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The 11th Science and Technology Foresight: S&T Foresight 2019

Summary Report

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Science and Technology Foresight Center
National Institute of Science and Technology Policy

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1. Background

In Japan, science and technology innovation policy has been promoted under the Science and Technology Basic Plans, which have been formulated every five years since 1996. In recent years, the rapid development of technology such as ICT (information and communication technology) has brought about significant changes in the structure of society, human behavior, and so on. This has increased the uncertainty about the future of society as well as changes in international/national social, economic, and political situations. Facing this kind of changes, policy framework is required to have flexibly to uncertainty about the future, by understanding science and technology developments and the various possibilities they can bring about in society, as well as the demands of society from a medium- to long-term perspectives.

This study aims to provide fundamental information to enable evidence-based discussion about science, technology, and innovation policies including the 6th Science, Technology, and Innovation Basic Plan.

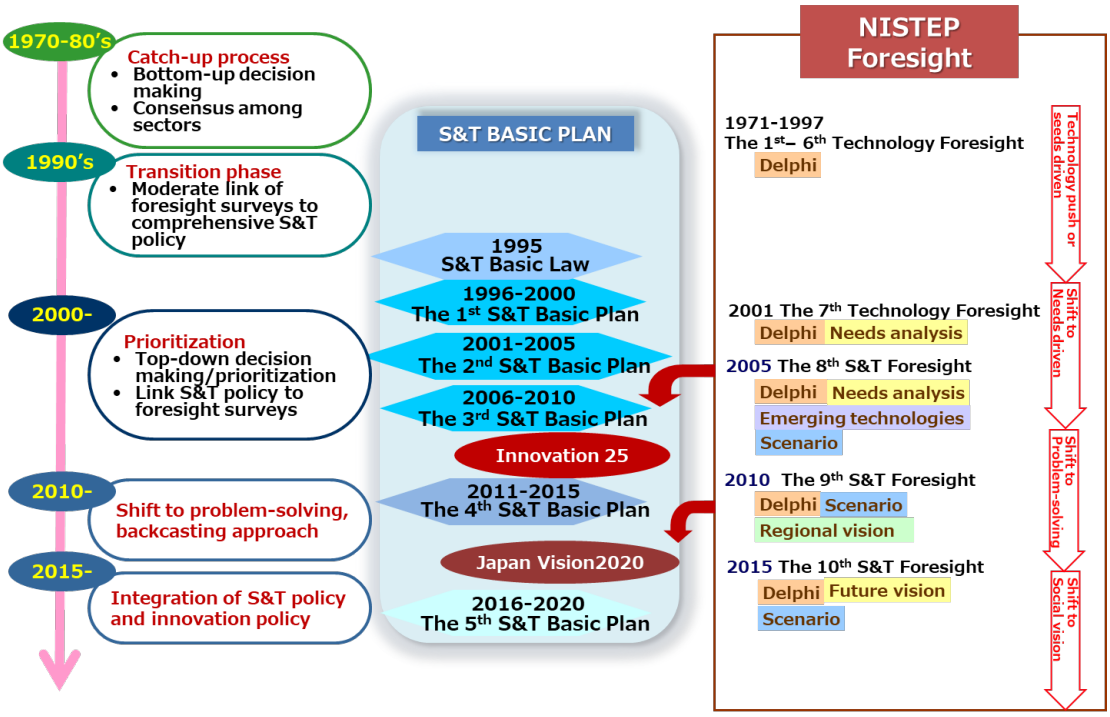


Figure 1. Progress of science and technology policy and NISTEP Foresight

2. Framework of the study

The Science and Technology Foresight has been carried out approximately every five years since 1971 in Japan, and this is the 11th study. Since around the year 2000, back casting or seeking for solution to challenges has become the mainstream attitude toward science and technology policymaking. To meet the requirements from policymakers, there was a change in the study framework from technology or seeds driven approach, where they consider the future of society based on science and technology developments, to society or needs driven approach, where they discuss the desired society before identifying relevant scientific and technological issues.

In consideration of the increased complexity of the relationship between technology and society, the study is promoted from the dual viewpoints of science and technology, and society (Figure 2). First, we grasped the science, technology, and social trends through a survey of reference materials, etc. [horizon scanning]. Next, we conducted separate investigations into the "future of society [visioning]," and "future of science and technology [science and technology perspectives]. Finally, we integrated the results to create the "future images of society brought about by the development of science and technology [scenario]." The study of "future of science and technology" consists of two approaches: discussion by field and interdisciplinary discussion. The period for looking into the future was set to the approximate 30-year point of 2050, with the target year set to 2040, in about 20 years' time. This duration assumes the progress of the ultra-smart society "Society 5.0" initiative.

The characteristics of this study are the positive use of information technology for data collection and analysis, as well as the encouragement for participation of the various stakeholders in the investigation process.

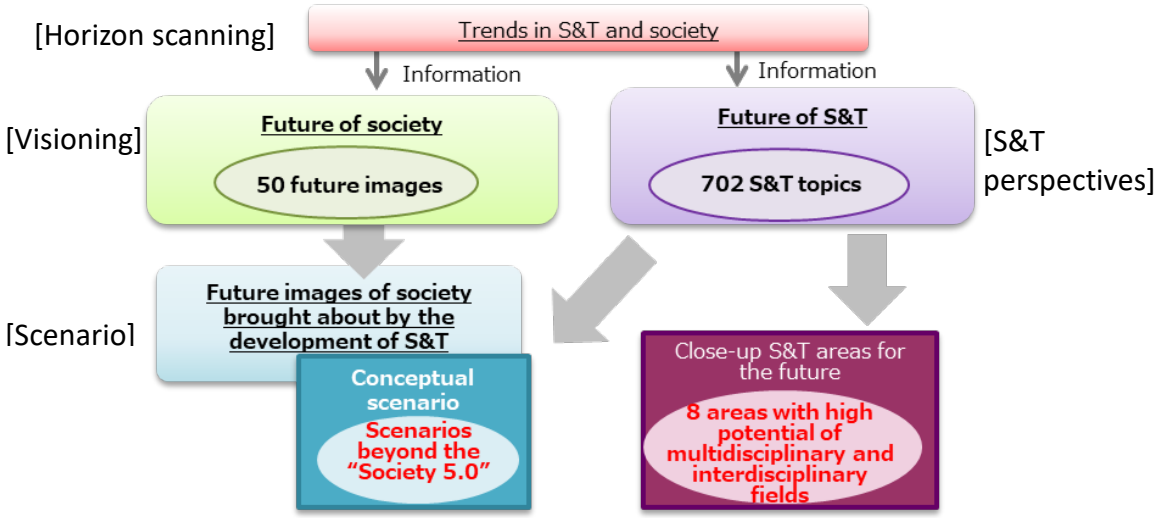


Figure 2. Structure of the 11th S&T Foresight

[The 11th S&T Foresight: S&T Foresight 2019 series]

