduced recycling costs
  - Consumer expenses reduced to ¥10,000-15,000 from the initial estimation of ¥20,000 (car recycling)
- Prevention of the deterioration of the living environment by reducing waste

Size of the markets created for home appliance recycling

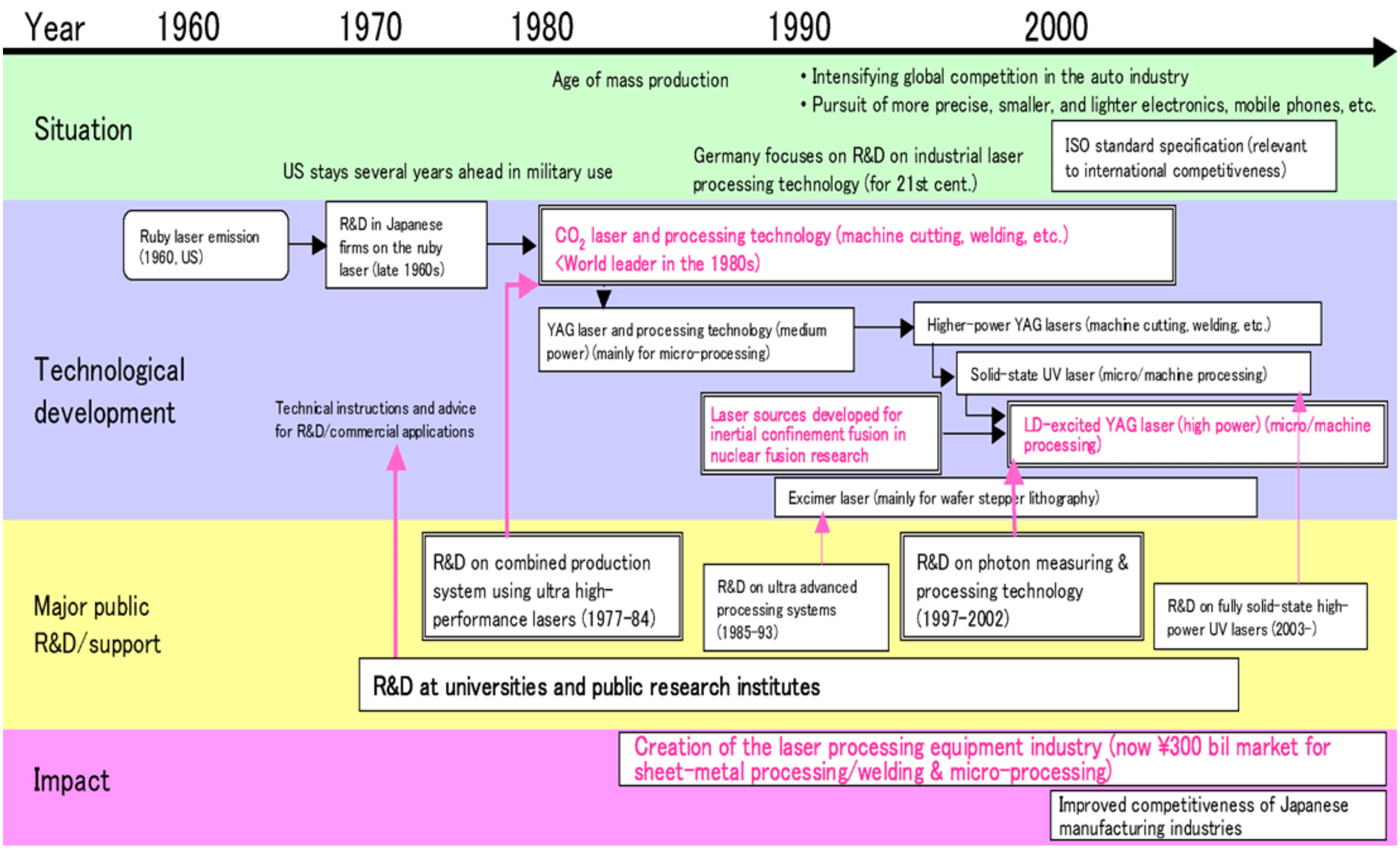
	Recycling cost (as makers publish)	Primary transport cost (tentative)	Total	Expected waste (1,000 units)	Market size (¥100 mil)
Refrigerator	4,600	1,000	5,600	4,521	253
Washing machine	2,400	1,000	3,400	4,403	150
TV	2,700	1,000	3,700	7,615	282
Air conditioner	3,500	1,000	4,500	6,273	282
Total	-	-	-	22,812	967

The primary transport cost is undecided and is thus a tentative value.
Expected waste is an estimated value for 2005 based on past results.
Source: Development Bank of Japan, Research Report 2001 "The Impact of the Introduction of the Home Appliance Recycling System and the Future"

Laser processing technology (Manufacturing)

<Case study topics>

- The CO_2 laser and the YAG laser, which have been developed through public R&D projects, have made major contributions to the creation of the laser processing equipment industry. Japan became the world leader in this area in the 1980s. (As a result of increased public investments in Germany and across the EU in the following years, Germany now leads the world.)
- This technology is the key to improving competitiveness in the manufacturing sector (cars, electronics, etc.) that involves machine processing and micro-processing, and has a large impact on the economy.
- The laser sources developed for inertial confinement fusion in nuclear fusion research have been applied for industrial purposes.
- Some experts suggest that recent public R&D and support projects have set goals that have little connection with industrial needs, such as "the world's highest level," making the results difficult to lead to applications.



<Economic impacts>

- Creation of the laser processing equipment industry
  - Size of the market for sheet metal processing and welding equipment
    Now ¥100 bil→¥200 bil a few years hence; estimations assuming Japanese makers account for 1/3 of the domestic market.
    Global market now valued at ¥300 bil→¥600 bil a few years hence (Now divided among regions at 2:1:1=Europe:Japan:US; potential for growth for Japan)
  - Size of the micro-processing equipment market
    Now ¥200 bil→¥400 bil a few years hence. The majority of the market is in Asia, and Japanese makers dominate.
- Improved competitiveness of Japanese manufacturing industries (cost competitiveness, high performance & precision, smaller & lighter products, design, reliability) and retainment of core technologies
- Increased sales, profits, and employment in the laser processing equipment industry as well as the user industries (e.g. automobile, electronics)

<Social impacts>

- Energy conservation as a result of improved fuel efficiency in cars
- Resource conservation (through reduced material use, etc.)
- Mitigation of environmental pollution with cleaner auto emissions
- Reduction in noise pollution by displacing punch presses from the shop floor

<Impacts on people's lives>

- Enhanced quality of life with improved usefulness of the equipment for daily use (cars, mobile phones, etc.) and reduced prices

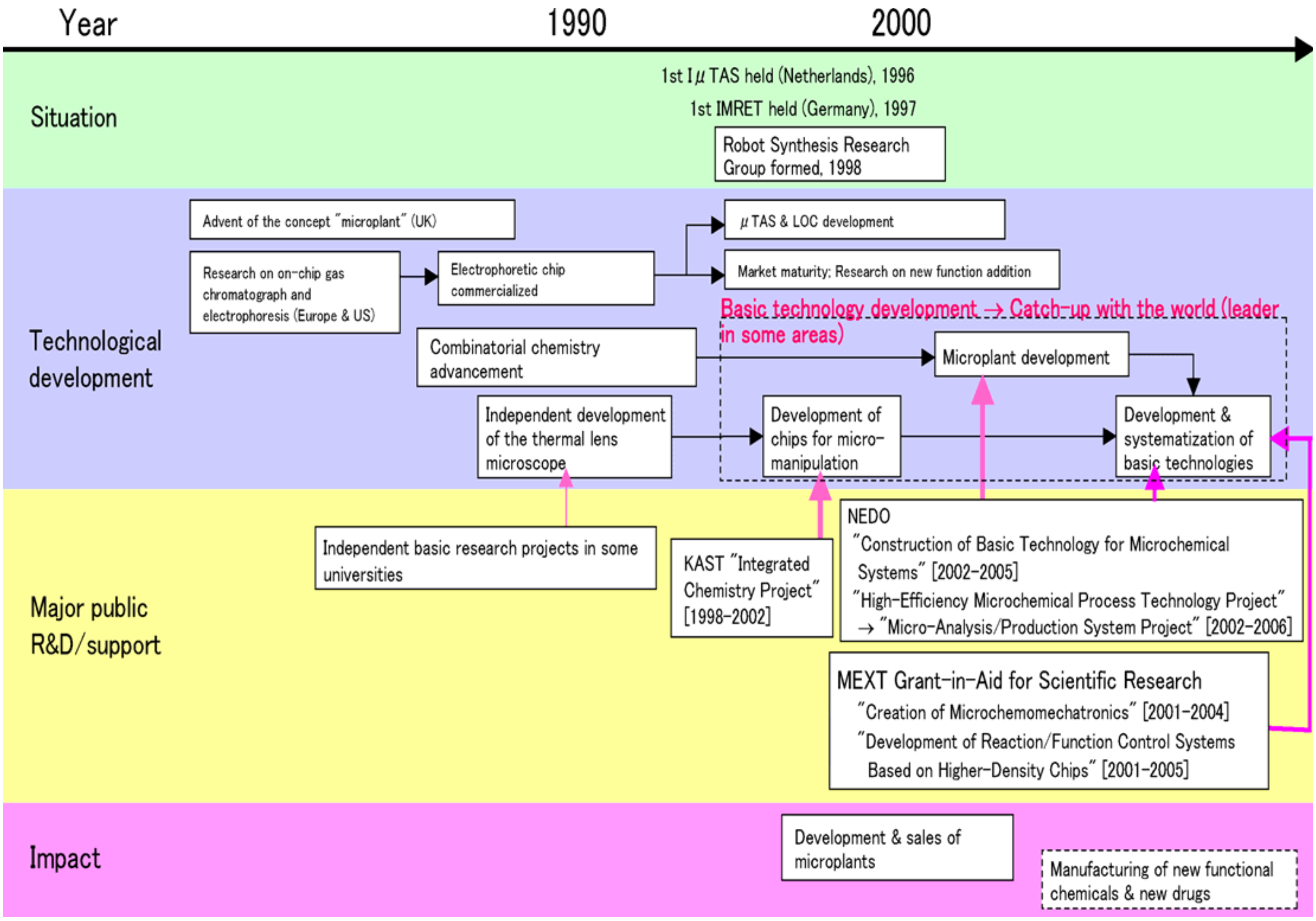
(International competitiveness)

- Germany leads the world in lasers for mechanical parts processing (high-performance YAG, LD-excited YAG, semiconductors), followed by Japan.
- Japan's presence is overwhelming in laser micro-processing.
- The U.S. has strength in lasers for military and scientific research and for semiconductor lithography.

Microreactors for chemical systhesis (Manufacturing)

<Case study topics>

- While the U.S. and Germany have been leading the development of microreactor technologies, Japan has launched several public projects since 2001 and has successfully caught up.
- Because this area is still in the basic technology development phase, which involves too much uncertainty for companies to voluntarily participate, public R&D and support such as the "Microanalysis/Production System Project" has assumed a major role in establishing basic technologies and accumulating research in the private sector.
- The major expected impacts are economic impacts as a result of the creation of new markets for chemicals and analyzers produced using microreactors and social impacts deriving from innovations in chemical manufacturing processes to contribute to waste reduction, energy conservation, and carbon dioxide reduction.
- The Japanese government should take the initiative in introducing microreactors to the public sector for initial market creation and in standardizing the relevant technologies.



<Economic impacts>

- The market currently centers on research. The current value is ¥2-3 bil.
- The market will begin to form in 2006 and reach ¥100-200 bil by 2010.
  (The market includes microreactors and chemicals/analyzers manufactured using them. R&D is still too immature to decide the kind of chemicals to be produced.)

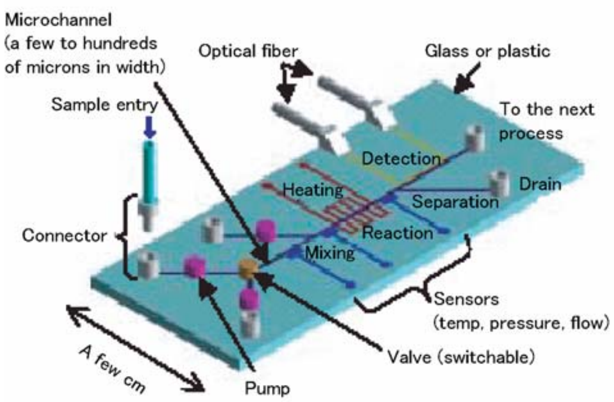
<Social impacts>

- Potential waste reduction effects
- Potential effects on energy conservation and CO_2 reduction
- Potential improvement of chemical reaction safety
- Potential commercialization and price reduction in precision chemicals (drug intermediates, etc.)
- Potential simplification of the environmental substance analysis procedure
- Potential contribution to the development of portable fuel cells

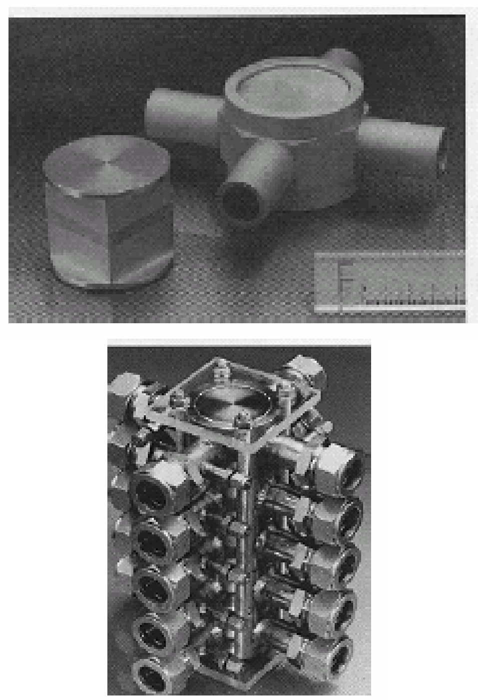
<Impacts on people's lives>

- Potential improvement of quality of life as a result of the commercialization of new functional chemicals and new drugs
- Potential for extensive, fast lab testing and diagnosis and for simplified self/routine examinations
- Potential contribution to the practical use of advanced small artificial organs

Microchip



Microplant

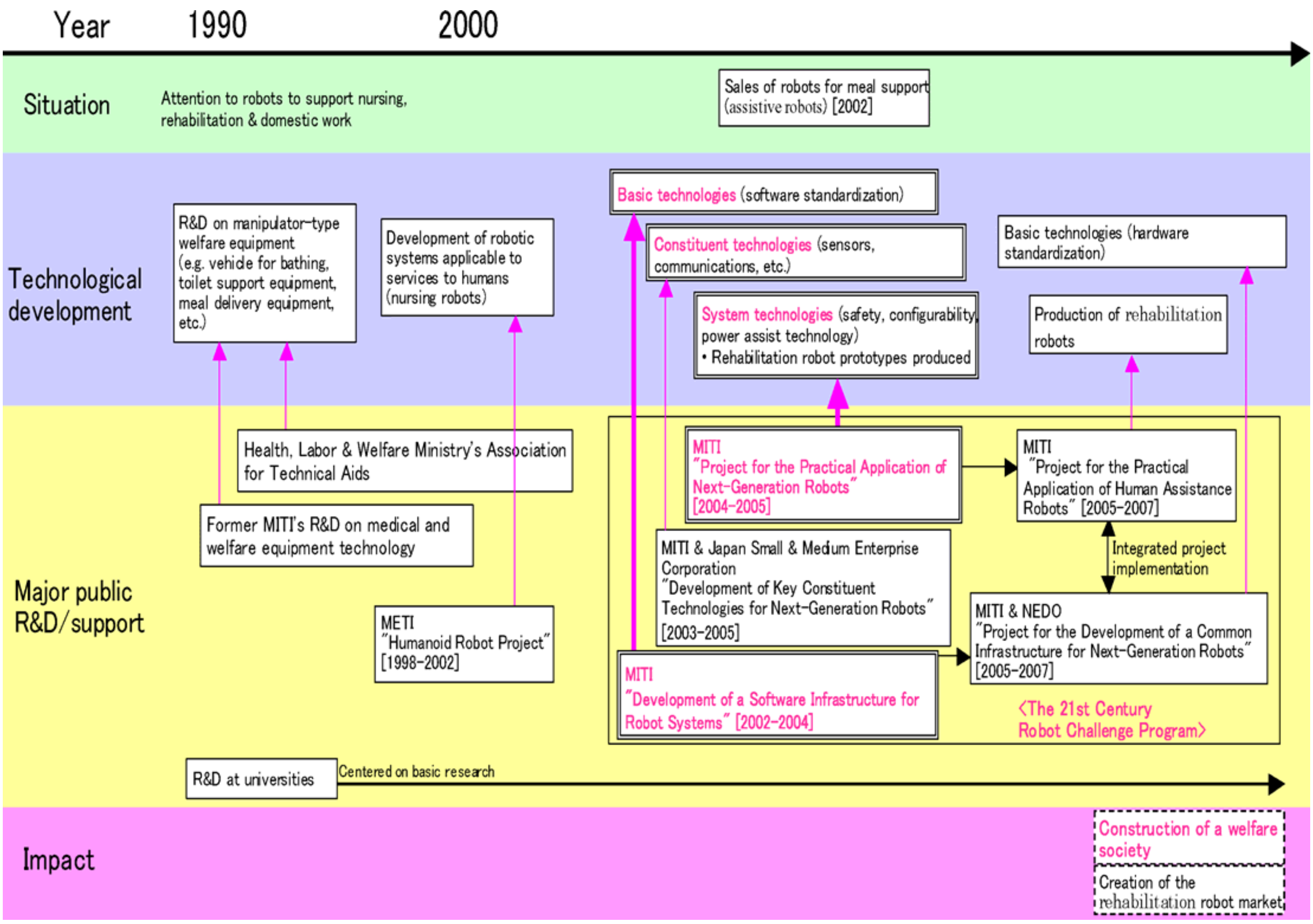


Source: Reprinted from the Micromachine Center website and NEDO's report on the "Micro-Analysis/Production System Project"

Rehabilitation robots (Manufacturing)

<Case study topics>

- Rehabilitation robots can be divided into assistive robots and nursing robots, and the former type has been commercialized mainly in Europe.
- Around 1990, attention was drawn to rehabilitation robots as society aged, leading to several public projects. However, since many researchers focused on either manipulator-type equipment or nursing robots, most of the results have yet to be commercialized because of safety and for other reasons.
- This technology is expected to contribute to reducing welfare costs by growing the robot market in the welfare sector and increasing the number of patients nursed at home (economic impacts), to promoting social participation of elderly people and those with disabilities (social impact), and to making life less stressful and more relaxed and easing the mental and physical burden on both care givers and receivers (impacts on people's lives).
- While nursing robots are high-tech equipment and highly marketable, they face many challenges in safety. Their commercialization is unlikely before 2010.



