Application Guideline-Annex

Chapter 6 Prioritized Theme for Research Proposals

R&D Type	Mission Areas / Prioritized Theme	R&D period	R&D costs	page
Small-start Type (Feasibility study)	**"Advanced Intelligent Information Society"** (R&D Supervisor (Program Officer): MAEDA Eisaku) Human-centric Digital Twins Services Utilizing AI, Big Data and IoT	up to two and a half years	up to JPY 35 mil.	4
	"New Social Challenges" (R&D Supervisor (Program Officer): TAKAHASHI Keiko) Sustainable and resilient social system for healthy nature	up to two and a half years	up to JPY 35 mil.	9
	"Society Optimized for Diversity" (R&D Supervisor (Program Officer): WAGA Iwao) Assistance and evaluation for enhancing human relationships	up to two and a half years	up to JPY 35 mil.	14
	"Low Carbon Society" (R&D Supervisor (Program Officer):HASHIMOTO Kazuhito) Realization of a low carbon society through game changing technologies	up to four and a half years	up to JPY 60 mil.	19
	"Common Platform Technology, Facilities and Equipment" (R&D Supervisor (Program Officer): OSAKABE Nobuyuki) Realization of common platform technologies, facilities and equipment that create innovative knowledge and products	up to two and a half years	up to JPY 35 mil.	33

*R&D periods represents terms of feasibility study. R&D costs represents direct cost for feasibility study.

For small-start type, JST sets prioritized themes for proposals based on mission areas selected by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), as shown below:

① Advanced Intelligent Information Society

In recent years, the rapidly evolving digitalization, data coordination and its utilization has created a new reality in which people, organizations, logistics—in reality, almost everything—are constantly connected on a global level and mutually influence one another. In this mission area, we aim to realize a next-generation information society that enables creation of new values and immediate response to uncertain and discontinuous changes through collection of diverse and reliable data in the real world and connection with various things to them.

② New Social Challenges

Japan faces a number of issues, including public health crises such as the new COVID-19 infection, unforeseen disasters, declining birthrate and aging population, climate change, rural-urban issues, food and resource problems, aging infrastructure, and the risk of natural disasters. Besides, there is demand for appropriate responses to the changes in Japan’s security environment, and the need to increase the resilience of our land and social functions. In this mission area, we aim to solve such emerging social problems.

③ Society Optimized for Diversity

In the future, people's life is expected to be changed intrinsically. The modes of behavior and action such as transportation, business practices, and lifestyle habits will be specifically released from the constraints of physical space and time, and thus transformed. In addition, human resources that have not been able to play active parts in the past will be released from restrictions, and the social diversity will be improved. In this mission area, we aim to realize a society in which merchandises and services are optimized for various users.

④ Low Carbon Society

In order to achieve a significant reduction in greenhouse gas emissions by 2050, we focus on technologies for energy creation, energy storage, energy conservation, stabilization of energy use, and carbon recycling, with the cooperation of related ministries and agencies to carry out seamless research and provide development support from basic research to practical application.

⑤ Common platform technology, facilities and equipment

We will promote common infrastructure technologies and advanced research equipment that will support a wide range of diverse R&D activities.

By means of this effort, we aim to：

・ Open up new interdisciplinary areas, support Japan's basic scientific capabilities as a foundation for the world's most advanced research achievements and contribute to the creation of sustainable science and technology innovation.
・ Contribute to the improvement of the competitiveness in Japan's measurement and analytical instrumentation industry by developing creative and original technologies and instruments that will drastically replace conventional technologies and instruments.

Meanwhile, while pursuing the above aims and objectives, we will specifically prioritize R&D activities in relation to the following subjects:

(i) High-risk, high-impact, advanced measurement and analytical technologies and equipment, etc.

(ii) Development of application and systemization concerning data analysis and processing

technologies
(iii) Development of technology that will contribute to increased productivity in R&D sites

6.1 Advanced Intelligent Information Society

R&D Supervisor (Program Officer: PO):
MAEDA Eisaku
(Dean/ Professor, Tokyo Denki University)

I. Goal of the Mission Area

Society 5.0 has been declared as the society that Japan is aiming for, and the Sixth Science, Technology, and Innovation (6th STI) Basic Plan states that the key to realization is to construct all elements of society as Digital Twins. In addition, as the fusion of the cyberspace and the real world is drastically changing our lifestyles and behaviors, placing humans at the center of system design (Human-in-the-Loop) is one of the essential requirements for the realization of Society 5.0. The creation of added value through the construction of Digital Twins has been making a progress in the manufacturing and other industries, but in recent years, there are growing expectations for the Digital Twinning of human activities and society itself, as well as Urban Digital Twins.