Summary:

Summary Report, NISTEP Report No.183, November 2019, NISTEP
DOI: https://doi.org/10.15108/nr183

Horizon Scanning:

Horizon Scanning Report, Discussion Paper No.183, June 2020, NISTEP
DOI: https://doi.org/10.15108/dp183

Visioning:

Discussion on Desirable Society 2040, Research Material No.276, September 2018, NISTEP
DOI: https://doi.org/10.15108/rm276

S&T Perspectives:

Close-up Science and Technology Areas for the Future in 2050 -Extraction and Analysis through a Combination of AI-related Technologies and Expert Judges-, Research Material No.290, June 2020, NISTEP
DOI: http://doi.org/10.15108/rm290

Delphi Survey, Research Material No.292, June 2020, NISTEP
DOI: https://doi.org/10.15108/rm292

Scenario:

Society in 2040 through the Development of S&T -Conceptual Scenario-, Research Material No. 291, June 2020, NISTEP
DOI: https://doi.org/10.15108/rm291

3. Results

3.1. Horizon scanning

We extracted related trends from existing sources etc. as background information for depicting the desired future of society in “future of society” part [visioning], and for setting science and technology topics (S&T topics) in “future of science and technology” part [S&T perspectives].

The information to be collected was future outlook and signs of changes; the former was extracted mainly from existing materials including press releases and policy information including government strategies and top-down-type funding information; the latter was based on opinions of experts and bottom-up-type funding information. Results from the separately conducted investigations into the future images of the world and domestic regions were also used as information for “future outlook” or “signs of changes.”

Table 1. Information collected in Horizon Scanning

Type	Awareness	Direction	How to get information
Society	Outlook	Prediction	✓ Extracted trends from existing materials
		Aim	✓ Desired future of domestic regions (regional workshop results)
			✓ Extracted intended direction from plans and strategies by the government
	Signs	Prediction	✓ Possible changes in society (International workshop results)
			✓ Collected opinions of specialists and experts ✓ Collected information through routine horizon scanning by NSITEP
Science and technology	Outlook	Prediction	✓ Extracted trends from existing material ✓ Extracted information from related reports
		Aim	✓ Crawled information from meeting minutes of the national diet, etc. ✓ Crawled information of themes and resource distribution of top-down competitive research funds
	Signs	Prediction	✓ Collected opinions of specialists and experts ✓ Collected information through routine horizon scanning by NISTEP
			✓ Extracted themes from Grant-in-Aid for Scientific Research Database KAKEN ✓Crawled themes of R&D-related press releases

3.2. Visioning

A workshop was held in January 2018 with approximately 100 participants consisting of various stakeholders, including experts in the humanities, social sciences, and natural sciences, younger and senior researchers, experts from industry, academia, and government. Discussion took place regarding the desirable future images of Japanese society.

As a result, fifty future images of Japanese society were proposed as images of society aimed for by 2040, from which four values of humanity, inclusion, sustainability, and curiosity were extracted (Figure 3). Under “humanity”, a society was depicted where we put value on human being and a wide variety of connections between people, as we coexist with artificial intelligence and machines such as robots. Under “inclusion”, a society was depicted in which we promote connections that enables respects for a diverse range of characteristics of humans and machines. Under “sustainability”, a society was depicted in which we can respond to a wide variety of issues, such as energy limitations, food supply and demand, and the environmental issues on a global scale. Under “curiosity”, a society was depicted in which the spirit of adventure and curiosity can be fully manifested.