<Economic impacts>

- Potential for the growth of the robot market in the welfare sector and employment creation in related industries
  - Robot market for healthcare and welfare in 2010: ¥167 bil
    Robot market for healthcare and welfare in 2025: ¥931 bil
- Potential expansion of the software and hardware markets through the promotion of robotic technology
- Potential reduction in welfare costs as a result of facilitating home care (eased burden on nursing staff at medical facilities and lower medical expenses)

<Social impacts>

- Potential promotion of social participation by those with disabilities and elderly people
- Potential promotion of social participation by caregivers as a result of eased burden of caring
- Potential construction of a welfare society
- Potential improvement of the living environment

<Impacts on people's lives>

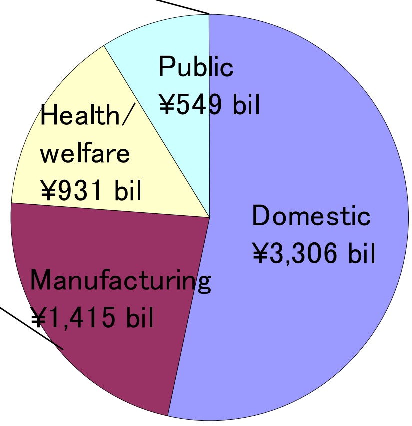
- Potential for enabling new lifestyles with less stress and greater ease and improving QOL (Quality of life)
- Potential reduction in the mental and physical burden on both care givers and receivers

Estimated size of the next-generation robot market (for 2025)

(in ¥100 millions)

Sector	Field	Robot application areas	Market value
Primary robot market	Manufacturing	Automobile, electric machinery, and other manufacturing industries	14150
	Domestic	Assistance in household chores & homecare	32640
		Assistance in home security service	20
		Entertainment	400
	Health/ welfare	Assistance in nursing and caring at facilities	9310
	Public	Maintenance work in power, railroad, telecom facilities	5270
		Security service at business facilities	200
		Sophistication of fire fighting facilities	20
Derivative markets	Applications	Software, replacement parts	22450
	Education	Safety and technical training	420
	Used goods sales	Sales of used robots	960
Other markets (note)	Maintenance		[4010]
	Property insurance		[760]

(Note) included in the primary robot market

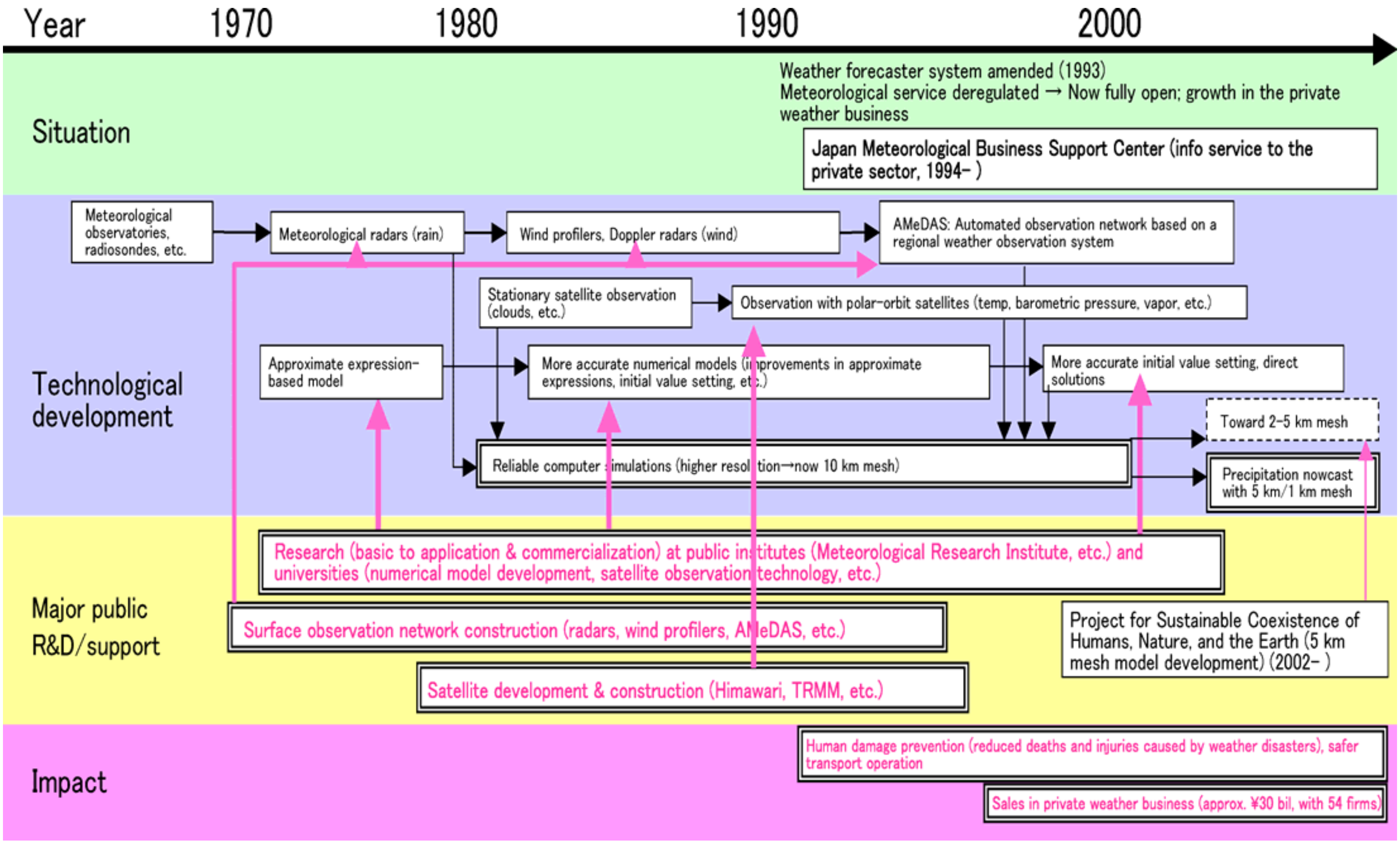


Source: Created by the Mitsubishi Research Institute based on the Discussion on the Vision of the Next-Generation Robots

Technology for regional weather forecasting (Social Infrastructure)

<Case study topics>

- The expanded observation networks and the development of more accurate numerical models have enabled regional weather forecasts (10 km mesh, as of 2001) in Japan, and the country leads the world in this area.
- The impact of this technology has expanded as a result of public research institutes' steady R&D efforts (e.g. to derive numerical prediction models) and construction of extensive observation networks (a nationwide observation network consisting of AMeDAS and other radars; a global weather observation system using satellites), combined with the deregulation to allow private businesses to enter this field.
- This technology has large impacts on people's lives, with a potential for improving safety and security in life by preventing death and injury in the event of disasters such as severe rainstorms and snowstorms. It also has social impacts such as enhanced protection against disasters in transport systems.
- Major concerns for this technology are that regular research projects are facing difficulties in continuity and that long-term research needs tend to receive limited attention.



<Economic impacts>

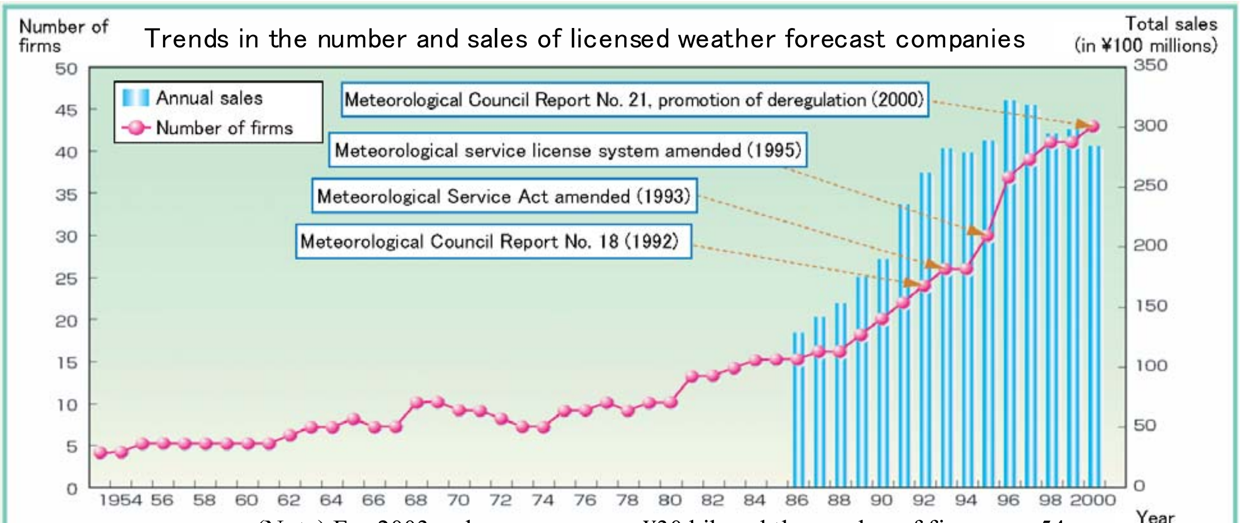
- Sales in private weather business (approx. ¥30 bil, with 54 firms)
- Job creation for weather forecasters (about 900 of them working in the private sector)
- Cost reductions in the power, gas, and new-energy industries through operation optimization (Weather information service firms in the new energy sector expect a ¥5 bil market in Japan and ¥50 bil overseas.)
- Energy cost reductions in buildings and factories
- Cost reductions in the distribution industry, including convenience stores
- Increased agricultural production and less damage to produce from weather disasters
- Cost reductions in the construction industry

<Social impacts>

- Safer transport operation (trains, airplanes, ships, roads)
- More stable and efficient energy supply
- Better preparation for disasters and accidents in nuclear power plants
- Improved urban and national disaster prevention against rainstorms, landslides, etc.

<Impacts on people's lives>

- Human damage mitigation (reduced deaths and injuries caused by weather disasters)
- Improved quality of life through better preparation for weather and well-planned recreational activities
- Greater convenience by allowing stock optimization at convenience stores, etc.



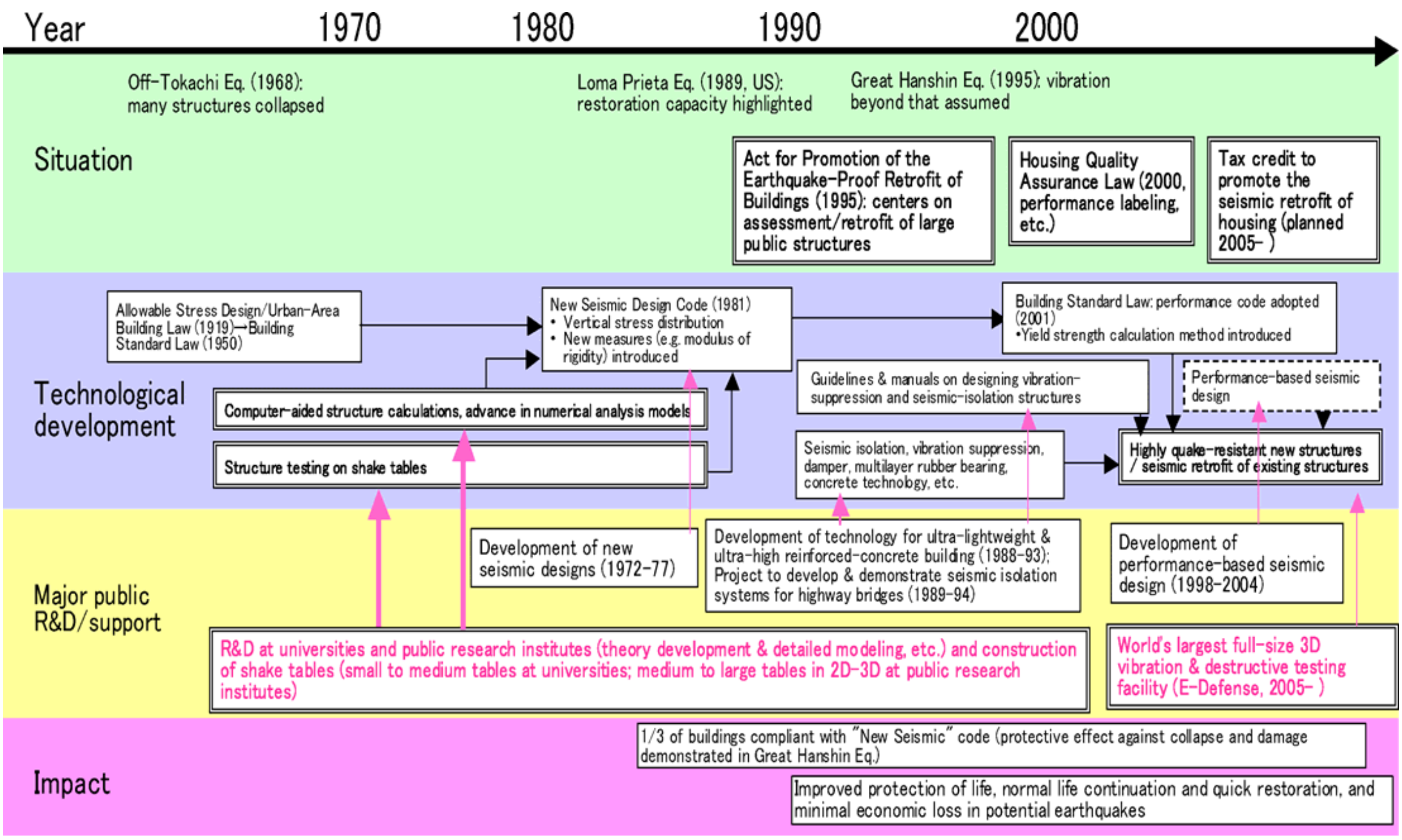
(Note) For 2003, sales were approx. ¥30 bil, and the number of firms was 54.

Source: Meteorological Agency, "Meteorological Service Now: 2002," June 2002

Earthquake motion simulation technology (Social Infrastructure)

<Case study topics>

- Universities, government agencies (public research institutes), and industry have been cooperating to establish technical guidelines and standards. This has led to the widespread application of approved technologies and has consequently generated various impacts.
- Universities have developed theories on numerical analysis simulation and detailed models, while public research institutes have built shake tables for testing. These advances in theory have helped design specifications be introduced and hardware and design methods be set up, resulting in structures with enhanced earthquake resistance.
- This technology centers on protecting structures and highway bridges in Japan from earthquakes and thus has a large social impact (i.e. ensured higher safety and functionality in potential earthquake disasters, and thus improved earthquake resistance in urban and national infrastructures).
- Experts point out issues to be addressed in this area: reduction in the total cost of construction by enabling the use of smaller columns and beams through the application of vibration suppression and seismic isolation technologies; establishment of a legal framework to ensure safety; and provision of more extensive information and economic support for building owners to promote the seismic retrofit of houses and other private structures.



<Economic impacts>

- Reduction in economic loss from earthquakes
- Potential creation of the seismic retrofit market
  - Low quake resistance in 25 mil houses: potential market of ¥10-20 trillion
- Creation of the market/industry for seismic isolation & vibration suppression device manufacturing and installation
  - Approx. 40 device manufacturers and construction firms
  - 400 domestic installations for vibration suppression and 1,000 for seismic isolation
  - Export to the US: seismic isolation bearings for 5 buildings, including a city hall and an animation studio from Firm A; seismic braces for 30 buildings from Firm B
- Creation of a market for ultra-high reinforced-concrete apartments
- Cost reductions in the construction industry through compact designs

<Social impacts>

- Improved earthquake resistance in urban and national infrastructures (ensured higher safety and functionality in potential earthquake disasters)
  - About 1/3 of buildings are compliant with the "New Seismic" code (protective effect against collapse and damage demonstrated in the Great Hanshin Eq.).
  - About 1/10 of new buildings use the latest seismic technologies for seismic isolation and vibration suppression (incl. yield strength design).
  - Seismic isolation technology (for resistance to a seismic force equivalent to the Great Hanshin Eq. (2G)) adopted by about 10% of the existing highway bridges

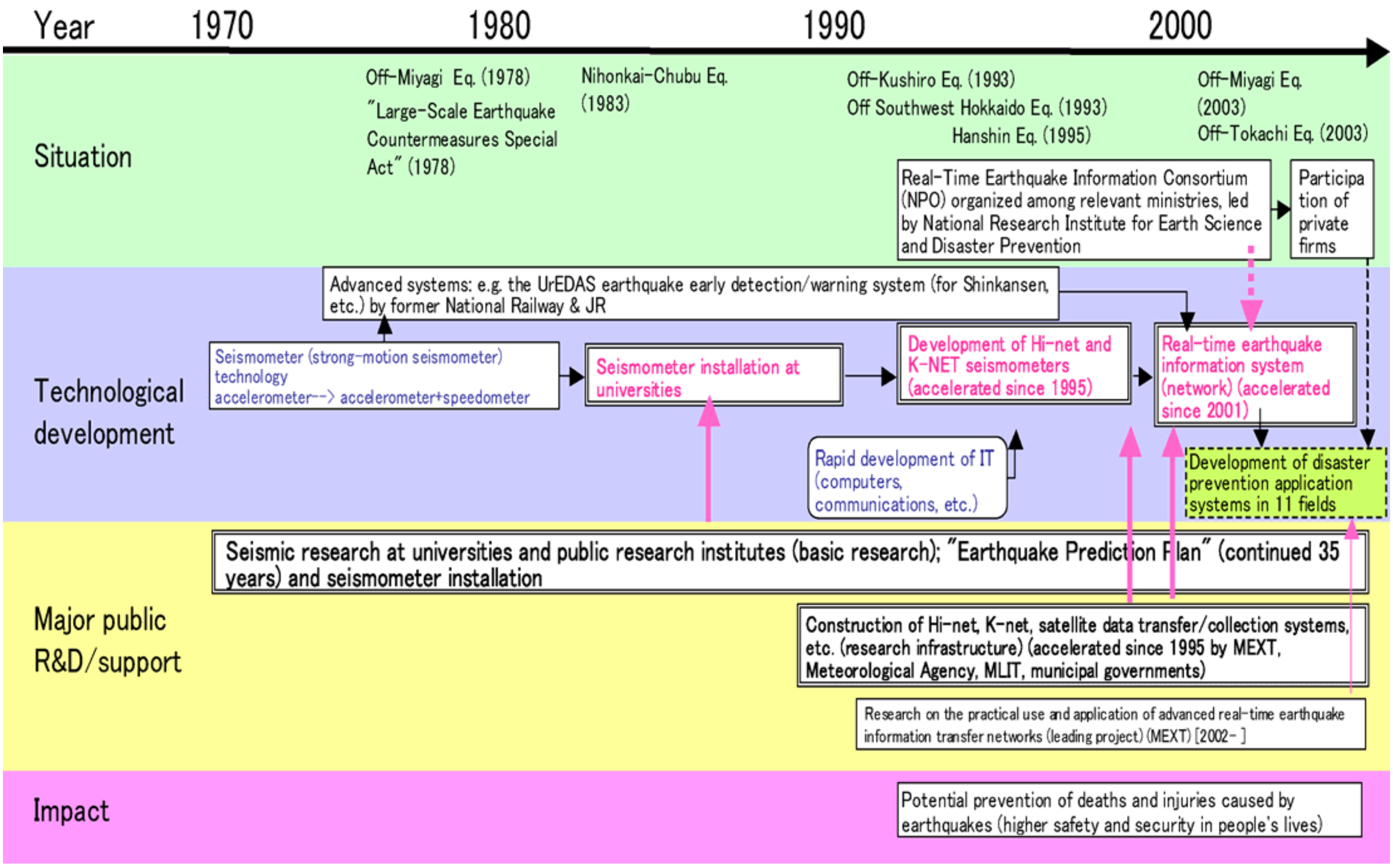
<Impacts on people's lives>

- Improved protection of life in an earthquake
- Capability of maintaining and quickly restoring normal life after an earthquake
- Greater convenience with taller and larger housing and urban facilities

Disaster prevention systems based on a nationwide network for detecting earthquakes (Social Infrastructure)

<Case study topics>

- To serve as an infrastructure for research activities, a nationwide seismic observation network has been constructed using the seismometers installed nationwide as part of the continuous basic research in seismology by universities and public research institutes, combined with those installed in related government and municipal offices.
- Real-time earthquake information systems constructed by public research institutes and universities have started pilot operation, while government and industry are jointly developing systems to apply them to seismic disaster mitigation. There would have been no such advances without public investments.
- These technologies have particularly remarkable impacts on people's lives, for reducing the deaths and injuries caused by earthquakes, and on society, for preventing fires in urban areas and better protecting transport systems from earthquakes.
- To generate these impacts, widespread use of the technologies in society is the key, suggesting the need to address disaster prevention systems based on these technologies as a social infrastructure and to have them first introduced to public service for wider recognition of their benefits and necessity among people.