On the other hand, the society around us is facing uncertain and discontinuous changes, such as instability of the world order caused by geopolitical changes, worsening climate change, loss of biodiversity, intensification of natural disasters, and unexpected global epidemics of infectious diseases. Also, two advanced technologies, machine learning and genome editing, which have made rapid progress in recent years, will not only transform our lifestyles and industrial structures but may also determine the future of the human race. In this transitional period of great change, for individuals and society to respond appropriately to the uncertain and discontinuous changes that may occur in society, there are high expectations for the use of various data to predict the future and to support decision-making by individuals as well as a society based on such predictions.

Based on this background, in this Mission Area, “a next-generation information society” is defined as “a society in which all elements of society are digitally twinned and the lifestyles and behaviors of people and organizations are renewed" and by building Human-centric Digital Twins, we aim to establish information technology that can bring change to new lifestyles and behaviors of people and society, as well as industrial structures, and create new services based on this technology. In FY2022, we have set the goal of "Establishment of Human-centric Digital Twins utilizing AI, Big Data, and IoT" in order to advance the fundamental technologies for the construction of Human-centric Digital Twins and social implementation of the value realized by it.

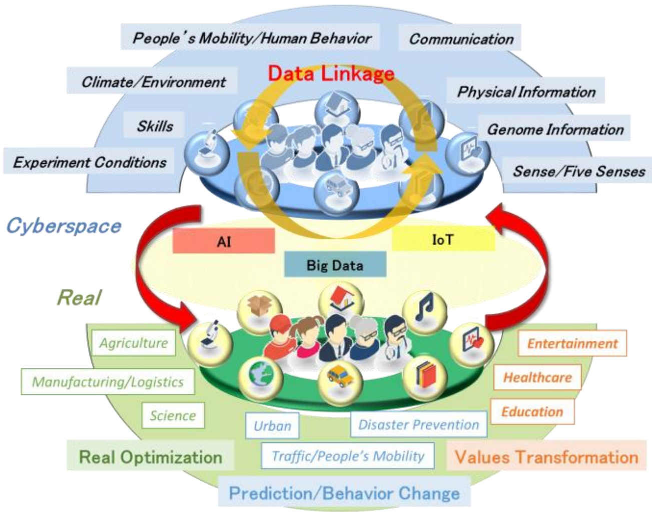

Fig.1 Concept of Human-centric Digital Twins

II. Prioritized theme

Human-centric Digital Twins Services Utilizing AI, Big Data and IoT

(1) Goal of the theme

In this prioritized theme, we aim to create services that transform people and society by digitally twinning all social elements, including human knowledge, with information technologies that make full use of AI, big data, IoT, etc.

These days, social reform and value creation through digitalization are being considered in all fields. In particular, the construction of Digital Twins, which is a reproduction of a real space, enables not only just digitization but also simulations based on realistic data in line with the real world to be conducted under enormous conditions. Digital Twins is being introduced in the manufacturing, agriculture, and healthcare fields, and is expected to expand its market to an even wider range of fields in the future.

On the other hand, the current Digital Twins is mainly targeted at physical systems easy to model, as it is difficult to construct systems that realistically reflect extremely complex human behavior and thoughts. However, without solving the difficult problem with placing humans at the center of system design, it will be difficult to realize a truly rich society in which humans and AI coexist.

In this prioritized theme, we consider the construction of Digital Twins that places humans at the center of system design (Human-centric Digital Twins) as the key to designing new future society, and will promote the development of technologies to realize it and the creation of new services by doing so. It requires digitization targeting at human beings, which involves various issues such as sensing of emotions and behavior, real-time conversion and processing of collected data, and data distribution that takes privacy into consideration. To solve these issues, it is essential to make full use of cutting-edge information technologies related to AI, Big Data, and IoT, including maintenance of data such as Big Data, measurement and sensing technologies, extraction of correlations between various data, data cleansing, real-time simulation and environment for data utilization.