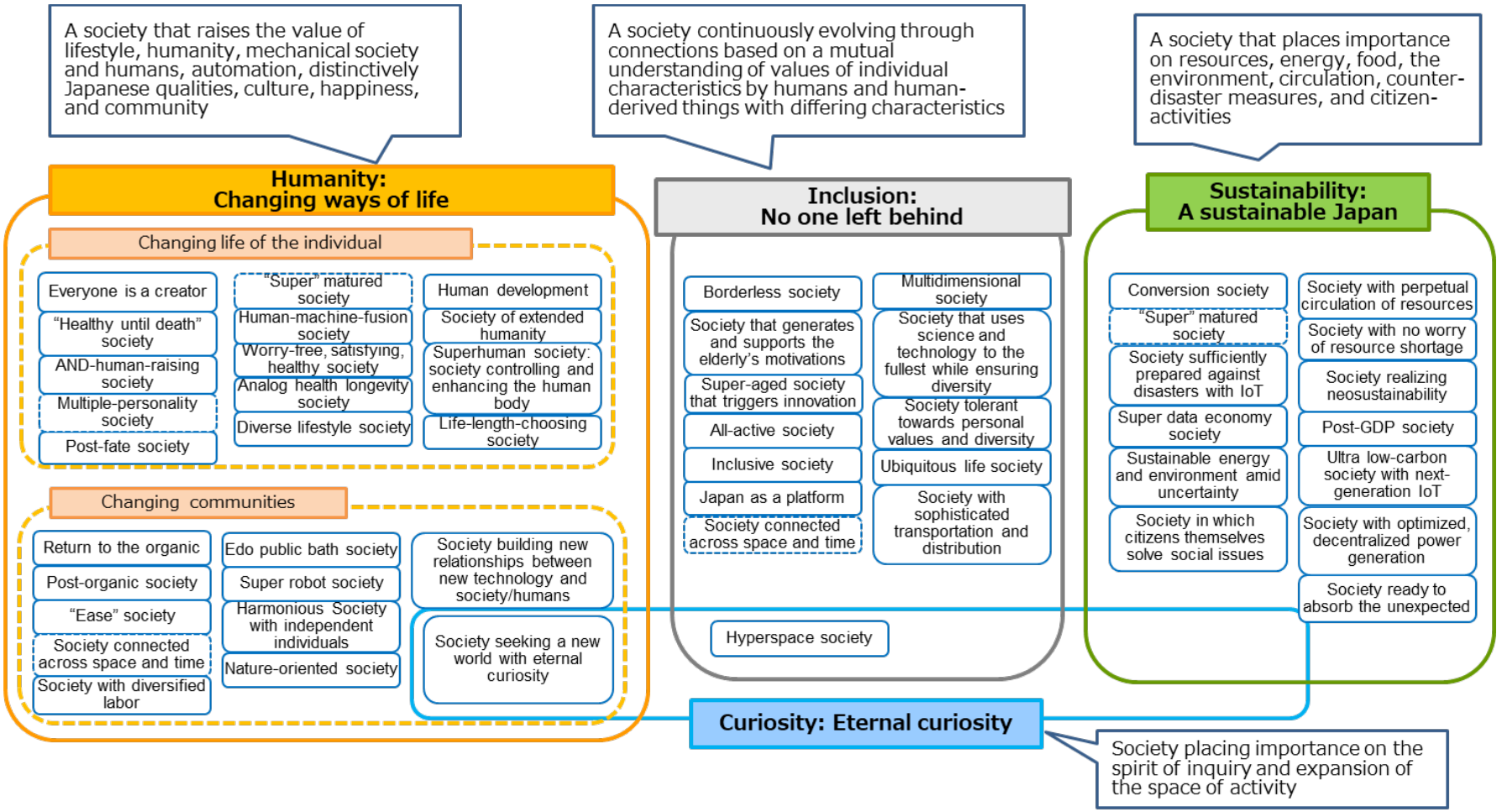


Figure 3. Future images of Japanese society

3.3. Science and technology perspectives

Delphi survey

For the seven fields of science and technology, 702 S&T topics were set for investigation by subcommittees in each field (comprised of a total of 74 experts). The S&T topics are research and development issues that are expected to be realized by 2050 and considered vital for the future. A questionnaire to experts was conducted from February to June 2019, and replies were received from 5,352 people. The questions to the S&T topics are their importance, their international competitiveness of Japan, their expected year of realization, and policy measures for their realization. The main results are as follows. Typical S&T topics are shown in Table 2 to Table 5.

- S&T topics with relatively high priority were often shown in the fields of health/ medicine/life sciences, ICT/analytics/service science, material/devices/processes, cities/architecture/civil engineering/transportation, and space/ocean/ earth/ science foundation.

- S&T topics with relatively high international competitiveness were often shown in the fields of material/devices/processes, cities/architecture/civil engineering/ transportation, and space/ocean/earth/science foundation. Health/medicine/life sciences field and ICT/analytics/service science field have more S&T topics with relatively low international competitiveness.

- It is predicted that approx. 90% of the S&T topics will be applied to society by 2035. Topics in the fields of health/medicine/life sciences, material/devices/processes, and cities/architecture/civil engineering/transportation are considered to be generally late in terms of scientific and technological realization and social realization.

- In terms of both the scientific and technological realization and social realization, there is a high necessity for establishing legal regulations among policy measures in the ICT/analytics/service science field, and after that in the cities/architecture/ civil engineering/transportation field. The need for consideration of ethical, legal, and social issues (ELSI) is high in health/medicine/life sciences field and ICT/ analytics/service science field.

Table 2. S&T topics with highest level of importance by field

Field	S&T topic (Number represents ID)	Score*	Realization**
Health, medicine, life sciences	39: Methods for prevention and treatment of motor function deterioration associated with aging	1.56	2028/2030
	58: Disease modification therapy effective for prevention and treatment of neurodegenerative diseases such as Alzheimer's disease based on pre-symptomatic biomarkers	1.55	2032/2035
Agriculture, forestry, fisheries, food, biotechnology	115: Agricultural robots to replace humans	1.35	2026/2029
	146: System for real-time high spatial and high temporal resolution meteorological prediction and disaster risk assessment, utilizing satellite and/or meteorological observation data	1.33	2028/2030
Environment, resources, energy	227: Long-life and low-cost secondary batteries that do not require replacement for electric cars	1.48	2029/2032
	261: Integrated water management technology in densely populated areas, including management of urban flooding, storm surge and land subsidence due to linear rain bands and torrential rain	1.36	2028/2029
ICT, analytics, service science	389: Technology such as AI, IoT, and robots that dramatically improves agricultural productivity, and eliminates labor shortages and lack of personnel	1.57	2029/2031
	350: Technology to prevent unauthorized access into control systems such as important infrastructure, vehicle control and personal IoT devices/ services	1.56	2028/2029
Materials, devices, processes	474: High-capacity, high-power battery with an energy density of 1 kWh/kg or more and a power density of 1 kW/kg or more	1.50	2030/2032
	497: Wearable devices that monitor in vivo information	1.32	2028/2031
Cities, architecture, civil engineering, transportation	541: Non-destructive inspection technology which may be used in the field to improve the reliability of inspection and diagnosis of infrastructure and to reduce the burden associated with this work	1.53	2025/2026
	546: Technology for creating highly accurate disaster hazard maps to enable detailed city planning	1.51	2027/2028
Space, ocean, earth, science foundation	629: Evaluation of the urgency of identifying the next volcano likely to erupt or unlikely to erupt, from all active volcanoes in Japan	1.51	2031/2033
	644: Technology for predicting localized heavy rain, tornadoes, hail, lightning, snowfall, etc., several hours ahead with spatial resolution of 100 m or less, using high-resolution simulation and data assimilation	1.50	2027/2029

*Importance scores were calculated based on the following point distribution: Very high (+2), High (+1), Neither high nor low (0), Low (-1), and Very low (-2).

** [Year of scientific/technological realization] / [Year of social realization] : Scientific/technological realization refers to the establishment of a technological environment. Social realization refers to a situation in which the realized technology can be used as products, services, etc.

Table 3. S&T topics with highest level of international competitiveness by field

Field	S&T topic (Number represents ID)	Score*	Realization**
Health, medicine, life sciences	63: Evaluation methods for the efficacy and side effects to develop the drugs of infectious diseases by using the cells established form the stem cells such as iPS cells, that can be substituted to animal models.	0.81	2028/2029
	5: Efficacy and safety evaluation technology using artificial organs and organoids derived from pluripotent stem cells that can reproduce the functions in the living body	0.75	2028/2030
Agriculture, forestry, fisheries, food, biotechnology	146: System for real-time high spatial and high temporal resolution meteorological prediction and disaster risk assessment, utilizing satellite and/or meteorological observation data	0.80	2028/2030
	121: Various functional foods based on the concept of foodmics that is conscious of the aging society	0.80	2027/2029
Environment, resources, energy	213: Car engines with 50% energy efficiency	1.09	2029/2031
	227: Long-life and low-cost secondary batteries that do not require replacement for electric cars	0.98	2029/2032
ICT, analytics, service science	344: Optical communication technology capable of accommodating innovatively large capacity and high-density communication, such as multi-core fiber and silicon photonics	0.82	2027/2028
	335: Robot equipment that supports the cognitive and motor function of elderly and mildly disabled people, enabling independent living, and driverless technology for robot equipment and robots that move at low speed over short distances	0.78	2028/2030
Materials, devices, processes	475: Aiming for a hydrogen society, a fuel cell where the amount of precious metal used is one tenth or less of that used in 2018, with consideration of catalyst deterioration	0.94	2032/2033
	412: High efficient power semiconductors for electrical power and motive power further exceeding silicon carbide (SiC) and gallium nitride (GaN)	0.92	2029/2033
Cities, architecture, civil engineering, transportation	587: Response control to long-term, long-duration ground motion of high-rise buildings and seismic base isolation buildings	1.16	2026/2028
	581: Technology that satisfies environmental standards for noise during continuous running at Shinkansen speed of 360 km, by using active noise control	1.10	2027/2029
Space, ocean, earth, science foundation	697: An optical lattice clock network using optical fibers, facilitating time measurement with an accuracy of 18 digits anywhere on Earth, enabling measurement of crustal and groundwater fluctuations and movement of magma chambers	1.11	2030/2033
	659: Elucidation of the origin of asymmetry of matter and antimatter in space	1.07	2033/-

※ Competitiveness scores were calculated based on the following point distribution: Very high (+2), High (+1), Neither high nor low (0), Low (-1), and Very low (-2).