<Economic impacts>

- Mitigation of damage caused by earthquakes (mainly fires)
  - Estimated ¥30 trillion damage from fires likely in an earthquake equivalent to the Great Kanto Eq.
- Potential sales of equipment that supports the system
  - Initial market value of ¥100 bil, including information appliances
- Potential improvement of operations at property insurance companies

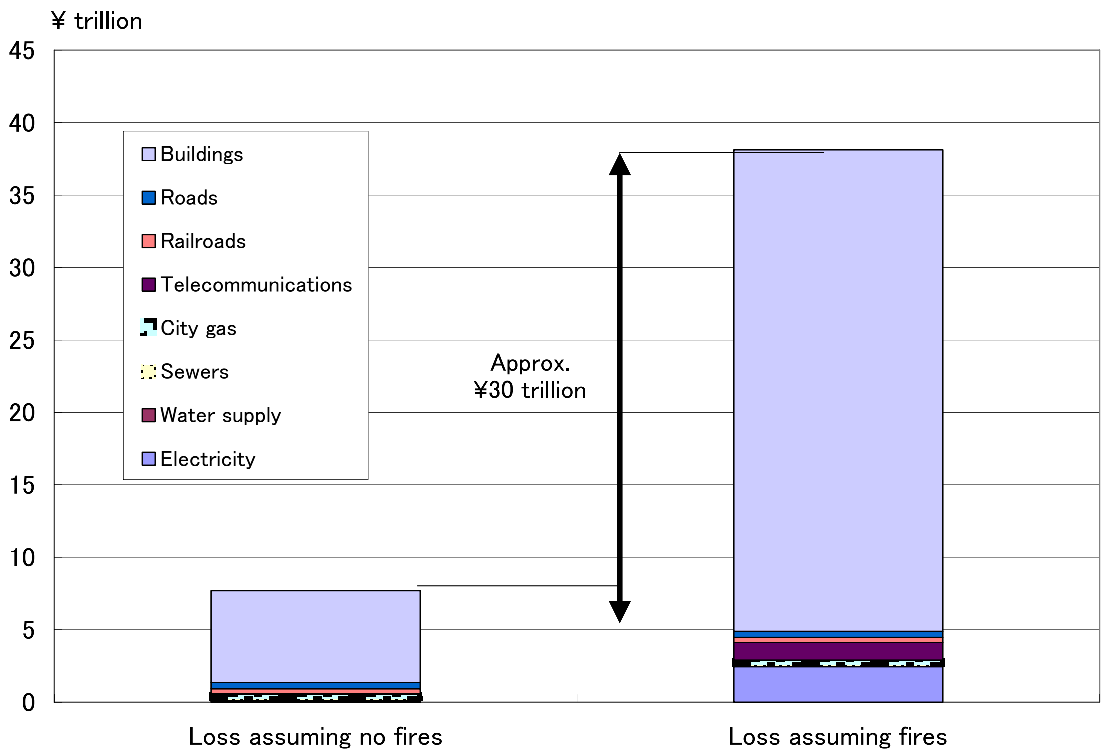
<Social impacts>

- Improved protection against earthquakes in urban cities (fire prevention, early recovery of city functions)
- Improved protection against earthquakes in transport systems (railroads, expressways, etc.)
- Verification of buildings' earthquake resistance (an indirect effect of the introduction of high-precision seismometers)

<Impacts on people's lives>

- Potential improvement of safety and security against earthquakes (prevention of deaths and injuries caused by earthquakes)
- Potential growth of earthquake disaster prevention awareness as a result of training and education using earthquake information systems

Estimated loss from an earthquake

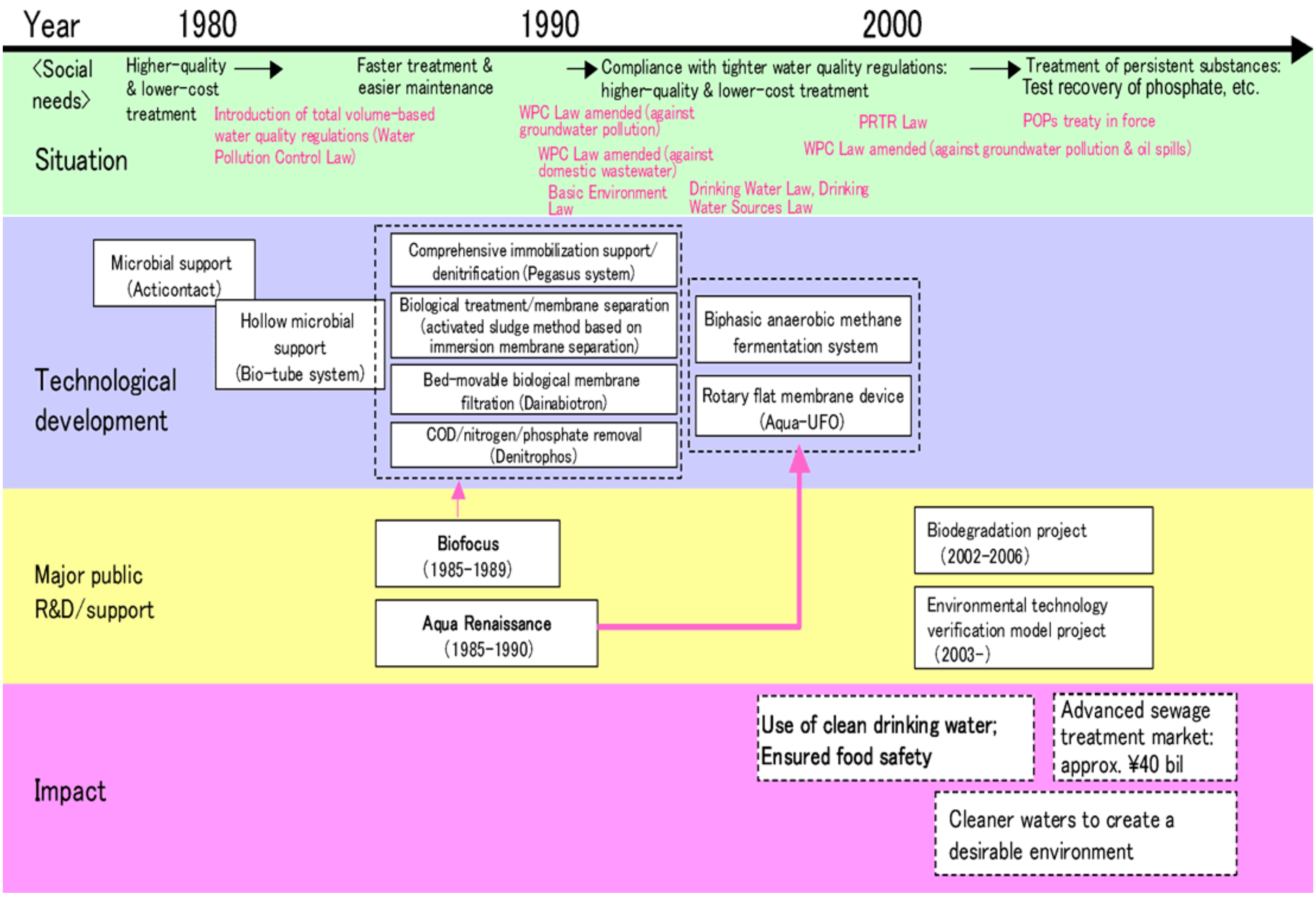


Source: Created by the Mitsubishi Research Institute based on "A Study on the Improvement of Safety and Reliability in Information Systems (March 2001)," The Japan Machinery Federation and Fuji Research Institute Corporation

Efficient biological treatment systems for wastewater containing persistent substances (Social Infrastructure)

<Case study topics>

- Japan's wastewater treatment technology is leading the world.
- Wastewater treatment technologies have advanced as wastewater and other regulations were strengthened. Among them, the development of sewage treatment technology has been driven by public sector procurement in response to the strengthened regulations. (Public R&D and support have contributed to raising the overall standard of Japan's wastewater treatment technologies.)
- The absence of wastewater treatment technology would have a major negative impact because it is "a must."
- The keys are the combination of basic university research with applied business sector research and the systematization of constituent technologies.



<Economic impacts>

- Potential growth of the advanced sewage treatment market (¥40 bil)
- Potential markets for industrial detoxification facilities and domestic on-site wastewater treatment facilities
- Potential price maintenance for agricultural produce as a result of proper wastewater treatment (improper wastewater treatment leads to price declines for produce)

<Social impacts>

- Potential creation of a desirable environment with cleaner waters
- Potential assurance of food safety
- Potential mitigation of a concern over the unknown environmental impacts of unregulated substances
- Potential prevention of groundwater/soil pollution by industrial waste
- Potential installation of temporary toilets for use in disaster situations when sewage treatment is not working
- Potential reduction in the water supply/sewage treatment load as a result of the wide adoption of wastewater reuse
- Potential promotion of recycling resources (nitrogen, phosphate, etc.)
- Potential reduction in electricity required for sewage treatment

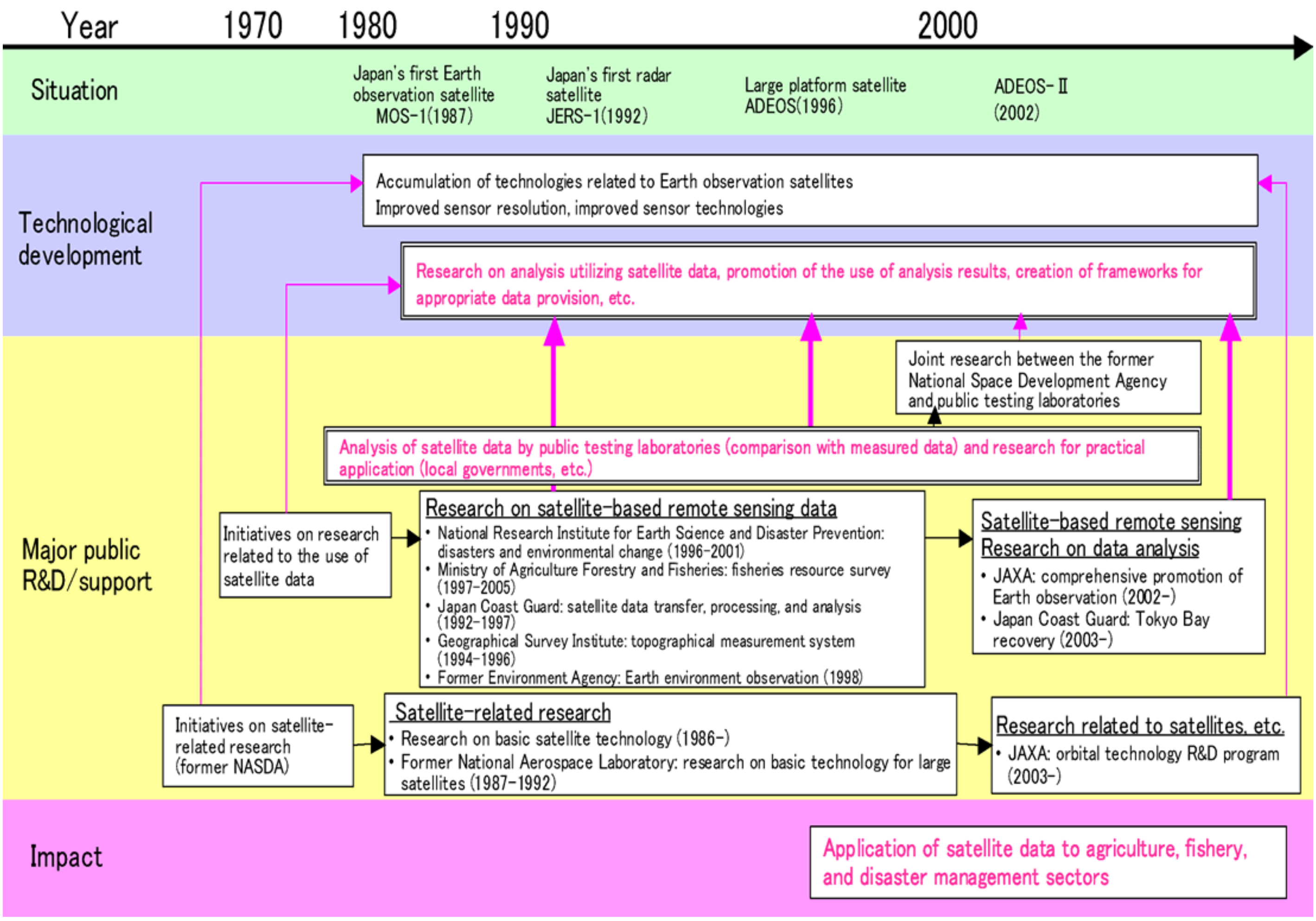
<Impacts on people's lives>

- Potential availability of cleaner drinking water
- Potential reduction in the septic tank sludge treatment load
- Potential reduction in the kitchen garbage disposal load (widespread use of disposers)
- Potential water conservation through the introduction of wastewater reuse
- Potential reduction in the excrement disposal load from home-care patient toilets

Satellite-based remote sensing technology (analysis and application of remote-sensed data; Frontier)

<Case study topics>

- The USA has been leading in the development of satellite-based remote sensing technology. Japan is conducting technical development led by the Japan Aerospace Exploration Agency (JAXA, the former National Space Development Agency of Japan).
- Impact is expanding through joint research (provision of satellite data, technical development related to data analysis, and accumulation of ground-based comparison data) between JAXA and public testing laboratories.
- As technology that forms part of the social infrastructure (through image data applied in a variety of fields), it has a broad impact on the economy, society, and people's lives. It affects numerous sectors, such as agriculture, fisheries, environment, and disaster management.
- To further increase the scope of its use, a system to regularly and continuously obtain necessary satellite data should be constructed.



<Economic impacts>

- Increased value of agricultural production from the production of high unit-price crops accompanying agricultural administration based on satellite data
- Improved fishing efficiency and reduced ship fuel costs through accurate recognition of fishing grounds
- Optimization of fisheries revenue using fishing ground data to make possible appropriate catches that meet market needs
- Accurate grasp of fisheries resources through understanding plankton and so forth, leading to systematic fishing

- Reduction in impact on fisheries by forecasting outbreaks of red or blue tides in closed-system waters

<Social impacts>

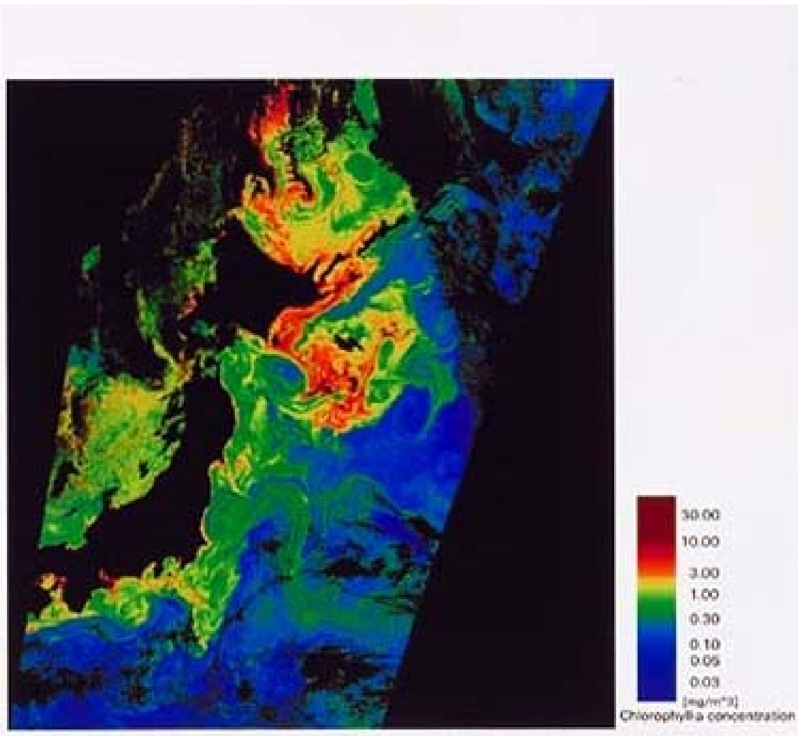
- Provision of data on the extent of damage from earthquakes, wildfires, etc.
- Provision of volcano data in response to predictions of eruption
- Achievement of safe ship navigation by preventing iceberg-related accidents

- Contribution to water quality in closed-system waters
- Implementation of environmental monitoring
- Towards utilization for evaluation of volcanic eruptions and earthquakes before they occur

<Impacts on people's lives>

- Creation and provision of maps through accurate topographical data

- Acquisition of satellite data on the spread of damage in areas where disasters occur
- In the environmental sector, achievement of a comfortable environment through forecasting and protection of water quality



OCTS Chlorophyll-a concentration image [Apr. 26, 1997 1:37 UT/Around Japan]

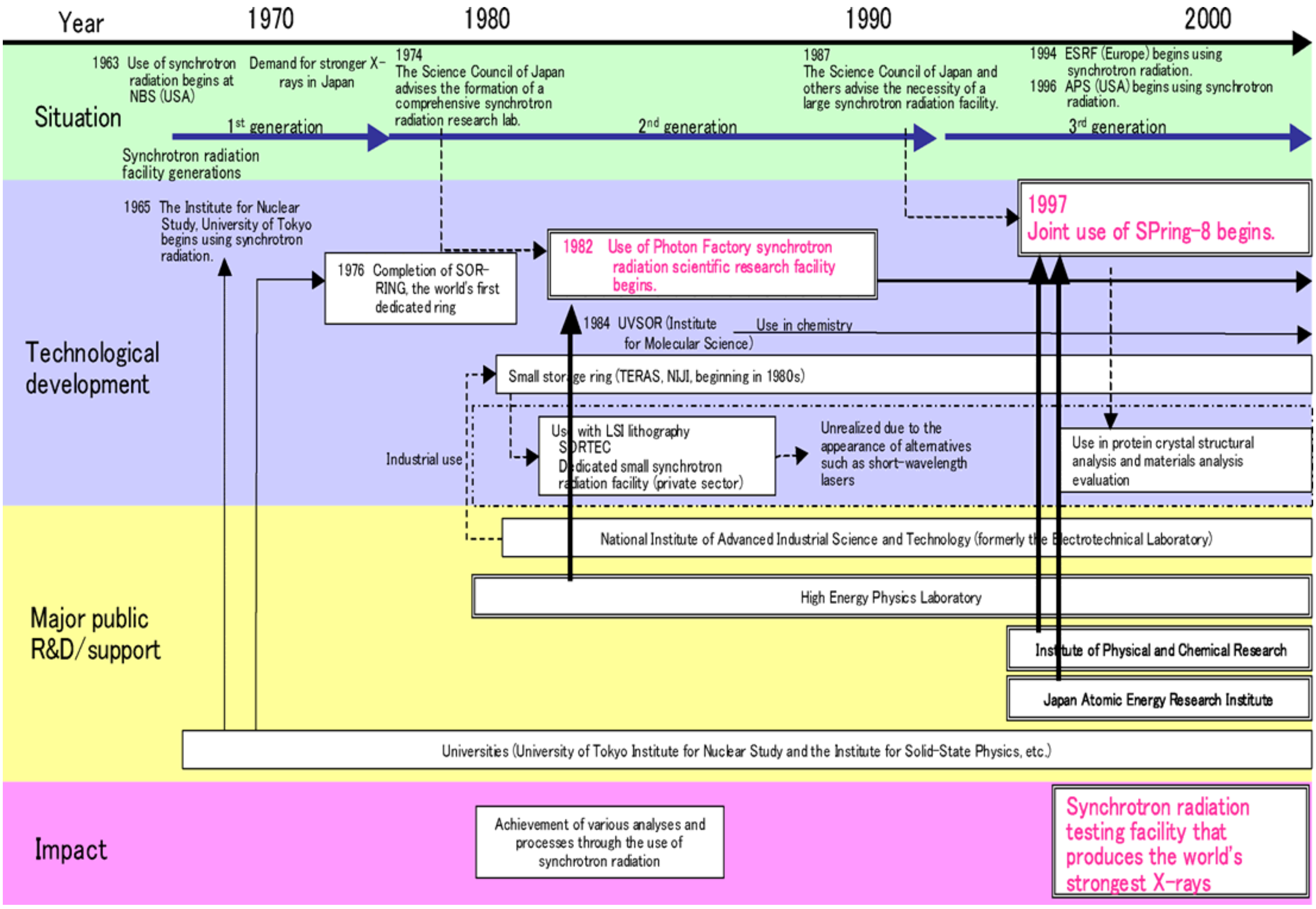
Concentration distribution of chlorophyll a showing an anomalous meandering black tide as seen from the Midori (ADEOS/OCTS) Earth observation satellite
(May 1997)

Source: Courtesy of Japan Aerospace Exploration Agency

Synchrotron radiation technology (Frontier)

<Case study topics>

- Japan's high-performance synchrotron radiation facilities have been upgraded as generations have advanced. SPring-8 is the world's leading synchrotron radiation facility with high-energy 8GeV. The only facilities of similar scale in the world are a facility in the USA and a facility in Europe.
- University and public R&D and support have contributed to continuous upgrades of the facility since the 1960s.
- The synchrotron radiation facility provides R&D infrastructure that aids scientific and technical research. In addition, the facility is also used by industry, and joint research with other countries is also conducted. Impacts include improved product performance and reduced costs in sectors such as electronics and materials. In the future, impact on the drug development sector is also expected.