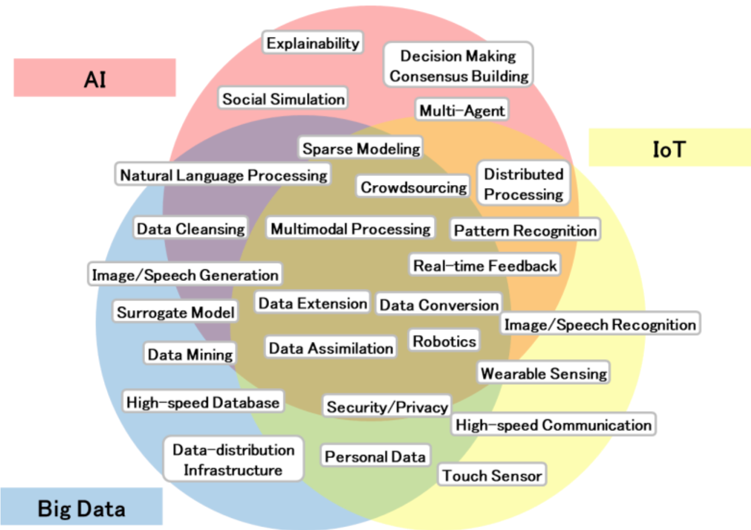

Fig.2 Examples of technologies for Human-centric Digital Twins

Although the purpose of the FY2021 prioritized theme "Human-centric Digital Twins Services" remains unchanged, the title has been changed to clarify the elements (AI, Big Data, IoT) necessary to resolve technological bottlenecks in building Human-centric Digital Twins, and the intention that we would like to require each proposal to have a concrete image of the future society that can be envisioned by such elements.

(2) R&D Supervisor’s policies for proposal selection, and R&D management

① Policies for proposal selection

The development of information technology has brought about a variety of innovations, and we are entering an era in which an infinite future can be envisioned. In addition to the “ideal future” considered by governments and policymakers and the “desired future” based on the hopes and expectations of consumers and companies, it is important to consider the "possible future" considering new possibilities and future prospects for lifestyles and industrial infrastructure from the perspective of researchers and engineers. The realization and Proof of Concept of the “possible future” may lead to changes in the “ideal future” and “desired future”. In this prioritized theme, we welcome original ideas that will serve as the basis for a “possible future” looking ahead to the future about 10 years from now.

In FY2021, we sought research and development proposals for a wide range of purposes. In FY2022, we will similarly accept proposals for “possible futures” from a variety of perspectives without any restriction on their fields. We are expecting innovative ideas that are not bound by existing concepts or academic disciplines.

Here, we will list examples of the future society by organizing the value that will be brought about by Human-centric Digital Twins as follows: a) optimizing the real with the cyberspace, b) predicting the future and encouraging people to change their behavior, and c) transforming values in the real and the cyberspace. These are just examples and we expect R&D applicant′s own innovative ideas and proposals based on consideration of technological scenarios to realize them.

(Assumed example) “Possible Future (Image of Future Society)”

a) Optimizing the real with the cyberspace
- Improving productivity through more efficient experiments. [Life Science and Agriculture]
- Sustainable society through an optimal environment and personnel allocation that take into account a personality and skills [Manufacturing and Logistics]

b) Predicting the future and encouraging behavior change
- A highly resilient society through real-time disaster risk prediction and visualization [Disaster Prevention]
- A society in which traffic and human flow are streamlined by avoiding traffic accidents, congestion, and overcrowding [Transportation]
- Smart society with appropriate real-time decision support [Urban]

c) Transforming values in the real and the cyberspace
- Implementation of a new learning and education environment that crosses the boundary between online and real life [Education]
- A society where people can experience and share their sensibilities in an immersive and simulated way through the cyberspace [Entertainment]
- A society where people can communicate through their senses, overcoming language and physical barriers [Education and Entertainment]

Please keep the following points in consideration when making a R&D proposal.

(About the scenario of the R&D proposal)
- Based on the purpose of the prioritized theme, the proposer should set the target field (e.g., industrial field as an outlet), POC (stage at which it can be determined whether a practical application is possible), indicate the requirements (e.g., peripheral technologies) for social implementation and the path for resolution.

- In the above, specify the "possible future" looking about 10 years into the future, and demonstrate the superiority and uniqueness of the R&D proposal based on science and technology that is not an extension of conventional technology, based on the proposer's strengths and domestic and international R&D trends.
- After the POC is achieved, specify how society and people's lives will change when technology is implemented in society.
- R&D proposals can be submitted even if the path to social implementation is not yet clear, as long as the original ideas and concepts are clear. Even in this case, the applicant should show objectively and concretely what is lacking at the time of the proposal and how it will be addressed during the feasibility study period.

(Presentation of goals for a feasibility study (FS) and full R&D project)

- Please clarify the concept of the POC achieved by the full R&D project and its social and economic impact. In addition, please quantitatively set and clarify milestones that will serve as indicators of the success or failure of the R&D plan.
- A feasibility study (FS) is to confirm the feasibility of conducting the full R&D project and achieving the POC, and the participants will be required to concentrate on solving technical bottlenecks, testing hypotheses, and team building necessary for the full R&D project concept.

(About the team structure)

- It is not necessary to organize the team to cover the entire R&D concept from the beginning. Nevertheless, if there are additional requirements that need to be met during the feasibility study period to realize the concept of full R&D project, clearly indicate which researchers will need to be collaborated with and the planned activities for collaboration.
- Based on the content of the R&D proposal, applicants may be asked to plan and participate in workshops for collaboration among proposals and team-building.