* [Years of scientific/technological realization] / [social realization] : Scientific/technological realization refers to the establishment of a technological environment. Social realization refers to a situation in which the realized technology can be used as products, services, etc.

Table 4. S&T topics for which the establishment of legal regulations is most needed

Field	S&T topic (Number represents ID)	S&T	Society
ICT, analytics, service science	302: Internet-based individual authentication technology to a level that would enable all elections to be implemented on the Internet	81%	90%
ICT, analytics, service science	300: Technology to digitize all economic transactions	77%	81%
ICT, analytics, service science	374:30% or more of the total amount of payments made by ordinary people in daily life will be conducted in virtual currency managed by block chain technology without being controlled by central banks	71%	78%
ICT, analytics, service science	380: A social consensus will be reached on the relationship between machinery (AI, robot) and human beings	68%	71%
ICT, analytics, service science	382: Autonomous decentralization without central institutions in the distribution of intellectual property, through utilization of distributed ledger technology and smart contracts	66%	73%
ICT, analytics, service science	355: Economic infrastructure providing security, efficiency and a sense of security, with the ability to facilitate almost 100% cashless transactions for individuals' social activities and corporate economic activities	65%	77%
Cities, architecture, civil engineering, transportation	570: "Flying cars and drones" able to carry people in urban areas	64%	80%
Health, Medicine, Life Sciences	73: The management system for medical history, medication history, and personal genome information based on insurance cards, etc., incorporating IC chips, which will contribute to achieving precision medicine and improved medical quality.	64%	74%
ICT, analytics, service science	387: A system for automatic creation/modification of laws and ordinances using AI technology etc.	64%	77%
ICT, analytics, service science	396: Various means of transportation, such as automatic travel, drones, etc., to facilitate maintenance of local public transportation networks, and reform the field of logistics, as well as technology to support management and operation of these networks	63%	75%

*Analysis extracted ten topics with the highest rates of selection of "establishment of legal regulations" as policy measures for scientific/technological realization (selections in the "S&T" column). Analysis additionally showed the rate of selection of the same policy measures for social realization (selections in the "society" column).

Table 5. S&T topics most necessitating ELSI considerations

Field	S&T topic (Number represents ID)	S&T	Society
Health, medicine, life sciences	84: Solutions to Ethical, Legal and Social Implications (ELSI) regarding utilization of genome information from the neonatal period	70%	73%
ICT, analytics, service science	380: A social consensus will be reached on the relationship between machinery (AI, robot) and human beings	62%	69%
Health, medicine, life sciences	13: Human organ for transplantation produced from human-animal chimeric embryo consisting of animal embryo and human stem cell-derived cells	61%	69%
Health, medicine, life sciences	73: The management system for medical history, medication history, and personal genome information based on insurance cards, etc., incorporating IC chips, which will contribute to achieving precision medicine and improved medical quality.	60%	67%
Health, medicine, life sciences	16: Highly safe intrauterine gene therapy for congenital genetic diseases	58%	71%
ICT, analytics, service science	388: Health maintenance system based on data linkage of information such as health, medical care, nursing care, etc., from birth to the present, using block chain technology (achieving a pre-symptomatic society)	56%	67%
Health, medicine, life sciences	74: Health and medical database that continuously collects genome information, medical records and biological and behavior information obtained through wearable sensors and smart devices, toward promotion of large-scale cohort studies.	56%	64%
Health, medicine, life sciences	15: Gene therapy methods that widely realize gene repair therapy and single genetic disease treatment with next-generation genome editing technology	55%	72%
Agriculture, forestry, fisheries, food, biotechnology	160: Medical model pigs capable of xenotransplantation using gene modification techniques	54%	69%
ICT, analytics, service science	376: With the spread of AI and the ability to automate the majority of work, it will become a society where about 30% of the working generation will not work	50%	52%
ICT, analytics, service science	381: A system that makes it possible to estimate the social and economic impact of legal regulation, provides appropriate advice and risk presentation, including ascertaining situations where individuals and groups are located in real-time (including policy advice systems, advanced medical care advice systems, etc.)	50%	50%

*Analysis extracted eleven topics with the highest rates of selection of "solutions for ethical, legal, and social issues" as policy measures for scientific/technological realization (selection in the "S&T" column). Analysis additionally showed the rate of selection of the same policy measures for social realization (selection in the "society" column).

An overview of each field is shown below.

< Health/medicine/life sciences field >

- Importance: High for S&T topics related to aging, neuroscience, and medical devices.
- Competitiveness: High for S&T topics related to regenerative/cell medicine, gene therapy, and treatment based on the immune system.
- Prospect of realization: Slow for S&T topics related to neuroscience, especially the elucidation of the neuronal basis of higher cognitive functions in humans.
- Policy measures: High requirement for addressing ELSI in the subfield of information for health and social medicine.

< Agriculture/forestry/fisheries/food/biotechnology field >

- Importance: High for S&T topics related to agricultural robots that replace humans, followed by the system construction such as resource prediction and management technology, and the fusion of food and information technology.
- Competitiveness: High for S&T topics related to weather forecasts, disaster risk assessments, and functional foods based on “foodmics.”
- Prospect of realization: Slow for the scientific/technological realization of the resource-ecosystem-related technologies. Social realization of next-generation biotechnology is slow.
- Policy measures: High requirement for the improvement of legal regulations in the subfield of safety, security and health.

< Environment/resources/energy field >

- Importance: High for S&T related to secondary batteries, natural disasters, radiation removal, global warming, and risk management.
- Competitiveness: High for S&T topics related to automobiles, natural disasters, water treatment, and waste collection /effective utilization.
- Prospect of realization: Quick for the scientific/technological realization of S&T topics related to energy systems, water, and risk management.
- Realization of S&T topics related to energy conversion and resource development is slow. Water-related S&T topics are socially realized quickly, and energy-conversion- related S&T topics are slow.
- Policy measures: High requirement for human resource development in S&T topics related to risk management. Resource development and risk management will need domestic collaboration. S&T topics related to global warming and water will be promoted by international collaboration and standardization.