<Economic impacts>

- Increased sales through new materials
  - Contributed to the installation of exhaust gas media in cars by elucidating the theoretical reasons for high performance
  - Contributed to longer lifecycles for lithium secondary batteries by elucidating deterioration in charging and discharge
- Creation of new product functions through microfabrication
  - Compound piezoelectric vibrators for ultrasound examinations with ultrasound endoscopes
  - MEMS and LSI processing
- Advertising effectiveness using imaging
  - Photography of the fibers of studless tires being struck by water was used in advertising.
- Sales of synchrotron radiation equipment
  - A small amount of compact synchrotron radiation equipment has been sold for R&D on microfabrication, etc.
- Potential development of new drugs through the elucidation of protein structures

<Social impacts>

- Elucidation of an archaeological mystery (a mirror found in a burial mound)
- Enhancement of Japan's position in international research through possession of the world's highest-performance facility
- Reduced environmental impact through new materials

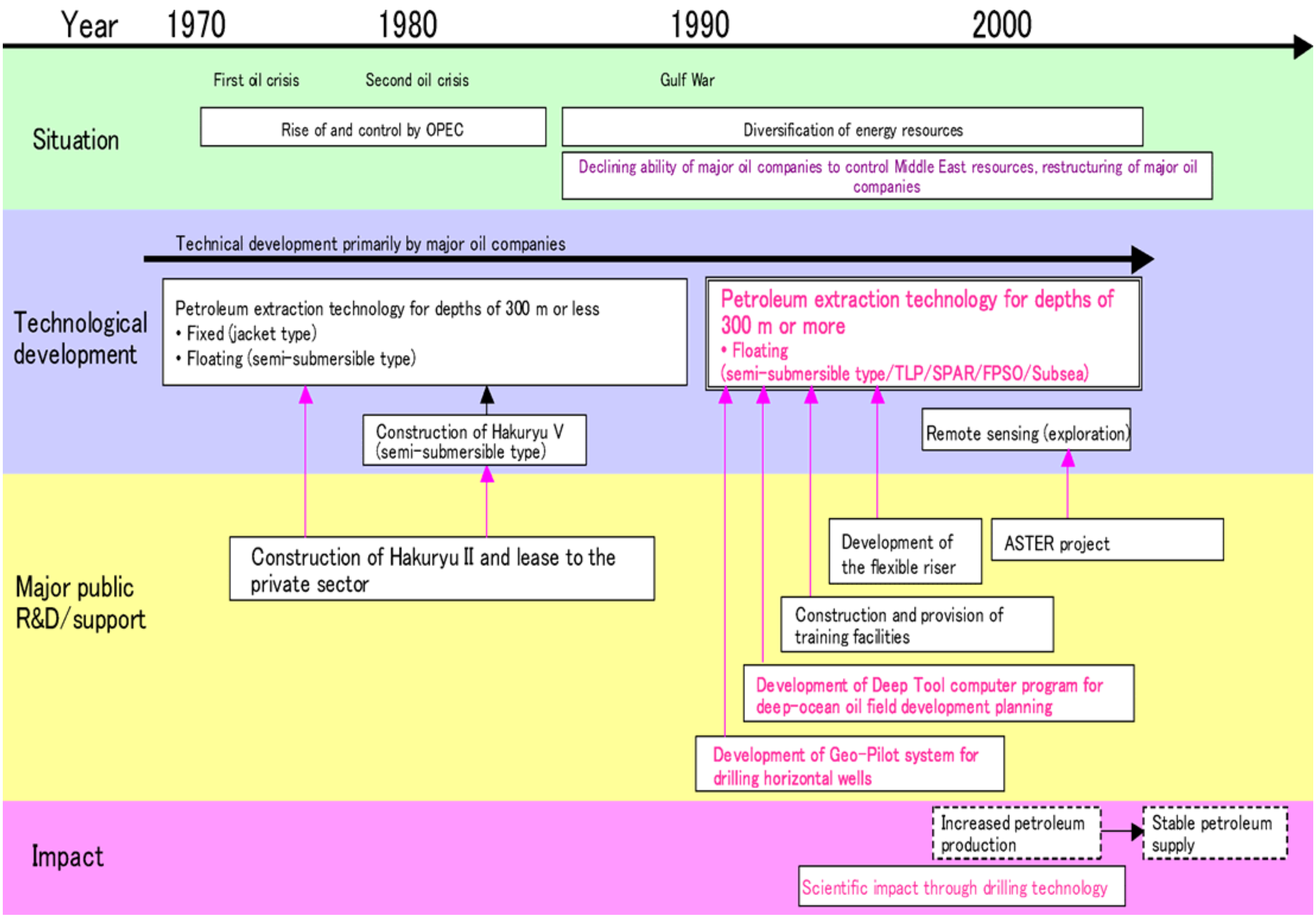
<Impacts on people’s lives>

- Use in crime investigation
- Potential for disease cure through new drugs
- Potential improvement of diagnostic technology such as that used for coronary arteries

Offshore oil rig technology (Frontier)

<Case study topics>

- Marine oil development is conducted primarily using international petroleum capital that is active on a global scale. In Japan, it has been conducted mainly by the Japan Oil, Gas and Metals National Corporation (JOGMEC, formerly the Japan National Oil Corporation), with particular emphasis on the development of drilling technology.
- Drilling technology developed by the private sector is aiding public research institution scientific and technical research, such as the scientific drillship *Chikyu* and the scientific drilling research at Mt. Unzen-Fugen.
- The economic impact will be greatest, with expected increases in investment in petroleum supply, which is fundamental to economic activity, and in petroleum exploration and development.
- Securing the ability to conduct marine oil development on its own is important for the stability of Japan's energy supply, and policy support enabling development in the East China Sea is necessary. In addition, public financing and government funding of infrastructure and of exploration and other basic surveying preparation are needed.



<Economic impacts>

- Potential increase in production of petroleum as a foundation of economic activity
- Potential increase in investment in petroleum exploration and development

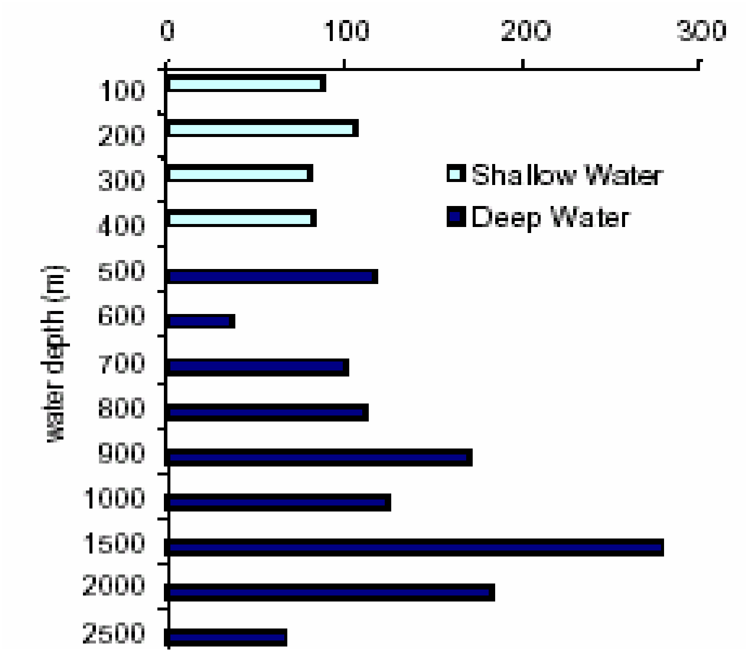
<Social impacts>

- Potential extension of life of petroleum as an energy source

<Impacts on people's lives>

- Potential stable supply of petroleum
- Potential stabilization of oil prices

Distribution of oil reserves by water depth

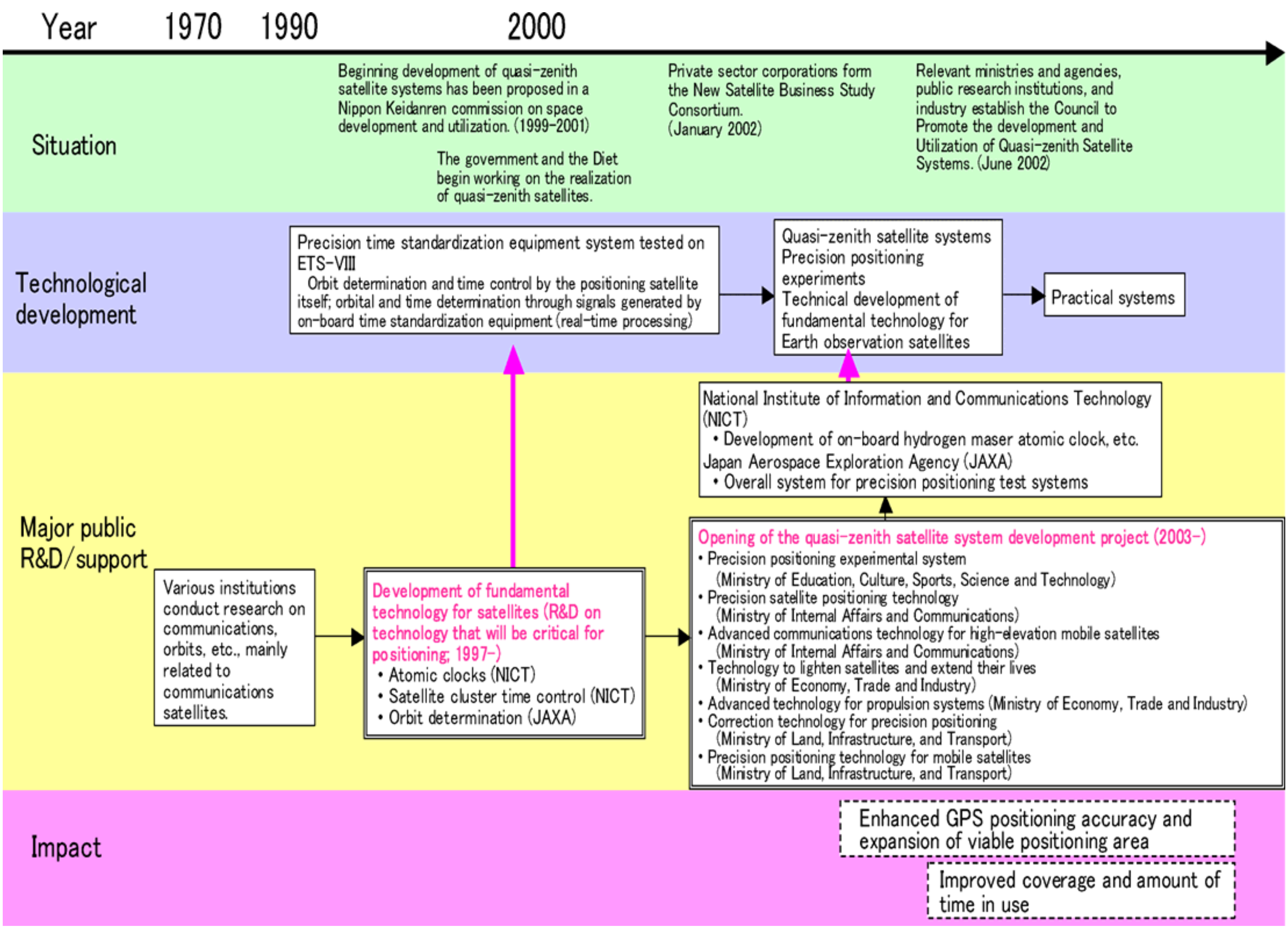


Source: http://www.dw-1.com, "The World Deep Water Market"

Quasi-zenith satellite systems (Frontier)

<Case study topics>

- The importance of positioning technology as a social infrastructure technology has been recognized in Japan. Intensive initiatives on quasi-zenith satellite systems are being conducted as part of this recognition.
- The division of labor regarding positioning has been government conducting R&D and verification, with the private sector performing application. (Research and development related to positioning has steadily advanced with public R&D institutions leading the way.)
- Issues regarding promotion are the advancement of systems integrating R&D and verification research with commercialization, systems in which science and technology policy and business influence each other, and a lack of clarity regarding which entities have jurisdiction over positioning as infrastructure.



<Economic impacts>

- Potential realization of impact through improved GPS positioning accuracy and viable positioning area
  - Improved transport efficiency (easing of traffic jams through navigation equipment, reduction in human travel time, distribution benefits)
- Potential realization of impact through improved coverage and amount of time in use

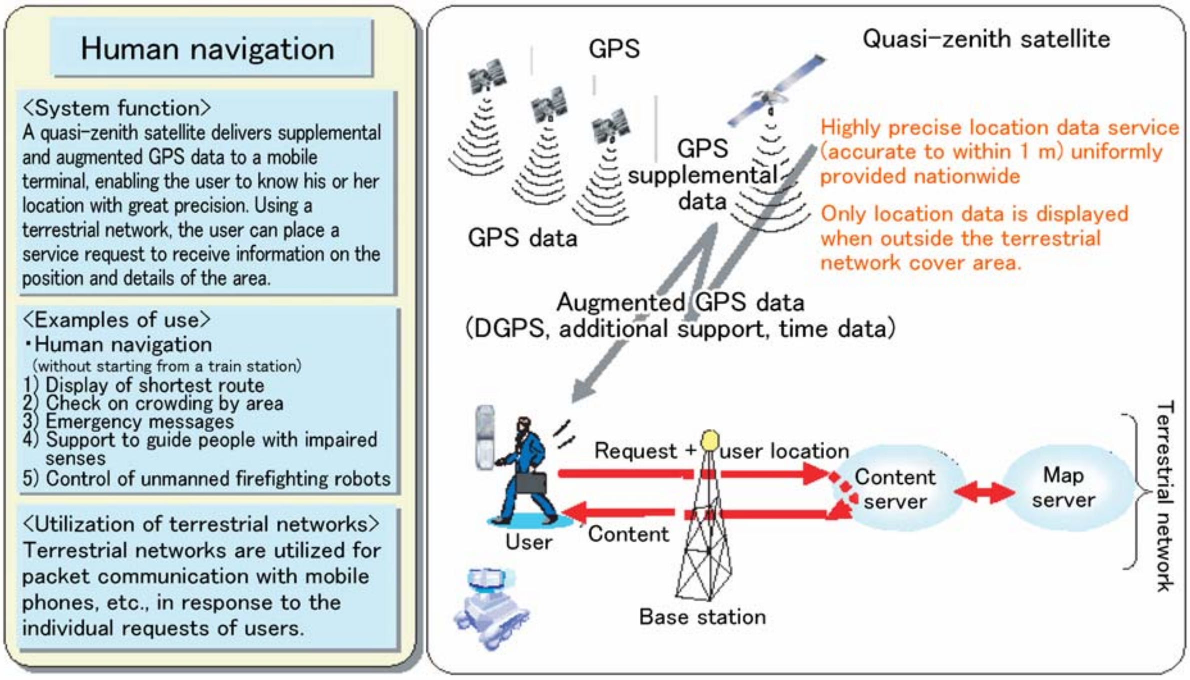
<Social impacts>

- Potential realization of positioning in urban and rural areas
- Potential improvement of safety and peace of mind by shortening the response time via improved ability to respond to emergency messages (quick, accurate verification of location, etc.)

<Impacts on people's lives>

- Potential realization of the ability to determine the whereabouts of children, elderly people, etc., through "human navigation"
- Potential realization of a safe society with peace of mind through emergency contact and messages

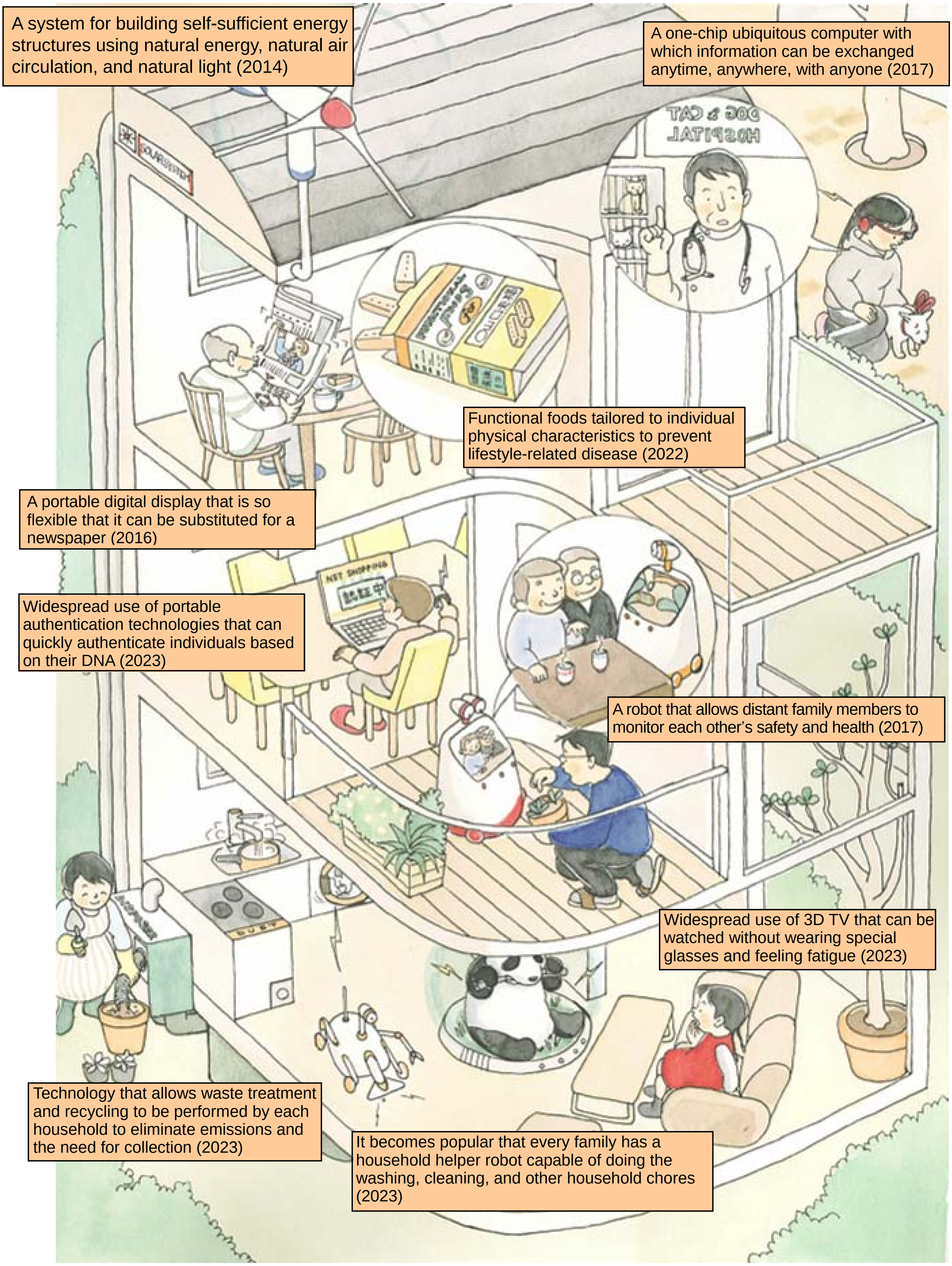
Example of application (human navigation)