< ICT/analytics/service science field >

- Importance: High for S&T topics in the subfields of “social implementation”, “security and privacy”, “IoT and robotics”, and “network infrastructure”.
- Competitiveness: High for S&T topics in the subfields of “network infrastructure”, “IoT and robotics”, “computer systems”, and “interaction”.
- Prospect of realization: Slow for the scientific/technological realization of S&T topics in the subfields of “policy and institutional design support”. Slow again for the social realization of S&T topics in the subfields of “computer systems”, “industry, business, and management applications”, “policy and institutional design support”, “social implementation”, and “interaction”.
- Policy measures: High requirement for human resource development for S&T topics in the subfield of “data science and AI”. High requirement for S&T topics in the subfield of “policy

and institutional design support" to address ELSI.

< Materials/devices/processes field >

- Importance: High for S&T topics related to secondary batteries, solar cells, fuel cells, wearable devices, biomaterials, and structure diagnosis.
- Competitiveness: High for S&T topics related to fuel cells, power semiconductors, and secondary batteries.
- Prospect of realization: Slow for the scientific/technological realization of S&T topics in the subfields of "applied devices and systems relating to ICT and nanoelectronics" and "applied devices and systems relating to environment and energy". Fast for social realization of S&T topics in the subfield of "process manufacturing"; slow for social realization of S&T topics in the subfield of "applied device systems relating to ICT and nanoelectronics".
- Policy measures: High requirement to develop human resources for S&T topics in the subfield of "computational science and data science". High requirement for R&D funding/project subsidies, research platform improvement/business environment improvement for S&T topics in the subfield of "applied devices and systems relating to environment and energy". High requirement to improve legal regulations and to address ELSI for S&T topics in the field of "applied devices and systems relating to life science and biotechnology".

< Cities/architecture/civil engineering/transportation field >

- Importance: High for S&T topics in the subfields of "social infrastructure facilities," "cities and environment," "information for disaster prevention and mitigation," followed by "transportation systems".
- Competitiveness: High for S&T topics in the subfields of "information for disaster prevention and mitigation" and "cars, rail, marine and aviation".
- Prospect of realization: S&T topics related to disaster, information on danger, and mobility are the fastest to be realized in the subfields of "information for disaster prevention and mitigation", "transportation systems", and "land use and preservation".
- Policy measures: High requirement for international cooperation and standardization for S&T topics in the subfields of "transportation systems" and "cars, rail, marine, and aviation." High requirement for domestic cooperation and collaboration on S&T topics related to infrastructure maintenance.

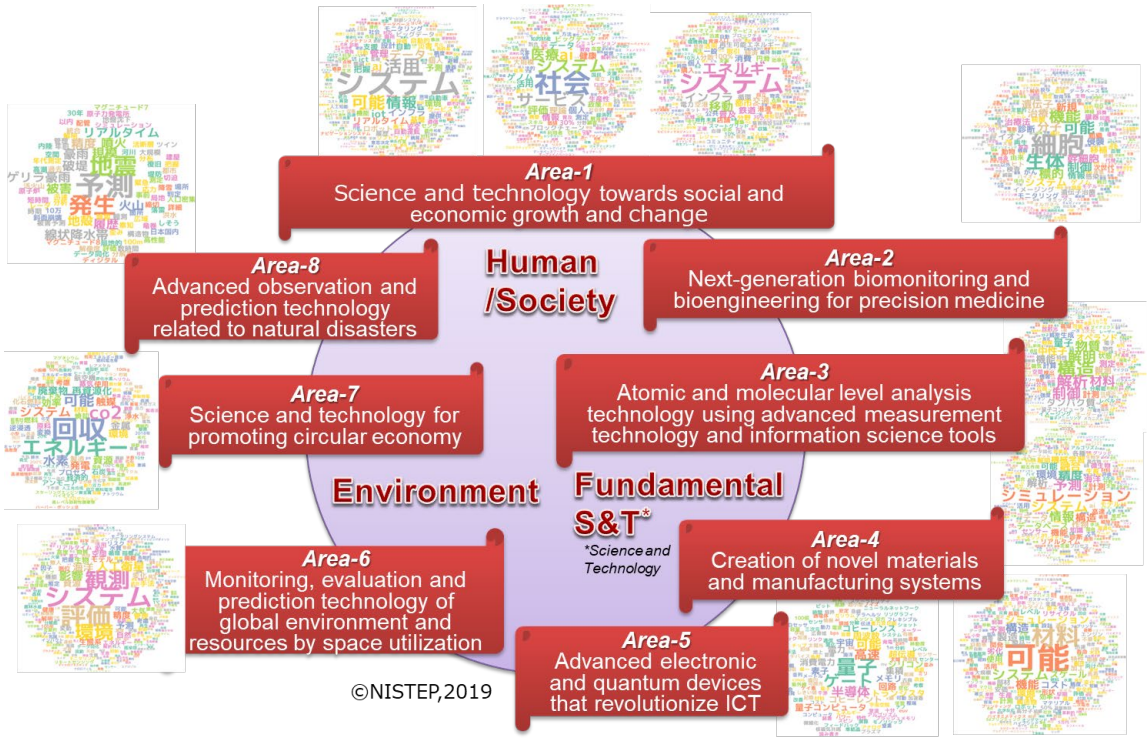
< Space/ocean/earth/science foundation field >

- Importance: High for S&T topics related to measurement and analysis using quantum beams, disaster prediction, and positioning for automation.
- Competitiveness: High in importance and international competitiveness for S&T topics related to phenomenon elucidation, prediction of local heavy rainfall, and material structure analysis using multiple beams.
- Prospect of realization: The realization of S&T topics related to quantum beam is fast, and the realization for S&T topics related to the space, elementary particles, nuclei, and accelerators is slow.
- Policy measures: Space-related and the ocean-related S&T topics generally have a high requirement for policy support. Overall, in addition to human resources, R&D funding, and research platform, there is a high requirement for international collaboration and standardization.

Close-up science and technology areas for the future

In recent years, cross-disciplinary areas have come under attention, from the perspectives of both social issues' solution and scientific and technological developments. Based on the 702 S&T topics set by the subcommittees for each field, research and development areas that need to be promoted were extracted regardless of the field. The characteristics of this approach were that it was conducted with processing using AI-related technology (artificial intelligence centering on machine learning and natural language processing) combined with expert judgement. The 702 S&T topics were classified into 32 clusters, based on AI-related technology before there was a discussion by experts. Then, eight areas with high interdisciplinary potential (Figure 4) and eight areas focusing on specific fields (Figure 5) were extracted.