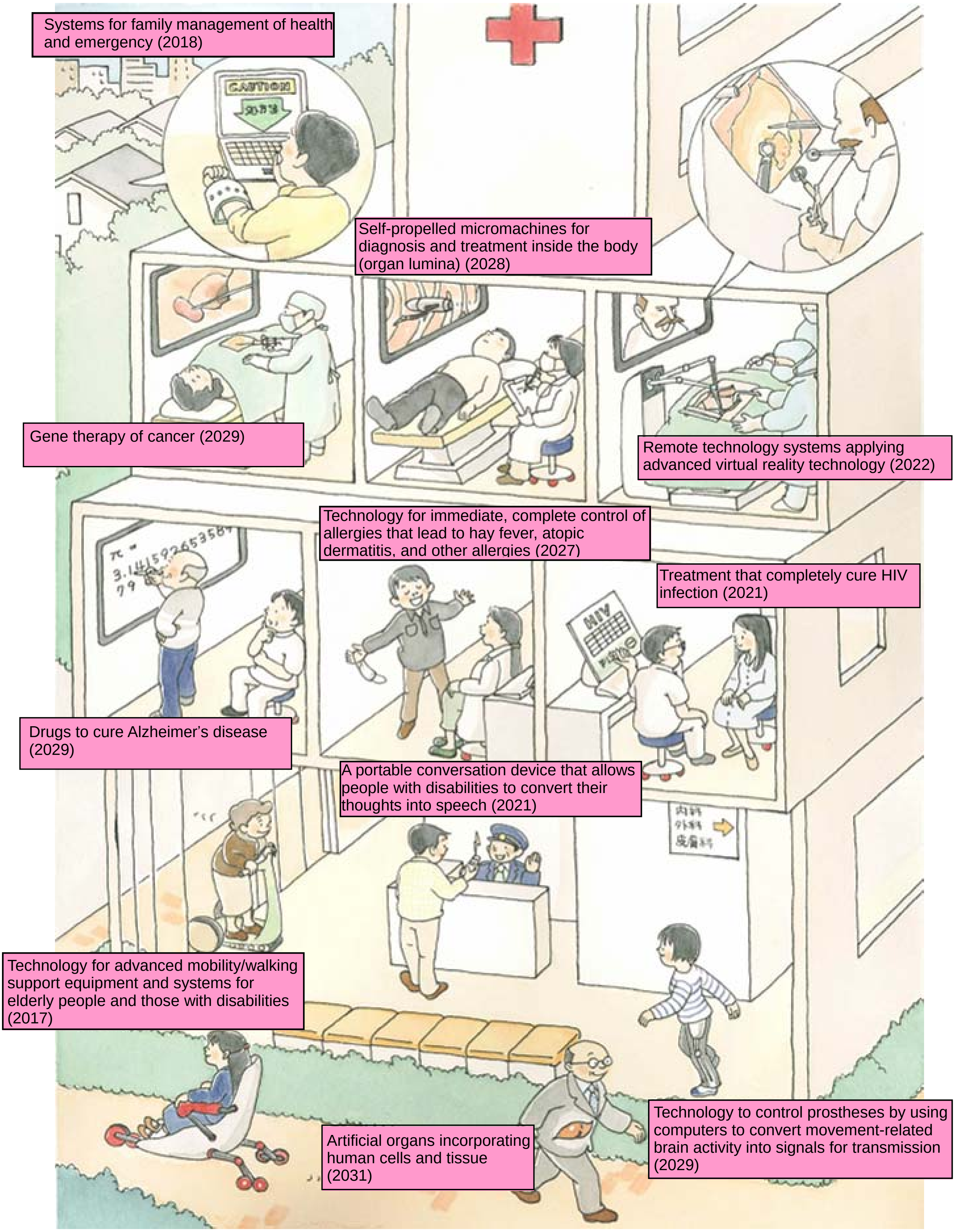
Source: Materials of the (2nd) Study Panel on Positioning Sector, Commission on Space development and Utilization, Council for Science and Technology Policy

Household and Life

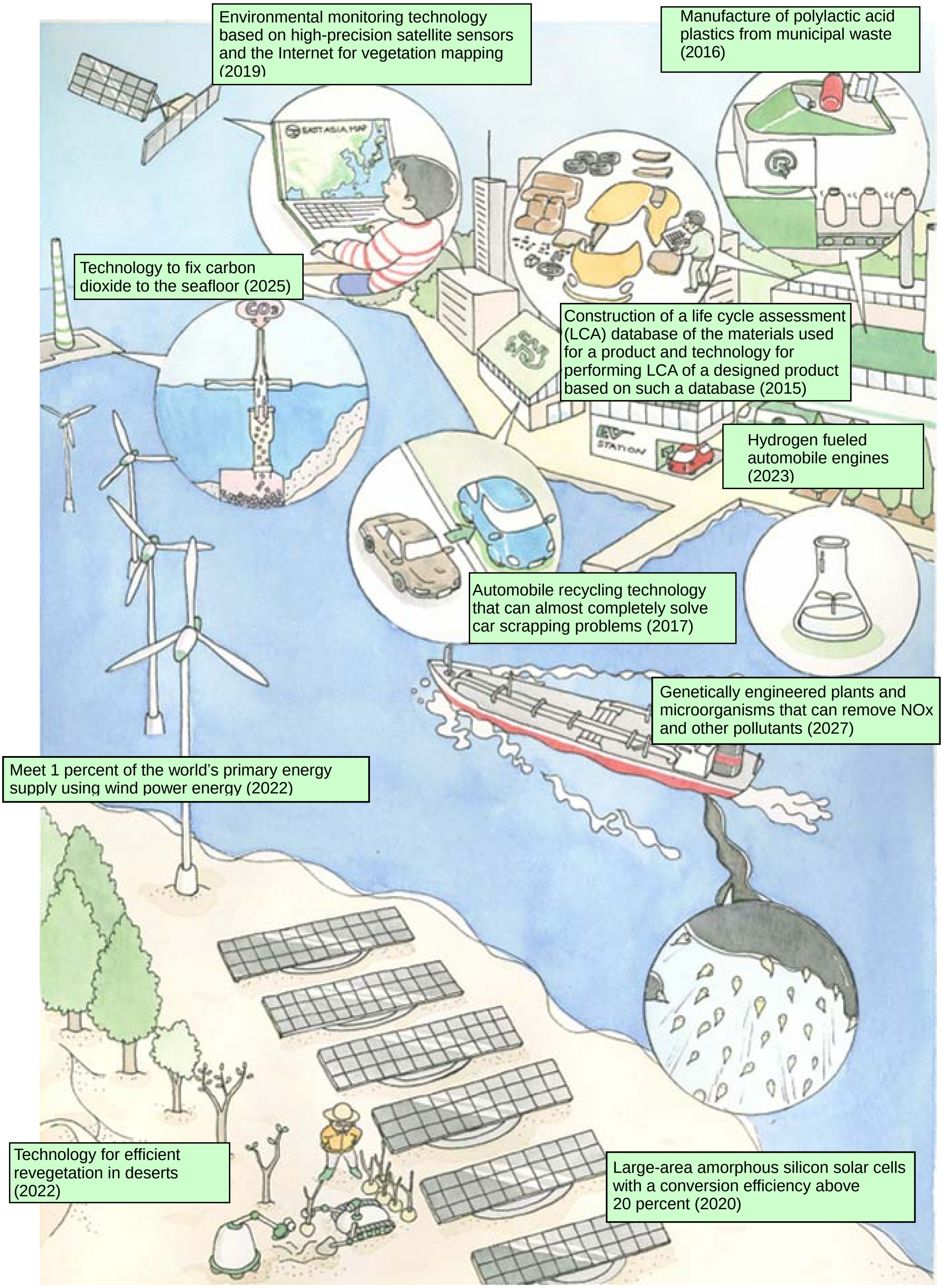
Reference Materials 2　Holistic foresight analysis with illustrations



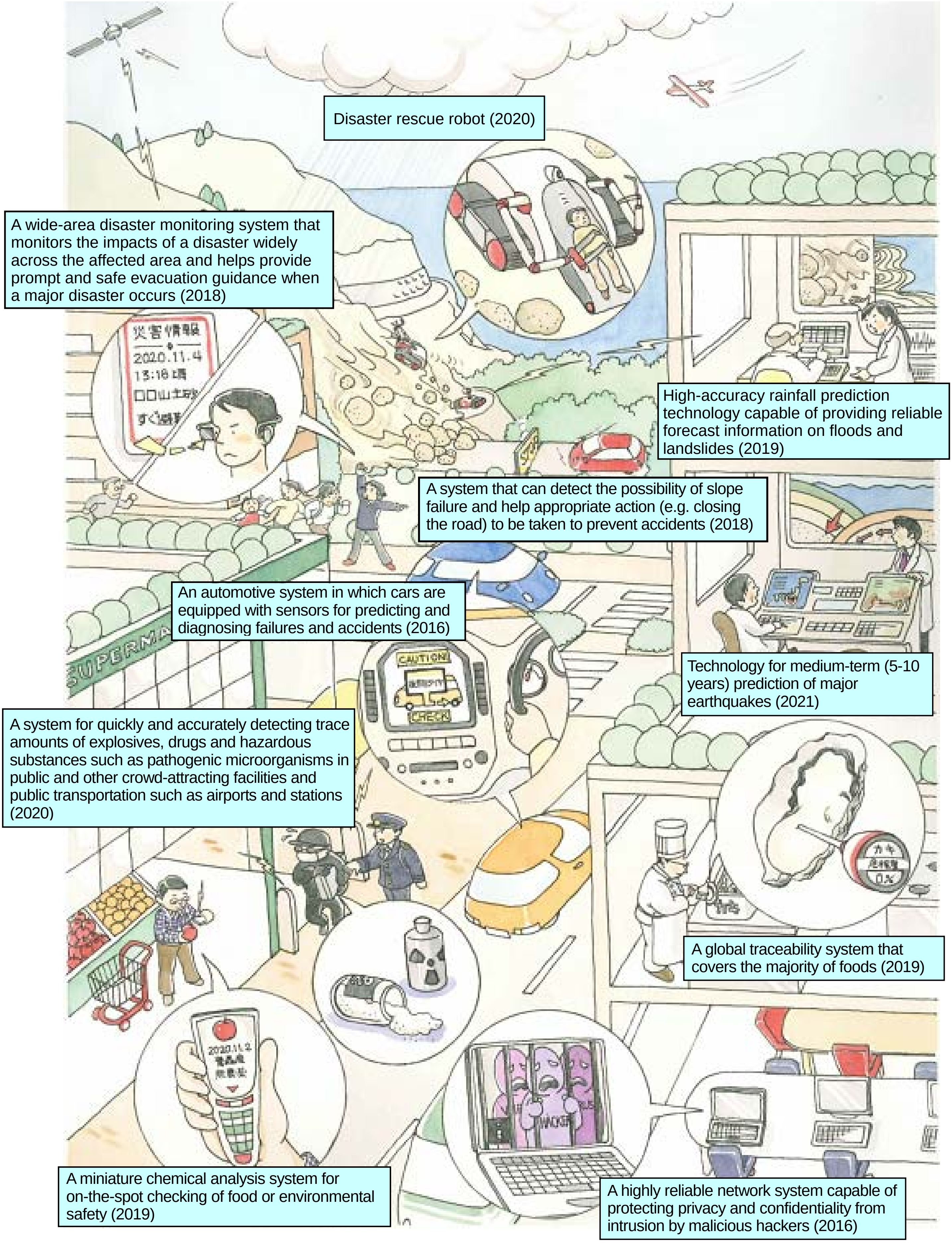
Medical care and Welfare



Environment and Energy



Disaster Prevention and Safety



Reference Materials 3: The 100 most important topics

	Level of Importance	Topic	Field	Category
1	98	52: A risk management system that utilizes disaster observation satellites, communications satellites, GPS, unmanned aircraft, and so on to observe disasters, understand situations after disasters occur, and respond swiftly (send the necessary information where it is needed).	Frontier	Disaster
2	98	58: Technology to forecast the timing and scale of volcanic eruptions by observing and assessing in real time magma conditions inside volcanoes that are likely to erupt.	Frontier	Disaster
3	98	57: Technology to precisely forecast the imminence (place and time period) of earthquakes (plate boundary earthquakes and inland earthquakes) of magnitude 7 or greater that are likely to cause damage, helping mitigate human disasters.	Frontier	Disaster
4	96	60: Technology to evenly and densely place comprehensive earthquake/crust change observation equipment in major cities, mountainous areas, continental shelves, and so on in order to predict earthquakes.	Frontier	Disaster
5	96	59: Formation of a worldwide consensus, including developing countries, on international regulations on the output of carbon dioxide and other greenhouse gases.	Frontier	Environment
6	95	61: Elucidation of the mechanisms of rainfall, snow accumulation, torrential rain, and so on.	Frontier	Disaster
7	95	15: Technology for safely and efficiently demolishing and removing commercial nuclear power plants after decommissioning.	Social Infrastructure	Energy
8	95	45: Technology that makes it possible to measure regional stress fields in the Earth's crust on a region-wide scale in earthquake zones.	Frontier	Disaster
9	95	51: High-accuracy rainfall prediction technology capable of providing reliable forecast information on floods and landslides.	Social Infrastructure	Disaster
10	95	27: Widespread use of production processes using low CO_2 emitting energy sources such as non-fossil energy (wind, geothermal, photovoltaic, solar heat, waste heat, etc.), cogeneration systems, stationary fuel-cell systems etc.	Manufacturing	Energy
11	95	59: Implementation of a new elementary and secondary education scheme that emphasizes science and mathematics to make Japan a world leader in science and technology.	Manufacturing	Others
12	94	47: A disaster prevention system in which the occurrence of an earthquake is reported through a nation-wide earthquake detection network to the areas more than 50 km away from the epicenter before the seismic waves reach there.	Social Infrastructure	Disaster
13	94	23: Forecasting technology for year-to-year variation of climate system.	Frontier	Environment
14	94	45: Technology for forecasting abnormal weather disasters resulting from climate change.	Environment	Disaster
15	94	56: A technical education program that ensures the handing down of expertise and craftsmanship by establishing technology for converting implicit knowledge on manufacturing and manufacturing technique (e.g. basic techniques and skills, know-how, experience) into explicit knowledge.	Manufacturing	Others
16	93	55: Technology to assess the safety of geologic disposal of high-level radioactive waste.	Frontier	Energy
17	93	53: An integrated national land management and use system (using Earth observation satellite data, GPS, communications satellites, GIS, and so on to digitize land use, ocean data, maps, etc.) that covers all of Japan, including the sea.	Frontier	Others
18	93	48: Technology for medium-term (5-10 years) prediction of major earthquakes (magnitude 8 or greater) by the analysis of crustal strain distribution and the records of past earthquakes.	Social Infrastructure	Disaster
19	93	19: Technology for recycling, rather than demolishing, deteriorated infrastructure and technology for maintaining and managing infrastructure to extend its life.	Social Infrastructure	Others
20	93	59: Technology for formulating an effective response strategy in the event of a major disaster, using systems for efficiently assessing the damage and predicting its spread.	Social Infrastructure	Disaster
21	93	58: Promotion of human resources mobility that is promoted across industry, academia, and government, leading to a greater number of joint or collaboration projects, and consequently bringing about innovations in manufacturing technology.	Manufacturing	Others
22	93	68: A crustal movement sensor that enables prediction of an earthquake a few minutes before it occurs.	Electronics	Disaster
23	93	34: Technology for predicting and assessing global depletion of the resources that are used in Japan.	Environment	Others

	Level of Importance	Topic	Field	Category
24	93	36: A highly reliable network system capable of protecting the privacy and secrecy of individuals and groups from intrusion by malicious hackers.	Information and Communications	Information
25	93	33: Risk management technology for harmful chemicals (endocrine disruptors, heavy metals, etc.) based on elucidation of their long-term impacts on human beings, crops, livestock, and ecosystems.	Agriculture, Forestry, Fisheries, and Foods	Life
26	93	50: Technology for accurately simulating the behavior of structures and the ground motion in response to a strong earthquake.	Social Infrastructure	Disaster
27	92	12: Technology for earthquake-resistance assessment and anti-seismic reinforcement to protect high-rise buildings and tanks from ocean-trench earthquakes that generate long-period seismic waves.	Social Infrastructure	Disaster
28	92	03: Elucidation of the pathogenesis of atherosclerosis.	Health, Medical care, and Welfare	Life
29	92	54: A major reduction in human suffering from river- and road-related disasters through advances in technology for short-term rainfall prediction and rainwater management (transport, storage, treatment) and in systems for warning, evacuation, and regulation.	Social Infrastructure	Disaster
30	92	40: Energy consumption per capita in Japan reduces by half.	Environment	Energy
31	92	35: Generalized technology, extended from total building management systems and home security systems, which is coupled with seismic detection systems so that the safety of human life can be ensured before seismic waves arrive, in an earthquake whose epicenter is distant.	Information and Communications	Disaster
32	91	28: Manufacturers' responsibility for collecting and disposing of discarded products is defined by law, and recycling systems in which more than 90% of used material is thermal- or material-recycled become widespread. Design for recycle/disassemble technology, easy assemble & disassemble production technology , selective collection system technology etc. enable it to achieve.	Manufacturing	Environment
33	91	55: Technology for supporting the restoration of the functions of an urban city that has been severely and extensively paralyzed by a large-scale power failure or a long-duration break in the water supply.	Social Infrastructure	Disaster
34	91	17: Super high precision process technology (for processing, analyzing, testing, and in-situ monitoring) at the angstrom level achieved through advances in beam technology (ion, electron, laser, etc.), machine control technology, and sensor technology.	Manufacturing	Others
35	91	63: A system that allows people to recognize and understand the disaster risk potential associated with natural phenomena (e.g. earthquakes, volcanic eruption, flood) and man-made accidents, so that they can construct disaster mitigation measures in cooperation with the government.	Social Infrastructure	Disaster
36	90	25: An "inverse" manufacturing system that combines "arterial" (production) and "venous" (disposal) activities in which the production system (design→produce→use→scrap) and the resources recycling system (collect→disassemble/sort→reuse→produce) are integrated.	Manufacturing	Environment
37	90	24: Earth environment change forecasting technology with a scale of several decades by Earth system models that handle the composition of the atmosphere and oceans, ecosystems, and the material cycles within them.	Frontier	Environment
38	90	44: Technology for minimizing the impacts of and restoring damage from large-scale industrial accidents.	Environment	Disaster
39	90	36: A social environment that encourages women to balance work and marriage, childbearing, and childrearing (e.g. 30% of listed companies set up day care centers) becomes a reality in Japan to promote the utilization of female human resources.	Industrial Infrastructure	Others
40	90	39: In Japan, for easier job changes, corporate pensions become “portable” so that the pension funds deposited under the pension program of the previous employer can be transferred to the new employer’s pension program when a worker changes jobs.	Industrial Infrastructure	Others
41	90	14: Production processing technology capable of controlling dimensions and shapes with single nanometer precision.	Nanotechnology and Materials	Others
42	90	04: Geologic disposal technology for high-level radioactive waste.	Energy and Resources	Energy
43	90	42: Introduction of an automobile tax based on CO_2 emissions.	Environment	Environment
44	90	34: Formation of positive understanding and consensus on genetically engineered plants and foods.	Agriculture, Forestry, Fisheries, and Foods	Life
45	90	13: Base-isolation and vibration-control devices that dramatically improve buildings’ safety and property protection.	Social Infrastructure	Disaster

	Level of Importance	Topic	Field	Category
46	90	14: Clean fuel (other than hydrogen) that does not emit particulates, NOx, etc.	Environment	Environment
47	89	02: Therapeutic application of the achievements on the pathophysiology of cancerization.	Health, Medical care, and Welfare	Life
48	89	58: Construction of effective information and social systems that help improve the capacity of community-based activities for disaster prevention and welfare.	Social Infrastructure	Others
49	89	12: Effective technology to prevent cancer metastasis.	Life Science	Life
50	89	18: Packaging technology at the few micron level for achieving super-small wearable equipment for use anywhere, anytime by a combination of optoelectronics, microelectronics, and micromachinery.	Manufacturing	Information
51	89	84: Automobile recycling technology that can almost completely solve car scrapping problems.	Social Infrastructure	Environment
52	89	32: Prevention, diagnosis, and treatment technology through the complete elucidation of BSE onset.	Agriculture, Forestry, Fisheries, and Foods	Life
53	89	87: Emissions treatment technology that allows all land and marine transport systems to satisfy the current automobile emissions limits (current limits for gasoline passenger vehicles in g/km: 1.27(0.67) for carbon monoxide; 0.17(0.08) for hydrocarbon; 0.17(0.08) for nitrogen oxides; in 10/15 mode tests, max. values per car, average of emissions per type of vehicle in parentheses).	Social Infrastructure	Environment
54	88	10: Technology for immediate, complete control of allergies based on elucidation of the immunoregulatory mechanisms and environmental factors that lead to hay fever, atopic dermatitis, and other allergies.	Life Science	Life
55	88	71: Methane hydrate mining utilization technology.	Frontier	Energy
56	88	38: Large-area amorphous silicon solar cells with a conversion efficiency above 20 percent.	Nanotechnology and Materials	Energy
57	88	15: Achievement of low costs agriculture and forestry and rural communities oriented towards zero emissions by using local agricultural and forestry resources, organic waste, and other sources of biomass energy.	Agriculture, Forestry, Fisheries, and Foods	Environment
58	88	22: Treatment for preventing the progression of Alzheimer's disease.	Life Science	Life
59	88	86: Fuel cell-powered transport systems (automobiles, ships, etc.)	Social Infrastructure	Energy
60	88	39: Technology to detect intrusions and viruses on the Internet backbone.	Information and Communications	Information
61	88	09: A wide-area disaster monitoring system that monitors, when a major disaster occurs, the impacts of the disaster widely across the affected area, by using satellite images and the analysis by laser radar equipment, to help provide prompt and safe evacuation guidance.	Social Technology	Disaster
62	88	13: A small-scale semiconductor fabrication plant that supports high-mix, low-volume production and allows a two orders of magnitude reduction in capital investment from the current levels.	Electronics	Information
63	88	55: Hydrogen production processes through photocatalytic decomposition of water with sunlight.	Nanotechnology and Materials	Environment
64	87	09: Discovery of the seeds of new practical technologies for the safe disposal of CO_2 with long-term stability.	Environment	Environment
65	87	01: Elucidation of the emission, absorption and fixation mechanism of greenhouse gases in a natural system as a result of climate change.	Environment	Environment
66	87	65: Biochip diagnostic systems that can accurately diagnose onset risk for cancer and other serious diseases and supply information for setting treatment within a very short time.	Nanotechnology and Materials	Life
67	87	07: An advanced virtual manufacturing system and its operation system to support optimization, efficiency improvement, license application, and other processes of production activities such as design, development, manufacture, operation, maintenance, and disposal.	Manufacturing	Others
68	87	02: A support system that explicitly shows experts' decision-making process, skills, and know-how for reuse and leaning by non-experts.	Manufacturing	Others
69	87	02: Technology to estimate long-term changes in resource amounts in order to appropriately manage true sardines and other important fisheries resources.	Agriculture, Forestry, Fisheries, and Foods	Others

	Level of Importance	Topic	Field	Category
70	87	22: Manufacturing technology for achieving innovative functions and properties through nanoscale manipulation and control of atoms and molecules or through control of materials structure or arrangement.	Manufacturing	Others
71	86	17: Almost all indoor lighting is replaced by semiconductor light sources.	Electronics	Information
72	86	47: Recycle systems for the production, distribution, and consumption of recovered materials and products based on new economic criteria/standards.	Energy and Resources	Environment
73	86	40: Capability of tracing back the source address of suspect packet in the Internet to detect intrusions.	Information and Communications	Information
74	86	10: A system for quickly and accurately detecting trace amounts of explosives, drugs, radioactive substances, and pathogenic microorganisms in public and other crowd-attracting facilities and public transportation such as airports, seaports, and railroads.	Social Technology	Others
75	86	06: A 100M-gate LSI whose logical function changes in real time.	Electronics	Information
76	86	01:Elucidation of the pathophysiology of cancer metastasis.	Health, Medical care, and Welfare	Life
77	86	51: Over half of Japan’s listed companies adopt management schemes that emphasize corporate social responsibility as the fundamental business policy.	Industrial Infrastructure	Others
78	86	07: Forecasts of diseases and disasters through advanced modeling and simulation technologies for large-scale ecological, environmental, or other systems.	Information and Communications	Information
79	85	17: Technology for efficiently reinforcing existing structures by assessing their structural soundness through nondestructive inspection.	Social Infrastructure	Others
80	85	51: Systems for early warning and prediction by experts (e.g. early detection of human/livestock infection and prediction of its impacts, early warning of the environmental effects of an accident or disaster) are established, enabling early detection and impact assessment of the problems that should be solved by science and technology.	Social Technology	Life Disaster
81	85	57: Widespread adoption of earthquake risk management as a result of the establishment of the technique for long-term estimation of the probability of earthquake occurrence.	Social Infrastructure	Disaster
82	85	15: Widespread home use of 10-Gbps access networks.	Electronics	Information
83	85	14: A reconfigurable manufacturing system in which production volume can be quickly and flexibly adjusted to each of many different products.	Manufacturing	Others
84	85	06: Japan's original manufacturing software for supporting autonomous adaptability, large variety small volume production, and short delivery time.	Manufacturing	Information
85	85	05: A microprocessor LSI with a clock frequency of 50 GHz or higher.	Electronics	Information
86	85	30: Prophylactic technologies to overcome hospital-acquired infection.	Health, Medical care, and Welfare	Life
87	85	50: Meso-scale (about 10-km mesh) precipitation simulation.	Environment	Environment
88	85	28: High-precision Earth environment models with about 100–500 m resolution for a short-range forecasting that can distinguish buildings and predict air pollution, and urban flooding.	Frontier	Environment
89	84	08: Digital mock-up technology with which, for the aim of shortening the design and R&D periods and reinforcing product competitiveness, all product evaluation parameters including strength, performance, reliability, environment-friendliness, and productivity can be assessed.	Manufacturing	Information
90	84	54: Integrated usage and conservation technology for entire bays such as Tokyo Bay and Osaka Bay that are densely used.	Frontier	Environment
91	84	13: Three-dimensional packing technology at the nanometer scale.	Nanotechnology and Materials	Others
92	84	23: Elucidation of the etiology of manic-depressive psychosis at the molecular level.	Life Science	Life
93	84	33: Technology to detect a cancerous tissue of the diameter smaller than 1 mm presenting anywhere in the body.	Life Science	Life

	Level of Importance	Topic	Field	Category
94	84	24: Elucidation of the etiology of schizophrenia at the molecular level.	Life Science	Life
95	84	19: A system that supports women's social participation by ensuring mothers the future availability of child-rearing support such as nursery schools, at the time of pregnancy or childbirth.	Social Technology	Others
96	84	07: An LSI containing transistors with a gate length of 3 nm.	Electronics	Information
97	83	07: Development of a global monitoring system for marine pollution.	Environment	Environment
98	83	25: Technology to precisely observe carbon dioxide gas emission and absorption within country, using space technology.	Frontier	Environment
99	83	71: Methods to overcome drug resistance in infections.	Health, Medical care, and Welfare	Life
100	83	62: Nanocarrier systems that deliver drugs and genes to target cells in the body and are directed by outside signals.	Nanotechnology and Materials	Life

Reference Materials 4: Areas that will have a significant impact

Areas that will have a significant impact for the short term (up to about 2015) (top one-third or top 43) and other areas (that will have a significant impact for the mid-term or for which specialists in other areas predict a significant impact) are marked in the boxes.

Field	Area	Short-Term Impact						Other
		Increased intellectual assets	Field expansion	Expansion of existing industries	Creation of industries	Safety and Security	Improvement in QOL	
Information & communications	Very large-scale information processing	○	○	○	○			
	High-productivity computing							○
	Human support (intellectual support)							○
	Ultra-transparent communications (space sharing); human interface (muscular strength support)							○
	Information security	○	○	○	○	○	○	
	Information technology for developing social systems							○
	New principles for information and telecommunications							
	Ubiquitous networking							○
	Software technology for large-scale networks							○
Electronics	Integrated systems	○						
	Silicon electronics	○	○	○	○		○	
	Optical and photonic devices	○	○	○	○			
	Wireless electronics	○	○	○	○	○	○	
	Bioelectronics	○	○					
	Molecular and organic electronics							○
	Storage	○	○	○	○			
	Displays	○	○	○	○		○	
	Energy conversion/storage devices	○	○	○	○	○	○	
	Digital home appliances	○	○	○	○	○	○	
	Ubiquitous electronics	○	○	○	○	○	○	
	Robot electronics	○	○	○	○		○	
	Car electronics	○	○	○	○	○	○	
	Network electronics	○	○	○	○	○	○	
	Security electronics					○	○	
Life science	Basic research in drug development	○		○				
	Basic research for new medical technologies							○
	Brain generation and growth							○
	Higher-order brain functions							○
	Understanding and treating brain conditions							○
	Regenerative medicine		○					

Field	Area	Short-Term Impact						Other
		Increased intellectual assets	Field expansion	Expansion of existing industries	Creation of industries	Safety and Security	Improvement in QOL	
Life science	Monitoring and sensor technology for biological substances	○	○					
	Control of higher-order biological functions							○
	Information biology		○					
	Environmental and ecological biology							○
	Nanobiology		○					
Health, medical care, and welfare	Personalized medicine	○			○	○	○	
	Elucidation of biological defense mechanisms and therapeutic application					○	○	
	Recovery of biological functions focusing on QOL and support for it		○	○	○	○	○	
	Application of IT to medicine		○	○	○	○	○	
	Human-centered medicine and construction of healthcare support systems					○	○	
	Preventive medicine					○	○	
	Measures against emerging and reemerging infectious diseases					○	○	
	Medicine and welfare for an aging society			○	○	○	○	
Agriculture, Forestry, Fisheries, and Foods	Elucidation of the complex interaction between biodiversity and ecosystems							○
	Biological solutions to environmental problems and achievement of a sustainable society		○		○			
	Development of production technology that harmonizes with ecosystems and improves the environment					○		
	Development of a food system for a safe, peaceful, long-lived, and healthy society and other new technologies for daily life				○	○	○	
	Elucidation of genome/proteome, and biological information signal transduction mechanisms and development of innovative production technology	○	○		○			
Frontier	Planetary exploration technology	○						
	Earthlike life and extrasolar planetary exploration technology	○						
	Space and particle research	○						
	Basic technology for space transportation and manned space activity	○	○					
	Space utilization technology—basic satellite technology—	○	○	○	○			
	Technology for high precise observation of Earth environments and for prediction of change	○	○			○	○	
	Technology to explore, capture, and cultivate life under extreme environment	○						
	Deep Earth observation technology	○						
	Ocean and deep ocean floor observation research technology	○						
	Space, ocean, and Earth technology for a safe and secure society	○	○			○	○	
	Space, ocean, and Earth technology that drives science and technology innovation	○	○	○	○			
Energy and Resources	Innovative nuclear power systems							○
	Nuclear fusion energy							○
	Hydrogen energy systems	○	○		○			
	Fuel cells	○	○	○	○			

Field	Area	Short-Term Impact: Increased intellectual assets	Field expansion	Expansion of existing industries	Creation of industries	Safety and Security	Improvement in QOL	Other
Energy and resources	Decentralized energy systems							
	Renewable energy							○
	Clean-coal technology							○
	Efficient energy conversion and use		○	○	○			
	Resource assessment							
	Recycling system (including biomass and waste)							○
Environment	Global environment (focus on global warming)					○		
	Urban environment					○	○	
	Focus on identification and mitigation of ecological effects (including soil and water)					○		
	Environmental economic index					○		
	Lifestyle based on environment							○
	Environmental disasters					○	○	
	Water resources					○	○	
Nanotechnology and materials	Nanomaterials modeling simulation							○
	Nano measurement and analysis technology	○	○	○				
	Nano processing, molding, and manufacturing technology	○	○	○	○			
	Matter and materials origination, synthesis technology and process technology	○	○	○	○			
	New materials from nanolevel structure control	○	○	○	○			
	Nano devices and sensors	○	○					
	NEMS technology	○	○					
	Environment and energy materials							○
	Nanobiology	○	○	○	○			
	Nanoscience for a safe and secure society							○
Manufacturing	Manufacturing technology utilizing advanced information technology		○	○	○			
	Manufacturing technology using virtual design			○				
	Manufacturing technology for high value-added products		○	○	○			
	Nano-machining/ micromachining technology	○	○	○	○			
	Recycling-oriented manufacturing technology with a low environmental load			○	○	○	○	
	Human and robot participation in manufacturing	○	○	○	○			
	Manufacturing technology in special environments							
	Advanced manufacturing technology for social infrastructure			○		○	○	
	Surface modification and interface control technology	○	○	○	○			
Industrial infra-structure	Optimization of industrial infrastructure through regional dispersion and concentration							
	Knowledge management	○	○	○	○			
	Corporate decision-making, governance, and management			○				

Field	Area	Short-Term Impact						Other
		Increased intellectual assets	Field expansion	Expansion of existing industries	Creation of industries	Safety and Security	Improvement in QOL	
Industrial infrastructure	Public sector governance and management							○
	Risk management and finance			○		○		
	Human resources management (relationship among education, competition, and cooperation)			○	○		○	
	Competition and cooperation in business			○	○			
	Higher productivity in service industries and the service sector			○	○			
	Environmental management			○	○	○	○	
	Art, culture, and entertainment that drive industry							
Social Infrastructure	Social infrastructure technology for non-densely populated areas						○	
	Improvement of structure performance			○		○	○	
	Revitalization, maintenance, and management of social infrastructure					○	○	
	Social infrastructure technology responsive to an aging society				○	○	○	
	Environmental technology in social infrastructure				○	○	○	
	Comprehensive water management technology					○	○	
	Environmental measures appropriate to architectural scale					○	○	
	Security technology as social infrastructure					○		
	Disaster prevention technology					○	○	
	Total management of social infrastructure that includes public involvement					○	○	
	New transport system technology			○	○		○	
	Traffic safety technology					○	○	
	Environmental management in the transport sector					○	○	
	Efficient and environmentally-conscious logistics systems technology							○
Social Technology	Safety, security, and stability of day to day life					○		
	Urban safety, security and stability					○	○	
	Universal availability of service							
	Support for elderly people and those with disabilities						○	
	Social application of brain research							
	Technology for solving international problems							
	Technology that supports education and learning							
	Handing down and preserving culture and technology							
	Knowledge production system							
	Entertainment technology							○
	Technology assessment							○

Reference Materials 5: Extraction of Delphi areas associated with need categories

Reference Materials 5.1. Investigation method

To predict the efforts required to address the needs of the future society and the size and details of the contributions of science and technology in particular, we attempted to analyze how the individual Delphi areas, which have been identified as notable science areas, contribute to the need categories to be met by science and technology.

A total of 130 areas (Delphi areas), identified in the Delphi Analysis conducted as part of the "Science and Technology Foresight Survey" along with the Socio-Economic Needs Analysis, were used as the areas of science and technology that we related to the need categories.

Practically, questionnaires were conducted for members of the technological subcommittees （13 fields consisting of a total of 170 members) who selected the Delphi areas to investigate the level of contribution of each Delphi area to the individual need categories. Chart: Reference Materials 5-1 is an image of the questionnaire.

Chart: Reference Materials 5-1 Image of survey slip（excerpt）

Information and Communications

	Delphi Area	Outline			I. Safety and Security	II. Major Accident & Disaster
	Example	Example	Example		**2**	**3**
			Example		**1**	**1**
			Example			○○○ **technology**
1	**Very large-scale information processing**	A technology expected in this area of research is platforms that integrate broadband, super-distributed, and ultra-fast computing environments such as high-speed mobile communications, wireless LANs, digital broadcasting, ETC, and RF tags. To comprehensively operate these constituent technologies having short life cycles, there will be a need for capabilities of handling interconnections and interoperations between individual functions autonomously and in a self-organized manner. This will make a large amount of information in mixed media available on a common platform..	(1) Contribution	1. Large, 2. Medium, 3. Small, 4. Nil	**1**	**2**
			(2) Contribution Method	1. Direct 2. Indirect	**1**	**1**
			(3) Example		**Monitoring System**	**Monitoring System**
2	**High-productivity computing**	High-productivity computing is a hot science and technology area where the comprehensive promotion of hardware, software, and network technologies is pursued, assuming supercomputers as a tool to generate high values in many scientific, technological, and industrial fields. More efficient utilization of supercomputers as a tool will be possible through the efficient use of computing resources, which involves not only improving the hardware of supercomputers, but also developing software with higher effective performance and using networks to achieve greater computing power.	(1) Contribution	1. Large, 2. Medium, 3. Small, 4. Nil	**2**	**2**
			(2) Contribution Method	1. Direct 2. Indirect	**2**	**2**
			(3) Example			**System for predicting the occurrence of disaster and other incidents**
3	**Human support (Intellectual support)**	Artificial intelligence is twofold: it pursues computers that can substitute for human intellectual functions based on the findings on the brain's cognitive and decision-making mechanisms; it aims to support and supplement human intellectual activities. For the former research area, advances are expected in natural language understanding. For the latter, capabilities of handling environments where a large amount of information is distributed and shared is important, including the capabilities of screening information to organize and present it in an easy-to understand form and of assisting human memory and record-keeping. To achieve these aims, new prospects are desired in autonomous agent technology and science and technology on interactions between the human brain and the artificial brain.	(1) Contribution	1. Large, 2. Medium, 3. Small, 4. Nil	**2**	**2**
			(2) Contribution Method	1. Direct 2. Indirect	**1**	**1**
			(3) Example		**System for predicting traffic**	**System for predicting occurrence of disaster and other incidents**

The chart Ref.5-3 shows that we investigated the level of contribution of each Delphi area (large, medium or small), type of contribution (direct or indirect) and concrete examples of contribution to extract a Delphi area for 9 need categories as shown in (Chart: Reference Materials 5-2).

Chart: Reference Materials 5-2 Description

(1) Level of Contribution

Enter "1" when the level of contribution of the corresponding Delphi area is large in addressing topics of a desirable future society, enter "2" when it is medium, enter "3" when it is small, and enter "4" when it is nil.

(2) Contribution Type

Enter "1" when direct contribution of the corresponding Delphi area will address the topic of the future society. Enter "2" when science and technology will make an indirect contribution such as devices and tools.

(3) Concrete Example of Contribution

Enter an example when there is specific science and technology that require attention, or when there are concerns about the technology application, regardless of the type of contribution.

Reference Materials 5.2. Relationship between need categories and Delphi areas

A total of 109 responses were obtained from all subcommittees (average of 8.4 responses per field). Based on the collected responses, the level of contribution of each area was identified and converted into an index, which was then tabulated by direct contribution and indirect contribution. Chart: Reference Materials 5-3 shows the results of the calculation. The level of contribution is expressed in numerical terms to provide an overall picture of the relationships between the needs and science and technology. These Charts, therefore, should not be used actively for policy objective. Care must be taken in the use of these Charts to ensure that they are not used inappropriately.

The results indicate a tendency among the Delphi areas expected to make a large direct or indirect contribution to certain need categories. Many of the fields that are expected to make direct contribution are deeply linked to the corresponding need categories. It was also found that the "soft" areas in the fields of industrial infrastructure and social infrastructure, and areas in fields such as electronics, frontier, and environment tend to be expected to make a large indirect contribution. However, one topic remains. Given that the assessment did not cover science and technology outside the scope of the Delphi areas and that the number of responses was limited to 109, it may be insufficient for identifying science and technology that successfully respond to the all needs.