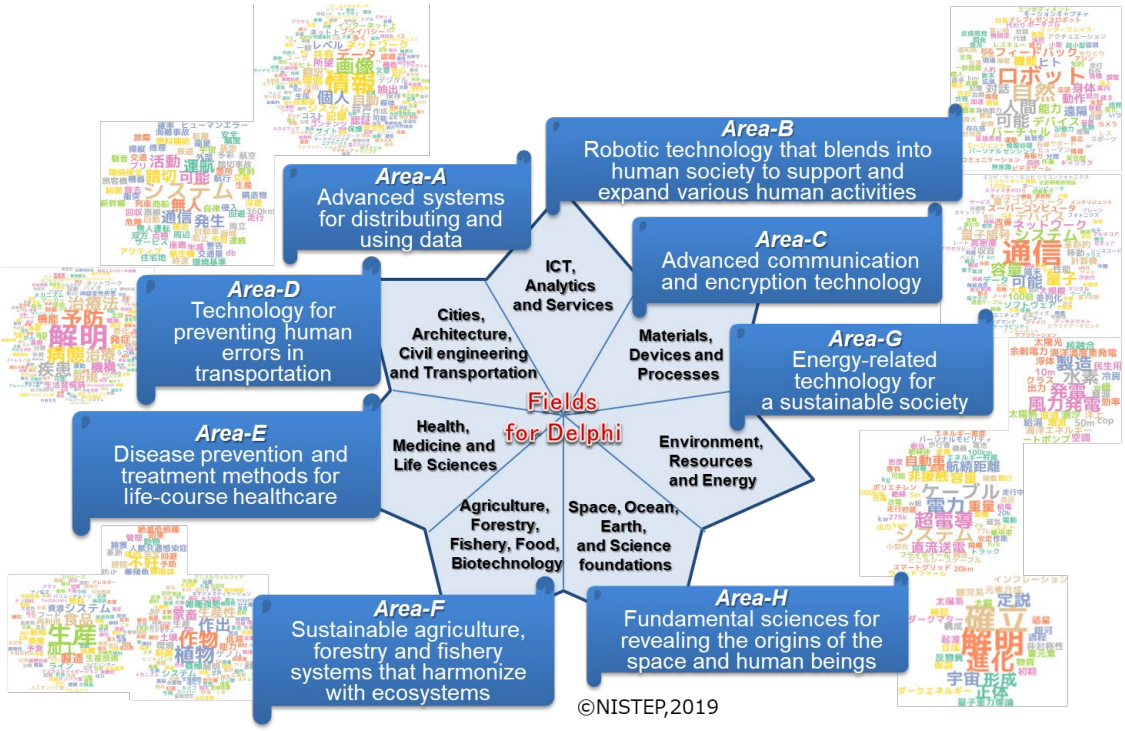
*Areas were formed based on S&T topics, and as it was not shown that these were definitely I interdisciplinary areas, these were set to areas with "high potential" as interdisciplinary areas.



ID	Name	Summary
1	Science and technology towards social and economic growth and change	A science and technology area that understands and controls more diversified and complicated social phenomena (Large Social Complex Systems) by modeling and simulating them by making full use of information processing technology and mathematical science.

ID	Name	Summary
2	Next-generation biomonitoring and bioengineering for precision medicine	A science and technology area consisting of biomonitoring that comprehensively understands various interactions in the human body, aiming at precision medicine that considers individual differences in genes, environment, and lifestyle, and also bioengineering that develops medical technology based on the results.
3	Atomic and molecular level analysis technology using advanced measurement technology and information science tools	A science and technology area that integrates advanced measurement that enables the observation and survey of previously unseen objects, and information science, such as simulation, informatics, and AI, to lead to scientific clarification and the development of technologies in a wide range of practical fields, including drug discovery, catalysts, materials, and crops.
4	Creation of novel materials and manufacturing systems	A science and technology area consisting of elemental technologies that form the basis of manufacturing that is expected to bring about new value creation through advanced manufacturing and distribution systems enabling mass customization and meeting the diverse needs of individuals and global society in the future, such as solving social issues related to the earth and the environment and improving humanities' QoL.
5	Advanced electronic and quantum devices that revolutionize ICT	A science and technology area consisting of the human-machine interface and sensing in the IoT, which are the basis of deepening and fusion of human-machine relationships. Electronic devices with new materials and functions such as high-efficiency and high-speed devices that support advanced ICT systems with less environmental impact. Furthermore, science and technology fields related to quantum devices that have enormous information processing capabilities and are expected to be able to non-invasively measure and sense living organisms with high accuracy.
6	Monitoring, evaluation and prediction technology of global environment and resources by space utilization	By observing the Earth extensively from space and on the ground, it is possible to deepen our understanding of the Earth's environment and resources, and improve our ability to predict changes that will lead to the exploration and management of energy and resources, and crisis management against natural disasters.
7	Science and technology for promoting circular economy	A science and technology area related to diverse technologies and systems such as renewable energy, waste reduction and recycling, and sharing to promote the "Circular Economy", a new economic model achieving economic growth by recovering, regenerating, and reusing consumed resources continuously.
8	Advanced observation and prediction technology related to natural disasters	A science and technology area for avoiding disaster damage so that no one is left behind, involving basic research to investigate the causes of natural disasters such as earthquakes, volcanic eruptions, and heavy rains that have occurred frequently in Japan in recent years, including technology for predicting the occurrence of these disasters, and science and technology related to national land conservation and design.

Figure 4. Eight areas with high potential of multidisciplinary and interdisciplinary fields



ID	Name	Summary
A	Advanced systems for distributing and using data	A science and technology area that collects, shares, analyzes, and utilizes a wide variety of large amounts of data such as industrial, medical, and educational data, personal information, and research data, while maintaining the balance between protection and use.
B	Robotic technology that blends into human society to support and expand various human activities	A science and technology area that supports and expands areas including various social and industrial activities such as manufacturing/services, medical/nursing care, agriculture, forestry and fisheries, construction, disaster response, in addition to individual abilities (e.g., memory and exercise) by integrating and utilizing autonomous robots, information terminals, and networks into human society.
C	Next-generation communications and cryptography	A science and technology area consisting of advanced encrypted technologies that support security in data usage in a wide range of fields, such as next-generation communication technology for wireless/wired and mobile devices that can use high-speed, large-capacity data that will be indispensable as an infrastructure for life and industry in general in the future society where data usage will increase.
D	Technology for preventing human errors in transportation	A science and technology area related to unmanned driving, maneuvering, and the operation of moving objects such as vehicles, aircraft, and ships based an intelligent transportation system by ICT to reduce the burden on humans and to expand the traffic capacity safely and efficiently in land, air, and sea traffic.

ID	Name	Summary
E	Disease prevention and treatment methods for life-course healthcare	A science and technology area related to research on genetic, environmental, and social factors related to diseases, research on the mechanism of aging/functional decline, development of prevention/diagnosis/treatment methods for age-related diseases, based on the concept of a life course approach that continuously captures the human developmental and experiential periods (fetal, infant, school-going, working, and old age) and provides appropriate prevention and treatment of diseases at each age stage, for lifelong health support (life course/healthcare) aimed at extending healthy life expectancy.
F	Sustainable agriculture, forestry and fishery systems that harmonize with ecosystems	A science and technology area for the development of agriculture, forestry and fisheries based on a data-driven approach and the relationship with local communities and resources through the sustainable and effective use of ecosystem services as a benefit that ecosystems provide to humankind.
G	Energy-related technology for a sustainable society	A science and technology area related to energy elemental technologies that are indispensable for the conversion from fossil fuels that emit CO2 to renewable energy as future energy technologies that will be the basis of daily life and industry to build a sustainable society.
H	Fundamental sciences for revealing the origins of the space and human beings	A science and technology area in astrophysics, which has developed rapidly in the 21st century, and aims to elucidate the basic science of various phenomena and existence related to the universe, which is still a mystery.

Figure 5. Eight areas focusing on specific fields

3.4 Scenario

Based on the fifty images of future Japanese society obtained through the investigation into the "future of society" and 702 S&T topics set through the investigation into "future of science and technology," we created the conceptual scenario as "the future images of society brought about by the development of science and technology" (Figure 6). The conceptual scenario consists of a description of the future society, relevant S&T topics, and societal issues to be discussed. Two axes (tangible/intangible, individual/society) are set, and the fifty images of future Japanese society are allocated to one of the four quadrants and embodied. The tangible/intangible axis assumes that virtual world will have more significant presence in our lives as the initiatives such as the "Society 5.0", the ultra-smart society are promoted. The individual/society axis is set based on the changes in the individuals (mainly focusing on two values of humanity and curiosity) and those in society (mainly focusing on two values of inclusion and sustainability).

The intangible - individual quadrant depicts a society in which people share values in communities they form beyond geographical connections, with geographical dispersion of resident areas and workplaces. The intangible - society quadrant depicts a cooperative society in which digitized information is shared, with connections for support work between humans and robots. The tangible - individual quadrant depicts a society in which new "individuality "extends mental and physical capabilities through the support of science and technology, leading to a society with higher quality of life. In the tangible - society quadrant, a society is depicted in which optimization with resource recycling achieves a balance with customization or human needs. Scenarios of each quadrant are as follows.

"Society of coexistence, rethinking what it means to be human and recognizing diversity"

This refers to a society where mutual understanding is promoted by sharing feelings and experiences through various means of communication, and where people live together while respecting each other's differences. Relevant scientific and technological issues include technology to support community formation, technology for normalization in daily life, and communication support technology.

- ✓ Society in which all people can live like human beings
- ✓ Society with diversities
- ✓ Society of coexistence

"Flexible society in which the real and the virtual are harmonized"

This refers to a society where data and knowledge are accumulated, shared, and utilized, and value is created by freely using virtual and real spaces to solve various problems and flexibly respond to rapid changes. Relevant scientific and technological issues include next-generation technologies of telepresence, security, automated driving, AI technology, and interface.

- ✓ Multi-dimensional society

- ✓ Data-shared society
- ✓ Healthy human/healthy earth

“Society that enhances individuality through fusing the maintenance/recovery of human functions with digital assistance”

This refers to a society where human mental and physical functions are expanded by science and technology, and each person acquires a new “individuality” by expanding their range of activities and their capacities through health management and maintenance according to individual characteristics. Relevant scientific and technological issues include technologies of pathological monitoring, the digitization of jobs, and technology to enhance skills and physical functions.

- ✓ Society with expanded physical functions
- ✓ Society with stable mind and body
- ✓ Everyone becomes a master

“Society in which personal customization and general optimization coexist, allowing individuals to have unique lifestyles”

This refers to a sustainable society where a new equilibrium point is found for partial and total optimization, and resources are appropriately allocated and circulated though individuals make their preferred choices without stress and act unintentionally. The relevant scientific and technological issues include technologies of next-generation energy, next-generation infrastructure, global monitoring and sensing, digital manufacturing, and recycling of resources.

- ✓ Prepared Society
- ✓ Optimized society
- ✓ Customized society

470 S&T topics were regarded as identified through linking the collation of the future images of society and S&T topics. Most of the topics in the health/ medicine/life sciences field, agriculture and fisheries/food/biotechnology field, and environment/ resources/energy field were expected to contribute to the realization of the desired society in 2040.