Chart: Reference Materials 5-3　Relationship between need categories and Delphi areas

Field (Number of samples: 109 in total)	Field	Area	Direct Contribution (Standard Value)									Indirect Contribution (Standard Value)								
			Ⅰ Safety and Security	Ⅱ Major Accident & Disaster	Ⅲ Health	Ⅳ Expansion of Capability	Ⅴ Population Decrease	Ⅵ Sustainable Society	Ⅶ Global Issues	Ⅷ International Competitiveness	Ⅸ Country with the respect of the international community	Ⅰ Safety and Security	Ⅱ Major Accident & Disaster	Ⅲ Health	Ⅳ Expansion of Capability	Ⅴ Population Decrease	Ⅵ Sustainable Society	Ⅶ Global Issues	Ⅷ International Competitiveness	Ⅸ Country with the respect of the international community
1 (8)	Information and Communications	1	1.5	2.0	0.4	0.5	1.8	1.0	1.3	1.8	1.3	1.8	1.5	1.3	1.3	1.0	1.5	1.4	1.3	1.3
		2	0.4	2.0	0.5	0.0	0.5	0.3	1.5	1.3	1.3	1.4	1.4	1.4	0.9	0.6	1.1	0.9	1.3	0.8
		3	1.0	0.5	1.3	2.0	1.0	0.0	0.0	2.5	2.3	1.5	1.4	0.9	0.5	1.1	1.1	1.3	0.8	0.6
		4	0.8	0.3	1.5	2.3	1.3	0.0	0.0	1.8	2.0	1.0	1.3	0.5	0.9	0.9	1.4	1.3	1.0	1.1
		5	4.0	1.3	0.0	0.0	0.3	0.5	1.4	1.9	1.3	0.0	1.0	1.5	1.8	1.9	1.4	0.9	0.8	1.1
		6	4.0	3.5	1.5	0.0	2.5	1.0	0.8	1.8	2.0	0.0	0.3	0.5	1.5	0.5	1.4	1.0	1.5	1.0
		7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.5	1.1	1.1	0.9	0.8	0.8	1.1	1.0	1.8	1.1
		8	3.0	3.3	1.5	1.0	1.3	0.8	1.5	2.3	2.5	0.0	0.5	0.8	0.9	1.1	1.3	1.1	1.3	0.8
		9	2.0	2.3	0.3	0.0	0.8	0.3	0.8	1.3	1.8	1.0	1.0	1.3	1.4	1.4	2.0	1.4	1.8	1.3
2 (9)	Electronics	10	0.0	0.0	0.4	0.0	0.0	0.0	1.1	1.8	0.7	1.7	1.6	1.1	1.0	1.3	1.2	0.9	0.7	1.3
		11	0.4	0.4	0.2	0.0	0.0	0.7	0.7	1.8	1.6	1.8	2.0	1.7	1.3	1.9	1.3	1.3	0.4	0.7
		12	1.1	1.1	0.7	0.0	0.2	0.9	0.9	2.2	1.6	1.4	1.9	1.1	1.2	1.3	1.1	1.0	0.7	0.9
		13	2.0	2.0	0.2	0.2	0.4	0.2	0.2	1.2	1.2	0.8	0.9	1.2	1.0	1.1	1.1	1.0	0.7	0.4
		14	0.7	0.2	3.3	0.0	0.2	1.1	0.7	2.0	1.2	0.8	0.8	0.4	1.4	1.1	1.0	1.3	0.3	0.6
		15	0.2	0.0	0.2	0.4	0.0	1.1	0.2	2.1	1.6	1.3	1.1	1.0	0.9	0.9	0.6	1.0	0.7	0.7
		16	0.2	0.0	0.0	0.4	0.2	0.0	0.2	2.7	1.8	1.3	1.7	1.4	0.8	1.0	1.2	1.0	0.2	0.3
		17	0.7	0.9	0.2	1.3	0.2	0.2	0.0	2.4	1.8	0.7	0.8	1.2	0.8	0.7	1.1	1.2	0.7	0.3
		18	0.0	1.8	0.0	0.9	0.2	1.6	2.4	2.7	1.2	2.0	1.2	1.3	0.6	0.8	0.7	0.4	0.2	0.9
		19	0.2	0.0	0.0	2.0	0.4	0.0	0.0	2.7	1.6	1.2	1.4	1.8	0.7	0.8	1.3	0.9	0.7	0.4
		20	2.7	2.9	0.2	0.2	0.7	0.4	0.7	2.4	2.2	0.4	0.2	1.6	1.2	1.0	1.3	0.7	0.7	0.4
		21	1.6	2.0	1.8	1.7	1.6	0.9	0.0	2.2	1.8	0.7	0.2	0.6	0.6	0.6	0.9	1.0	0.4	0.7
		22	4.0	2.0	0.0	0.7	0.4	0.2	0.7	2.4	1.6	0.0	0.6	0.9	1.0	0.8	1.1	1.0	0.6	0.9
		23	1.6	1.4	0.2	0.7	0.4	1.1	0.4	1.8	0.9	1.1	0.8	1.2	1.3	1.2	0.7	1.0	0.8	1.0
		24	3.8	3.6	1.0	0.9	0.2	0.7	1.3	1.6	0.9	0.0	0.0	0.3	0.8	1.1	0.9	0.3	1.0	0.6
3 (7)	Life Science	25	0.0	0.4	3.4	0.0	0.0	0.0	0.9	1.9	2.0	0.4	0.3	0.0	1.6	0.7	0.6	0.4	0.6	0.6
		26	0.0	0.0	3.4	0.0	0.3	0.1	0.6	2.1	2.0	0.6	0.7	0.0	1.1	0.6	0.6	0.6	0.3	0.9
		27	0.6	0.0	1.7	1.7	0.0	0.3	0.0	1.0	1.0	0.6	1.0	0.7	0.4	0.7	0.3	0.4	0.7	0.9
		28	1.0	0.0	1.4	1.7	0.1	0.3	0.1	1.3	1.3	0.4	0.9	0.6	0.6	0.7	0.1	0.4	0.3	0.6
		29	1.1	0.3	2.6	2.9	0.4	0.1	0.7	1.3	1.0	0.4	0.6	0.6	0.3	0.7	0.4	0.0	0.6	0.9
		30	0.0	0.3	2.6	0.9	0.1	0.1	0.7	2.6	2.0	0.6	0.3	0.0	0.9	0.6	0.4	0.3	0.0	0.3
		31	0.0	0.1	1.1	0.3	0.3	0.3	0.6	1.7	2.0	0.7	0.3	1.0	0.7	0.4	0.4	0.7	0.7	0.9
		32	0.0	0.1	2.9	0.3	0.1	0.1	0.6	1.0	1.4	0.1	0.6	0.0	1.0	0.6	0.6	0.4	0.9	1.1
		33	0.1	0.1	1.6	0.7	0.3	0.3	0.6	1.4	1.7	0.4	0.4	0.9	0.7	0.6	0.7	0.9	0.7	0.6
		34	0.3	1.7	1.7	1.1	1.4	1.7	3.1	1.3	2.6	0.9	0.3	0.9	0.9	0.3	0.3	0.0	0.7	0.3
		35	0.3	0.3	0.3	0.1	0.1	0.3	0.3	2.9	2.9	0.4	0.6	1.6	0.7	0.1	0.4	0.6	0.0	0.0
4 (10)	Health, Medical care, and Welfare	36	0.2	0.8	3.8	1.1	0.9	0.4	0.4	1.9	1.6	0.6	0.3	0.0	0.8	0.7	0.6	0.4	0.4	0.3
		37	0.0	1.2	4.0	0.4	0.7	0.4	1.0	1.4	1.5	0.9	0.5	0.0	1.2	0.7	0.5	0.4	0.4	0.3
		38	0.0	1.6	3.6	1.6	0.9	0.4	0.0	2.3	2.2	0.9	0.2	0.1	0.7	0.4	0.5	0.9	0.2	0.2
		39	0.2	2.0	3.6	0.6	0.7	0.4	0.6	2.4	1.8	0.7	0.6	0.0	1.1	0.6	0.7	0.5	0.2	0.3
		40	0.2	1.0	2.8	2.4	0.5	0.9	0.1	0.8	0.8	0.5	0.3	0.3	0.8	0.7	0.5	0.7	0.5	0.4
		41	0.8	1.0	4.0	1.6	1.1	1.0	1.0	1.4	1.2	0.2	0.3	0.0	0.8	0.5	0.5	0.6	0.7	0.8
		42	0.6	1.2	3.5	0.4	0.5	0.4	2.0	1.4	1.2	0.4	0.8	0.0	1.3	0.5	0.8	0.3	0.6	0.7
		43	0.4	0.4	3.6	2.2	2.0	1.0	0.4	1.2	1.6	0.2	0.4	0.0	0.9	0.9	0.5	0.7	0.7	0.6
5 (11)	Agriculture, Forestry, Fisheries, and Foods	44	0.2	1.3	0.2	1.1	0.0	2.4	2.5	0.5	1.1	0.4	0.8	0.6	0.6	0.7	0.7	0.5	0.6	0.2
		45	0.0	0.2	0.0	0.2	0.5	2.9	3.1	2.2	1.1	0.3	0.7	0.9	0.5	0.4	0.2	0.2	0.3	0.2
		46	0.2	0.5	1.2	1.1	1.5	2.6	2.5	1.5	1.4	0.2	0.3	0.7	0.5	0.3	0.2	0.1	0.2	0.1
		47	0.4	0.3	3.6	1.5	0.7	0.0	0.2	2.5	0.9	0.4	0.1	0.0	0.9	0.5	1.2	0.8	0.4	0.3
		48	0.0	0.0	2.1	0.2	0.4	1.0	1.4	2.3	1.6	0.3	0.3	0.3	0.6	0.3	0.3	0.5	0.4	0.0
6 (9)	Frontier	49	0.0	0.7	0.0	0.4	0.2	0.4	0.4	1.8	2.0	1.4	1.3	0.6	1.4	0.6	1.0	2.1	0.8	0.1
		50	0.0	0.1	0.0	0.4	0.0	0.0	0.4	1.3	2.2	0.9	0.7	0.6	1.7	0.7	0.9	1.6	0.9	0.2
		51	0.0	0.0	0.0	0.9	0.0	0.0	0.4	1.1	2.7	0.7	0.8	0.6	1.0	0.6	1.3	1.2	1.1	0.0
		52	0.4	1.1	1.1	1.3	0.0	1.1	1.8	3.1	2.0	1.4	0.9	0.6	1.4	1.2	1.1	1.4	0.0	0.1
		53	2.0	3.1	0.0	1.3	0.7	1.6	3.6	4.0	2.7	1.0	0.2	0.9	0.9	0.6	0.6	0.2	0.0	0.0
		54	0.0	2.2	0.7	1.1	0.2	1.9	3.6	3.1	2.0	1.3	1.0	0.9	1.4	1.1	0.9	0.1	0.2	0.4
		55	0.0	0.0	1.1	0.4	0.0	0.2	0.7	1.3	0.9	0.6	0.7	0.8	1.4	1.6	1.2	1.3	0.7	1.0
		56	0.0	1.8	0.2	0.0	0.0	0.0	2.4	1.6	1.3	0.8	0.6	0.4	1.3	0.8	1.1	0.4	0.6	0.7
		57	0.0	2.7	0.0	0.2	0.0	1.8	3.1	1.1	1.6	1.1	0.0	0.7	0.8	1.1	0.3	0.0	1.1	0.4
		58	1.6	4.0	0.2	1.6	0.4	1.8	3.6	2.4	1.6	1.0	0.0	0.8	0.6	1.3	1.1	0.2	0.7	0.7
		59	1.1	2.4	0.9	0.9	0.4	1.3	3.3	3.1	1.3	1.1	0.9	1.1	1.1	1.3	1.7	0.1	0.4	1.3
7 (6)	Energy and Resources	60	0.0	0.0	0.3	0.0	0.0	2.3	2.3	2.5	1.7	0.0	0.0	0.5	0.5	0.7	0.7	0.7	0.0	0.0
		61	0.0	0.0	0.3	0.0	0.0	1.7	2.7	2.7	1.3	0.0	0.0	0.3	0.5	0.7	0.3	0.0	0.0	0.0
		62	0.0	0.7	0.0	0.0	0.0	1.7	3.0	3.3	2.0	0.2	0.2	1.0	0.8	0.7	0.7	0.0	0.0	0.0
		63	0.0	0.7	0.0	0.0	0.0	1.7	2.3	3.3	2.0	0.2	0.2	0.8	0.7	0.7	0.2	0.2	0.0	0.0
		64	0.0	0.0	0.0	0.0	0.3	2.0	1.7	2.7	1.3	0.2	0.3	0.5	0.5	0.7	0.2	0.2	0.0	0.0
		65	0.0	0.7	0.7	0.2	0.0	2.0	2.8	2.5	1.7	0.2	0.2	0.7	0.8	0.7	0.7	0.0	0.0	0.0
		66	0.0	0.0	0.7	0.0	0.0	2.0	3.3	3.3	1.2	0.0	0.0	0.5	0.7	0.5	0.3	0.0	0.0	0.0
		67	0.0	0.0	0.0	0.0	0.0	1.7	2.7	3.0	1.5	0.2	0.2	0.3	0.5	0.7	0.2	0.2	0.0	0.0
		68	0.0	0.0	0.0	0.0	0.0	1.3	0.8	1.2	1.2	0.0	0.0	0.3	0.3	0.5	0.2	1.2	0.7	0.0
		69	0.0	0.0	0.0	0.0	0.0	2.5	2.8	2.5	1.2	0.0	0.2	0.3	0.5	0.7	0.0	0.0	0.0	0.0

Field (Number of samples: 109 in total)	Field	Area	Direct Contribution (Standard Value)									Indirect Contribution (Standard Value)								
			Ⅰ Safety and Security	Ⅱ Major Accident & Disaster	Ⅲ Health	Ⅳ Expansion of Capability	Ⅴ Population Decrease	Ⅵ Sustainable Society	Ⅶ Global Issues	Ⅷ International Competitiveness	Ⅸ Country with the respect of the international community	Ⅰ Safety and Security	Ⅱ Major Accident & Disaster	Ⅲ Health	Ⅳ Expansion of Capability	Ⅴ Population Decrease	Ⅵ Sustainable Society	Ⅶ Global Issues	Ⅷ International Competitiveness	Ⅸ Country with the respect of the international community
8 (8)	Environment	70	0.0	0.3	0.3	0.0	0.5	1.5	2.0	1.0	2.0	0.4	0.5	0.8	1.0	1.0	0.6	0.9	1.3	0.5
		71	1.5	1.3	0.8	1.3	0.5	1.5	1.8	2.0	1.5	0.5	0.6	0.9	0.8	0.8	0.8	0.6	0.3	0.4
		72	0.0	0.3	0.3	1.3	0.0	1.3	1.8	0.8	1.3	0.4	0.6	1.1	0.6	0.9	0.6	0.9	0.6	0.5
		73	0.0	0.0	0.6	1.0	1.5	2.3	1.8	2.4	3.0	0.4	0.1	0.8	0.8	0.5	1.0	1.3	0.8	0.5
		74	0.1	0.0	1.0	1.0	1.0	1.8	1.0	1.3	1.3	0.6	0.5	0.8	1.8	0.9	1.3	1.3	0.6	1.0
		75	0.3	3.0	0.3	0.5	0.5	1.3	1.5	1.5	1.8	0.5	0.5	1.1	0.9	0.5	0.6	0.5	0.5	0.4
		76	0.3	1.0	1.8	0.8	0.5	1.5	2.0	0.8	1.3	0.6	0.5	0.4	0.8	0.8	0.6	0.6	0.9	0.9
9 (9)	Nanotechnology and Materials	77	0.0	0.4	0.7	0.0	1.0	0.7	1.6	2.7	1.6	1.4	0.9	0.8	1.0	0.4	1.3	0.4	0.4	0.3
		78	0.9	0.7	2.6	0.2	0.4	1.3	1.6	2.7	2.2	1.0	1.0	0.0	1.2	1.0	0.7	0.9	0.9	0.1
		79	0.9	0.7	1.0	0.4	0.4	1.3	1.6	3.6	2.4	0.7	0.9	1.1	0.9	1.0	0.7	0.7	0.0	0.0
		80	0.7	0.2	0.6	0.2	0.2	1.8	1.8	3.1	2.3	1.0	1.2	1.2	0.9	1.1	0.2	0.6	0.2	0.0
		81	0.2	0.2	2.3	0.7	0.2	2.4	2.4	4.0	2.9	1.3	1.2	0.7	0.9	1.1	0.0	0.6	0.0	0.0
		82	2.4	1.3	2.2	0.4	0.9	2.2	2.1	3.6	2.4	0.2	0.9	0.2	0.8	0.6	0.1	0.6	0.0	0.0
		83	2.2	1.3	2.2	0.4	0.9	2.2	2.6	3.6	2.4	0.2	0.7	0.2	0.9	0.6	0.1	0.1	0.0	0.0
		84	0.1	0.9	1.7	0.3	1.1	2.7	2.3	3.1	2.0	1.2	0.9	0.4	0.9	0.4	0.1	0.6	0.2	0.2
		85	1.3	0.7	3.4	1.1	1.7	2.1	2.4	3.1	2.7	0.8	1.2	0.0	0.6	0.2	0.6	0.3	0.7	0.2
		86	1.8	2.4	2.4	1.1	1.8	1.7	2.0	1.1	1.1	0.6	0.1	0.0	0.6	0.3	0.6	0.3	1.1	0.7
10 (10)	Manufacturing	87	0.0	0.9	0.1	0.6	2.2	1.0	0.5	2.2	2.0	0.5	0.8	0.5	0.7	0.5	1.0	0.9	0.8	0.0
		88	0.0	0.1	0.1	0.4	0.8	0.8	1.0	2.2	1.4	0.4	0.9	0.4	0.5	0.8	1.1	1.1	0.3	0.1
		89	0.0	0.0	0.2	1.8	0.7	0.2	0.4	2.6	1.4	0.4	0.3	0.5	0.4	0.8	0.9	0.7	0.8	0.6
		90	0.3	0.3	0.8	0.2	0.1	0.0	0.2	2.8	2.0	0.3	0.5	1.1	0.7	0.7	0.8	1.0	0.3	0.0
		91	0.0	0.6	1.1	0.6	0.0	3.6	3.8	2.6	1.4	0.5	1.1	0.7	0.7	0.8	0.0	0.0	0.4	0.2
		92	0.4	1.4	0.1	0.6	2.6	1.4	0.4	1.8	1.4	0.9	0.6	0.8	0.7	0.4	0.8	1.0	1.0	0.2
		93	0.0	0.0	0.2	0.2	0.2	0.1	1.0	1.1	0.8	0.2	0.5	0.8	0.2	0.6	0.6	0.3	1.1	0.8
		94	1.6	2.7	0.5	0.8	0.8	1.4	1.6	1.0	0.6	0.1	0.1	0.6	0.6	0.4	0.2	0.5	1.0	0.8
		95	0.1	0.1	0.1	0.2	0.5	0.4	0.7	2.6	1.6	0.2	0.7	0.4	0.4	0.4	0.7	0.5	0.2	0.2
11 (5)	Industrial Infrastructure	96	0.0	1.6	0.8	2.0	2.4	2.8	1.6	0.8	0.0	1.4	1.6	1.2	0.8	0.6	0.2	1.0	0.6	1.2
		97	0.0	0.8	0.8	0.8	0.8	1.6	0.8	2.4	2.4	1.6	0.8	1.2	0.6	1.4	1.2	1.4	0.2	0.0
		98	0.0	0.4	0.4	0.0	0.4	0.4	0.0	0.4	1.6	0.8	0.8	0.6	1.0	1.0	1.6	1.6	1.2	0.8
		99	0.4	0.8	0.0	0.4	0.4	1.2	0.4	0.0	0.8	1.0	1.4	1.6	1.2	2.2	1.2	1.8	1.0	0.8
		100	2.4	2.8	1.2	0.0	1.6	1.6	2.4	0.0	0.8	0.8	0.8	1.4	1.4	0.6	1.2	0.6	1.4	0.6
		101	0.0	0.0	0.8	1.2	2.2	1.6	0.8	2.4	2.4	0.8	1.0	0.8	1.0	0.4	0.8	1.0	0.2	0.8
		102	0.0	0.8	0.8	0.8	0.4	0.8	0.8	1.6	1.6	0.6	0.6	0.6	0.4	1.2	1.2	0.8	1.2	1.2
		103	0.0	0.4	0.0	0.0	0.0	0.8	0.8	1.2	1.6	1.0	0.6	1.0	1.2	1.8	1.6	1.2	1.2	1.0
		104	0.0	0.0	2.0	1.8	0.0	3.2	3.2	2.4	2.4	1.0	1.4	0.8	1.0	2.2	0.8	0.8	0.8	0.8
		105	0.0	0.0	0.8	2.8	0.8	1.6	1.6	2.4	2.8	0.6	0.6	1.0	0.8	1.4	0.4	0.4	0.8	0.8
12 (7)	Social Infrastructure	106	0.3	0.9	0.0	0.6	3.4	1.4	0.0	0.1	0.0	0.9	0.7	1.3	1.7	0.0	1.1	0.3	0.3	0.1
		107	0.0	3.1	0.0	0.0	0.6	1.7	0.0	1.1	0.0	0.7	0.0	0.7	0.7	0.4	0.4	0.4	0.6	0.4
		108	0.0	2.3	0.0	0.0	2.0	3.1	0.0	0.6	0.0	0.9	0.1	0.7	0.7	0.4	0.0	1.1	1.0	0.4
		109	1.7	0.4	2.0	0.9	2.0	1.1	0.0	0.6	0.0	0.6	1.1	0.6	1.7	0.7	0.4	0.6	0.6	0.4
		110	0.0	0.0	0.0	0.0	1.7	3.4	2.6	0.6	0.0	0.6	0.7	1.6	1.1	0.3	0.0	0.3	0.9	0.7
		111	0.3	0.6	0.6	0.0	0.1	2.0	2.6	0.3	0.0	0.1	0.6	0.9	1.1	0.7	0.6	0.3	0.6	0.3
		112	0.0	0.0	1.7	0.0	0.3	1.4	0.6	0.1	0.0	0.4	0.7	0.7	1.4	0.6	0.6	1.0	0.9	0.4
		113	3.1	1.7	0.0	0.0	0.9	0.3	0.0	0.7	0.0	0.0	0.3	0.9	1.3	0.7	1.0	0.3	0.7	0.4
		114	0.0	3.4	0.0	0.0	0.6	0.6	0.0	0.9	0.0	1.0	0.0	1.0	1.4	0.9	0.7	0.4	0.6	0.6
		115	0.3	0.3	0.0	0.7	0.6	1.1	0.0	0.0	0.0	0.4	0.9	0.6	1.0	0.9	0.4	0.4	0.3	0.4
		116	2.6	0.9	0.0	0.3	1.3	0.9	0.6	1.1	0.0	0.3	1.0	0.3	1.0	0.7	1.3	0.9	1.0	0.6
		117	4.0	2.0	0.0	0.0	0.0	0.6	0.0	1.7	0.0	0.0	0.7	0.4	1.3	1.1	1.3	0.6	0.9	0.4
		118	0.0	0.0	1.4	0.3	0.0	1.1	1.7	1.4	0.0	0.6	0.4	0.7	1.1	0.9	1.6	1.0	0.9	0.6
		119	0.9	0.0	0.3	0.0	0.1	0.9	1.1	0.4	0.0	0.0	0.7	0.9	1.0	0.7	1.3	1.0	1.1	0.6
13 (10)	Social Technology	120	3.3	2.8	0.4	0.6	0.4	0.2	0.6	1.0	0.8	0.0	0.1	1.2	1.1	0.7	1.2	0.6	0.8	0.3
		121	3.2	2.8	0.6	0.6	0.2	0.2	1.3	0.6	0.8	0.0	0.1	0.8	0.8	0.8	1.2	0.4	1.1	0.1
		122	0.0	0.2	1.8	1.6	2.2	0.8	0.2	0.7	0.5	0.6	0.8	0.2	0.8	0.2	0.7	0.9	1.0	0.2
		123	0.0	0.4	2.9	2.2	3.2	1.2	0.2	0.3	0.2	1.0	0.8	0.1	0.4	0.1	0.8	0.8	0.9	0.6
		124	0.0	0.0	1.4	1.0	1.0	0.0	0.0	0.6	0.6	0.5	0.5	0.8	0.7	0.6	0.6	0.5	1.0	0.4
		125	1.2	1.8	0.6	0.2	0.2	1.2	2.8	0.2	1.0	0.6	0.3	0.6	0.8	1.0	0.8	0.2	1.3	0.2
		126	0.6	0.0	0.4	1.8	0.8	0.6	0.0	0.4	0.6	0.4	0.7	0.8	0.6	1.3	1.3	1.4	1.0	0.4
		127	0.0	0.1	0.0	1.2	0.0	0.2	0.0	0.5	0.4	0.2	0.2	0.7	0.8	0.7	0.9	0.9	0.8	0.5
		128	0.0	0.0	0.0	0.3	0.6	0.8	0.4	1.4	0.6	0.9	0.6	0.6	1.4	0.7	0.9	1.0	0.4	0.3
		129	0.0	0.0	0.0	1.3	0.0	0.0	0.0	2.0	1.0	0.3	0.3	0.4	0.5	0.7	0.8	0.3	0.4	0.2
		130	0.6	0.6	0.0	0.0	0.7	1.4	1.1	0.4	0.8	0.8	0.7	1.1	1.3	0.6	0.7	1.0	0.7	0.4

Reference Materials 5.3. Relationship between visions of future society and Delphi areas

Reference Materials 5.3.1 Extraction of Priority Areas That Correspond to Visions of a Future Society

Various cases comprising a combination of different need categories can be envisaged for a vision of a future society, depending on the prerequisites of such a society and individual measures of value. In practice, various cases that reflect social trends that require examination or several cases with significantly different trends can be developed to make an analysis appropriate for the vision of the future society.

Chart Reference Materials 5-3 shows the tendency in the relationship between science and technology and need categories. Further more combined with the priority to the cases of the vision of the future society, Delphi areas that make a large contribution may be extracted for individual cases.

For this purpose, three cases were developed as shown in Chart Reference Materials 5-4, based on the vision of the future society presented by the panel from the perspective of citizens and industrial activities, and with reference to existing reports on the future society. Important need categories for each case were weighted to extract areas that correspond to the vision of the future society (Chart Reference Materials 5-5).

Chart: Reference Materials 5-4 Case of vision of future society

Case of Vision of Future Society	Priority	Keyword that requires attention
Case A	Focus on civil life (Focus on need categories I, II and III)	・ Longest healthy life expectancy in the world ・ Comfortable life environment ・ Realization of safe society, etc.
Case B	Focus on sustainable economic growth (Focus on need categories V, VI and VIII)	・ Aging society with a declining birthrate ・ Sustainable development of industries ・ Retention of international competitiveness, etc.
Case C	Focus on spiritual wealth and contribution to the world (Focus on need categories IV, VII and IX)	・ Spiritual fulfillment achieved from contribution to the world and other activities than accumulating material wealth ・ Science and technology that encourage people to have dreams, etc.

Chart: Reference Materials 5-5 Weighting by case of vision of future society

	I Safety and Security	II Major Accident & Disaster	III Health	IV Expansion of Capability	V Population Decrease	VI Sustainable Society	VII Global Issues	VIII International Competitiveness	IX Country with the respect of the international community
Case A	4	4	4	2	2	2	1	1	1
Case B	2	1	1	1	4	4	2	4	2
Case C	1	2	2	4	1	1	4	2	4

(Note) Concept of weighting : Top priority (4 points), Priority (2 points), Standard (1 point)

Chart: Reference Materials 5-6 shows the relationship between each Delphi area and each vision of the future society based on Chart: Reference Materials 5-3. In this Chart, the name of the field is used to refer to the relevant Delphi area.

According to these results, the fields with a large, direct contribution are considered to contribute to elements that are specific to each case, given that these fields directly relate to elements selected as a keyword for each vision of the future society. Meanwhile, fields with a large, indirect contribution are considered to make a large, overall contribution, since common trends were observed among all visions of the future society.

Chart: Reference Materials 5-6 Example of fields that contribute to envisioned future society

<table>
<tr><th>Envisioned Future Society</th><th>Elemental Contribution</th><th>Overall Contribution</th></tr>
<tr><td>Case A
（Focus on civil life）</td><td>・Health, Medical care, and Welfare
・Life Science
・Social Infrastructure
・Electronics
・Environment
・Frontier
・Nanotechnology and Materials
・Information and Communications, etc</td><td rowspan="3">・ Information and Communications
・ Electronics
・ Industrial Infrastructure
・ Frontier
・ Social Infrastructure
・ Social Technology
・ Nanotechnology and Materials
・ Environment</td></tr>
<tr><td>Case B
（Focus on sustainable Economic growth）</td><td>・Energy and Resources
・Nanotechnology and Materials
・Frontier
・Electronics
・Manufacturing
・Information and Communications
・Social Infrastructure, etc</td></tr>
<tr><td>Case C
（Focus on spiritual wealth and contribution to the world）</td><td>・Environment
・Nanotechnology and Materials
・Energy and Resources
・Frontier
・Manufacturing
・Information and Communications
・Industrial Infrastructure
・Social Infrastructure, etc</td></tr>
</table>

The field of nanotechnology and materials was extracted as the priority area with a large elemental contribution, since this field tends to make a large direct contribution regardless of the case. To determine the validity of this result, a follow-up survey of the respondents was conducted. The survey revealed that respondents were strongly aware that advancement of technologies that handle materials and microscopic matters would directly lead to the development of products and systems that better respond to social and economic needs, and that the benefits of such development would be epoch-making. Given the Study on Social and Economic Needs, which assumed contributions of technologies in a given area to be indirect when they contribute to the realization of a “desirable future society,” and that technology trends in the nanotechnology and materials field are expected to have large ripple effects in the peripheral domain, we decided that the contribution of this field is more indirect than direct and categorized it under overall contribution.

Among the environment-related technologies, “soft” areas, which are pertinent to assessment, measurement and prediction, are included in the field of “environment,” and “hard” areas such as countermeasure systems are included in other fields such as “energy and resources” and “agriculture, forestry, fisheries, and foods.” It was found that the soft Delphi areas in the environment field have a tendency to make an overall contribution, regardless of the vision of the future society.

List of Committee Members (without titles from names, As of March 31, 2005)

"Science and Technology Foresight Survey"

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<Information and Communications Subcommittee>

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	ISHIZUKA Mitsuru	Professor, Graduate School of Information Science and Technology, The University of Tokyo
	KAMITAKE Takashi	General Manager of Core Technology Center, Toshiba Digital Media Network Company
	KAWAI Naoki	Director, Planning and Coordination, NHK Science and Technical Research Laboratories
	MASUMURA Tatsuro	Managing Director, NTT DoCoMo Wireless Laboratories
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	NAMIKI Junji	Manager, NEC Corporation
	OHGA Kimiko	Manager, Customer Equipment Department, Consumer Business Headquarters, Nippon Telegraph and Telephone East Corporation
	SANO Susumu	Vice President, Japan Registry Services Co., Ltd.
	TSUDA Toshitaka	Member of the Board, Fujitsu Laboratories Limited

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	IMAI Hajime	Professor, Faculty of Science, Japan Women's University
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	KOYAMA Fumio	Professor, Microsystem Research Center, Precision and Intelligence Laboratory, Tokyo Institute of Technology
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	NISHINO Toshikazu	General Manager, Central Research Laboratory, Hitachi, Ltd.
	SONE Jun'ichi	General Manager, NEC Fundamental and Environmental Research Laboratories
	TORIUMI Akira	Professor, School of Engineering, The University of Tokyo

<Life Science Subcommittee>

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	GOJOBORI Takashi	Director and Professor, Center for Information Biology and DNA Data Bank of Japan, National Institute of Genetics, Research Organization of Information and Systems
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	KITANO Hiroaki	Deputy Director, Sony Computer Science Laboratories
	NAKAUCHI Hiromitsu	Professor, Center for Experimental Medicine, The Institute of Medical Science, The University of Tokyo
	OGASAWARA Naotake	Professor, Graduate School of Network Science, Nara Institute of Science and Technology
	OKONOGI Kenji	Director, Frontier Research Laboratories, Takeda Chemical Industries, Ltd.
	SAKURAI Masaki	Professor & Chairman, Department of Physiology, Teikyo University School of Medicine,
	SHIMAZU Kozo	Deputy General Manager, Corporate Officer, Analytical & Measuring Instruments Division, Shimazu Corporation
	SUGIYAMA Tatsuo	Director, RIKEN Plant Science Center
	TAKATSU Kiyoshi	Professor, Department of Microbiology and Immunology, The Institute of Medical Science, The University of Tokyo

<Health, Medicine and Welfare subcommittee>

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	FUKUUCHI Yasuo	Director, Ashikaga Red Cross Hospital
	IMAI Yutaka	Associate Director and Professor, Department of Radiology, Tokai University School of Medicine
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	KATO Norihiro	Director, Department of Gene Diagnostics and Therapeutics, International Medical Center of Japan
	KIMURA Akio	Director and Professor, Keio University Tsukigase Rehabilitation Center
	KIMURA Satoshi	Director General, AIDS Clinical Center, International Medical Center of Japan
	KOMATSU Hiroko	Professor, St. Luke's College of Nursing
	MUTO Tetsuichiro	Hospital Director, Cancer Institute Hospital
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	IKEGUCHI Atsuo	Department of Livestock Industry Environment, National Institute of Livestock & Grassland Science
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	INUBUSHI Kazuyuki	Professor, Faculty of Horticulture, Chiba University
	ISHIKAWA Yutaka	Researcher, Agriculture, Forestry and Fisheries Research Council
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	WATANABE Okitugu	

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	HIKITA Tomoji	Director General, Japan Institute of Energy,
	INABA Atsushi	Director, Research Center for Life Cycle Assessment, National Institute of Advanced Industrial Science and Technology
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	TAKEUCHI Kuniyoshi	Professor, Interdisciplinary Graduate School of Medicine and Engineering
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	WASHITANI Izumi	Professor, Graduate School of Agricultural and Life Sciences, Faculty of Agriculture, The University of Tokyo

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	MURAKAMI Hiroya	Professor, Graduate School of Science and Engineering, Tokyo Institute of Technology
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	OBIKAWA Toshiyuki	Professor, Graduate School of Science and Engineering, Tokyo Institute of Technology
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＜Industrial Infrastructure Subcommittee＞

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	KANAMITSU Jun	Researcher, The Institute of Politics and Economy
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	YAMAGUCHI Fujio	Professor, Graduate School of Global Business, Meiji University
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<Social Infrastructure Subcommittee>

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	FUNAMIZU Naoyuki	Professor, Graduate School of Engineering, Hokkaido University
	FUNO Shuji	Associate Professor, Graduate School of Engineering, Kyoto University
	HARA Kayoko	Manger, Nissan Research Center, Nissan Motor Co., Ltd.
	HINO Takanori	Director, Center for CFD Research, National Maritime Research Institute
	ISHIBASHI Tadayoshi	Manager of Construction Department and Director of Structural Technology Center, East Japan Railway Company
	ITOIGAWA Eiichi	Professor, Graduate School of Systems and Information Engineering, University of Tsukuba
	KASAI Kazuhiko	Professor, Structural Engineering Research Center, Tokyo Institute of Technology
	KASUKABE Osamu	Professor, Graduate School of Engineering, Tokyo Institute of Technology
	NOJIMA Nobuoto	Associate Professor, Faculty of Engineering, Gifu University
	OKI Taikan	Institute of Industrial Science, The University of Tokyo Associate Professor
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	SHIBASAKI Ryosuke	Professor, Center for Spatial Information Science, The University of Tokyo
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＜Social Technology Subcommittee＞

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	INOUE Kotaro	Principal Fellow, Center for Research and Development Strategy, Japan Science and Technology Agency
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	KISHI Tohru	Director, Department of Third Forensic Science, National Research Institute of Police Science
	KOBAYASHI Shinichi	Director, Center for Exploratory Research, Research Institute of Science and Technology for Society (RISTEX), Japan Science and Technology Agency
	MATSUURA Hiroyuki	Department Head, Department of Gerontechnology, National Center for Geriatrics and Gerontology
	NARA Yumiko	Associate Professor, Faculty of Liberal Arts, The University of the Air
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"Analysis of Socio-Economic Impact of Science and Technology Policy in Japan"

＜Advisory Committee on Analysis of Socio-economic Impact of Science and Technology Policy＞

Chairperson	SAKAKIBARA Kiyonori	Professor, Faculty of Policy Management, Keio University
	KIKUCHI Junichi	Professor, The Graduate School, Division of Law, Department of Business Law, Aoyama Gakuin University
	NAGATA Akiya	Associate Professor, Faculty of Economics, Kyushu University
	SUMIKURA Koichi	Associate Professor, Public Policy Program, National Graduate Institute for Policy Studies
	WATANABE Takashi	Professor, Graduate School of Engineering Management, Shibaura Institute of Technology
	YAMAGUCHI Eiichi	Professor, Graduate School of Business, Doshisha University
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Implementation Structure and List of Participants Concerning This Analysis

This report outlines the results of comprehensive analysis based on the “Benchmarking Research & Development Capacity in Japan,” “Analysis of Socio-Economic Impact of Science and Technology Policy in Japan,” “Achievements of National/Public Universities and Public Research Organizations” and “Science and Technology Foresight Survey.”

The National Institute of Science and Technology Policy administered survey operations. We gained the cooperation of many knowledgeable experts. We sincerely thank them for their kind cooperation. The implementation structure and persons who prepared the report are as follows. (As of March 31, 2005)

National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology

(Summary)

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(Coordinator)

SAKA Ayaka	Science and Technology Foresight Center	Visiting Researcher

(Researcher who analyzed fields)

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KOMATSU Hiroshi	Science and Technology Foresight Center	Visiting Researcher
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MOGI Shin-ichi	Science and Technology Foresight Center	Senior Research Fellow [up to December 31, 2003]
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OMORI Ryota	Science and Technology Foresight Center	Senior Research Fellow [up to June 30, 2004]
OKUWADA Kumi	Science and Technology Foresight Center	Senior Research Fellow
SAKA Ayaka	Science and Technology Foresight Center	Visiting Researcher (already mentioned)
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TACHIKAWA Makoto	Science and Technology Foresight Center	Affiliated Fellow
TATSUNO Kimio	Science and Technology Foresight Center	Affiliated Fellow
TAMOU Yoshitaka	Science and Technology Foresight Center	Visiting Researcher [up to March 31,2004]
TSUJINO Teruhisa	Science and Technology Foresight Center	Visiting Researcher

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WATARI Masao	Science and Technology Foresight Center	Visiting Researcher [up to June 30, 2004]
YAMAMOTO Yoshika	Science and Technology Foresight Center	Senior Research Fellow
YOKOO Yoshiko	Science and Technology Foresight Center	Senior Research Fellow
YOKOTA Shinji	Science and Technology Foresight Center	Senior Research Fellow

(Survey Assistant)

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KOTSUKI Rieko	Science and Technology Foresight Center	Clerical Assistant
SAKAMOTO Kaoru	Science and Technology Foresight Center	Clerical Assistant
TANIMURA Sachiie	Science and Technology Foresight Center	Clerical Assistant

The Institute for Future Technology

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SAWAKI Masataka	Director, Research Center On Knowledge-based Society & Social System
SUZUKI Jun	Director, Research Center On R&D Strategy
ITO Takayori	Senior Researcher
OGATA Saburo	Senior Researcher
NAKAHARA Izumi	Senior Researcher
MORI Yasuko	Senior Researcher
OTAKE Hiroyuki	Researcher
TAKAHASHI Toshimasa	Researcher
NAKAJIMA Hiroaki	Researcher
MIMA Tadashi	Researcher
URAKAWA Nobuko	Assistant Researcher
WADA Yoshiko	Assistant Researcher

Mitsubishi Research Institute, Inc.

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OKADA Mitsuhiro	Senior Researcher, Industrial Policy Department, Industry and Market Strategy Research Division
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FURUKAWA Ryuzo	Researcher, Industrial Policy Department, Industry and Market Strategy Research Division
HIRANO Kimiyasu	Researcher, Industrial Policy Department, Industry and Market Strategy Research Division

SUGIE Shuhei — Industrial Policy Department, Industry and Market Strategy Research Division

OKATANI Naoaki — Senior Researcher, Industrial Strategy Department, Industry and Market Strategy Research Division [up to March 31, 2004]

KOIKE Isao — Senior Researcher , Industrial Strategy Department, Industry and Market Strategy Research Division [up to March 31, 2004]

HOSAKA Takanobu — Senior Researcher, Research Center for Regional Management

The Japan Research Institute, Limited.

ICHIKAWA Motoyuki — Senior Producer　Center for the Strategy of Emergence

＜Implementation Structure＞

○ "Benchmarking Research & Development Capacity in Japan" NR.90
Core Institute：National Institute of Science and Technology Policy　Commissioned Institute：Mitsubishi Research Institute, Japan Research Institute
The National Institute of Science and Technology Policy conducted a "quantitative analysis of theses." Mitsubishi Research Institute, Inc. undertook the "Assessment of Research Activities in Japan in Terms of Commendation and Guest Lecture" and "Assessment of Top Overseas Scientists and Researchers (US Edition)," for which Rand Corporation conducted the actual investigation in the United States. The Japan Research Institute conducted "Assessment of Top Overseas Scientists and Researchers (European Edition)," for which Policy Research in Engineering, Science and Technology (PREST) of the University of Manchester of the UK conducted the actual investigation in Europe.

○ "Analysis of Socio-Economic Impact of Science and Technology Policy in Japan" NR.89
Core Institute：National Institute of Science and Technology Policy, Commissioned Institute：Mitsubishi Research Institute

○ "Achievements of National/Public Universities and Public Research Organization " NR.93
Core Institute：National Institute of Science and Technology Policy, Commissioned Institute：Mitsubishi Research Institute

○ "Science and Technology Foresight Surveys" NR.94, 95, 96, 97, 98
Core Institute：National Institute of Science and Technology Policy, Commissioned Institute：Institute for Future Technology

Comprehensive Analysis of Science and Technology
Benchmarking and Foresight

May 2005

National Institute of Science & Technology Policy (NISTEP)