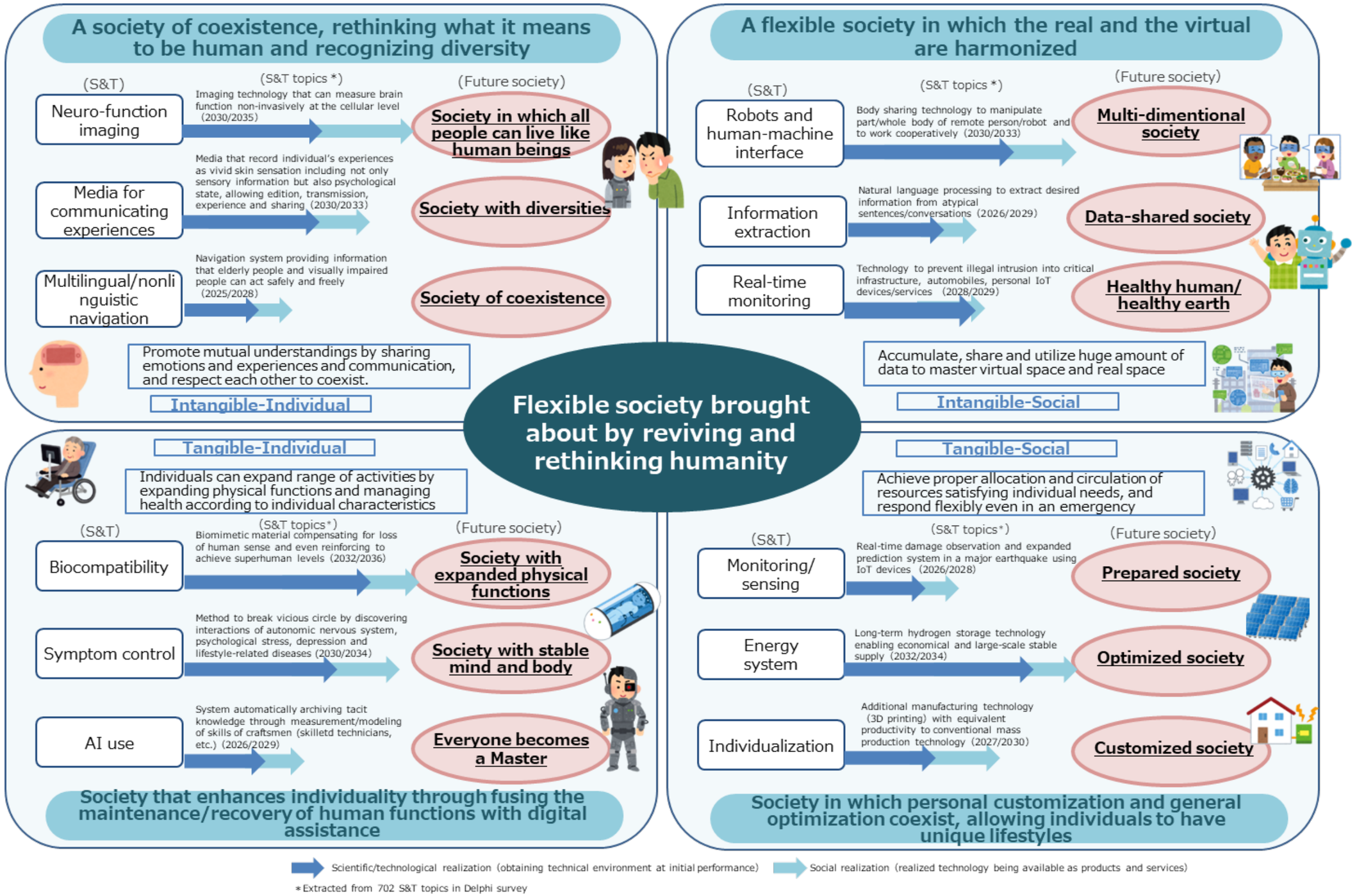


Figure 6. Future image of desired society brought about by the development of science and technology (Conceptual scenario)

4. Summary

The study aims to provide foundational information to contribute to formulation of science, technology, and innovation policies/strategies including the 6th Science, Technology, and Innovation Basic Plan. With social conditions as a given, we investigated the possibility of new science and technology, and depicted the future image of desired society based on science and technology development. In the investigation into the “future of society”, fifty future images of desired society and four values were extracted. In the investigation into the “future of science and technology,” opinions were received from 5,352 experts regarding the priority and outlook for achievement of the 702 S&T topics. Additionally, discussion on the automatic clustering of the 702 S&T topics took place, and eight areas with a high interdisciplinary potential and eight areas focusing on specific areas were extracted. In the final investigation into the future images of society brought about by the development of science and technology, the future of society and the future of science and technology were integrated to create the conceptual scenario.

In the study, we investigated desired future society based on science and technology development. It is expected that further discussions will take place, assuming other condition setting and changes. At the Science and Technology Center, we plan to set themes and perform a detailed investigation.

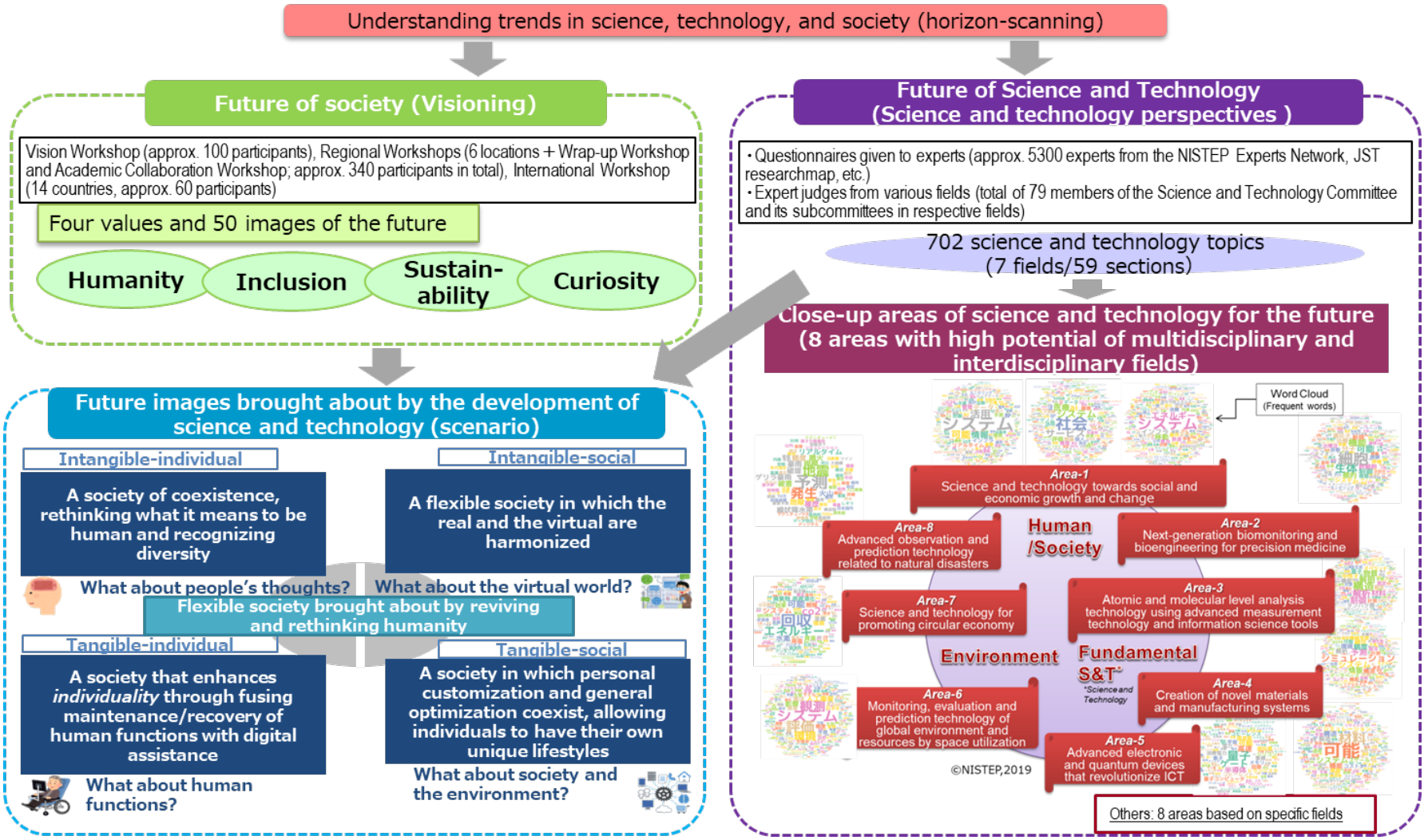


Figure 7. Overview of the study

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