② Policies for R&D management

At the R&D management committee, we will establish a management system that can provide appropriate advice and guidance through the reviews of research plans and site visits, study groups, and so on. The R&D management committee, including the R&D Supervisor, the R&D management committee members and the R&D practitioners work together to promote R&D, aiming to achieve the theme goal.

A feasibility study is to confirm the feasibility of achieving POC, conducting R&D with an emphasis on solving technological bottlenecks and testing hypotheses, consider the composition of the R&D team consisting of companies and academia that is necessary and optimal for achieving POC, and brush up the full R&D project concept in preparation for full R&D project. Also, even during the feasibility study period, the project will proactively disseminate the results of the research when high-impact research results are obtained.

③ R&D period, timing of Stage-gate evaluation, and R&D costs

For FY2022, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2024) and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period. Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2024.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period.

After adoption, we will flexibly allocate the budget according to the R&D content.

6.2 New Social Challenges

R&D Supervisor (Program Officer: PO):
TAKAHASHI Keiko
(Senior Researcher/ Professor, Waseda University)

I. Goal of the Mission Area

The repetition of deterioration and improvement in situation of global pandemic caused by COVID-19 is about to bring major changes not only in our awareness and daily lives, but also in the relationships among global society, economy, industry, and the global environment. We are required to take actions, hammering out a design to solve the issues: what the key factors in shaping the world of the future are, and how we can overcome the social issues emerging or becoming apparent.

It has become clear that the spread and progress of human activities have a significant influence on the sustainability of the global environment, and that changes in the global environment affect human activities. It has also been pointed out that changes resulting from these interactions affect natural resources and social, economic, and industrial structures, which leads to uneven distribution of wealth and disparities. In addition, the negative by-product effects of science and technology are also being highlighted. Since the Budapest Declaration (1999) by the World Science Forum, "which states that the role of science in the 21st century is not only to create knowledge, but also to serve peace, development, and society," countries around the world have been promoting research and development to solve social issues, but they are still on the way.

The nature of social issues continues to change along with global social changes, changes in the global environment, and changes in our awareness. For example, regarding the public health crisis caused by the spread of infectious diseases directly related to life not just COVID-19, it has been pointed out that such a disease is carried by wild animals. Besides, it is also related to changes in natural ecosystems, the severity of natural disasters, depopulation, and changes in industrial structure. In addition, agriculture, forestry, and fisheries, which are related to many natural resources and are fundamental industries for human activities, are not only required to change due to the global environment, but are also deeply related to pollution by various chemical substances such as plastics, so this is an issue that is forcing us to review our economic activities. The depletion of natural resources, including water, has already caused people to move from one place to another, and at the same time, it has affected the food supply areas such as farmlands, creating various disparities. Furthermore, these disparities not only affect consumption and production, such as imbalance of natural resources, food loss, and waste disposal, but also lead to new environmental burdens. Solving these social issues has become very difficult. However, we need to take a serious look at these issues, reassess them from a new perspective, and find ways to resolve them. We believe that we are entering the era that our predecessors have never experienced before and requires the creation of new solutions.

Social issues cannot be solved by a single technological solution. Although science and technology are a major source of support, we must look beyond the walls of academic disciplines and organizations to understand the future from different points of view and continue to search for solutions with the cooperation of various people. In addition to the interrelationships and complexity of multiple issues, solutions to social issues must also take into account the uncertainty of future changes in society, the economy, and the environment, how to think about the balance between normal and emergency situations, as well as the balance between cost and risk. Methodologies for such solutions have not yet been established.

In this mission area, we aim to identify how to understand social issues, clarify the knowledge and technologies required to solve these issues, analyze, integrate, and develop new technologies, newly design inclusive social systems, and find a way to solve these issues in the real world. To achieve this, in addition to research and development of cutting-edge science and technology, it is necessary to work in new partnerships with social science, economics, mathematical science, etc., to collaborate with industry, and to actively promote strong partnerships with companies, governments, NPOs, etc. to incorporate new value created by the solution of social issues into the real world. We expect challenging proposals from young researchers and engineers with a desire to go beyond conventional academic fields and create society.

II. Prioritized theme

Sustainable and resilient social system for healthy nature
(1) Goal of the theme

As shown in the figure, this prioritized theme organizes the emerging social issues into seven categories and considers the four elements of digital, data, mathematical sciences, and ELSI as the foundations that support these issues. In FY2022, we will target at the multiple perspective shown ② in Figure with the perspective of "Food, Water, and Environment" and "Consumption and Production," which are internationally pointed out as urgent tasks, taking into account their relationship with "Decarbonization and Energy" and "Climate change, Disasters, and Infrastructure". In addition, regarding the sustainable and resilient social system constructed from social issues and their solutions, we will put emphasis on R&D proposals that include "novel creation of environment" and "maintenance of life and living organisms and utilization of biological resources" as key concepts.

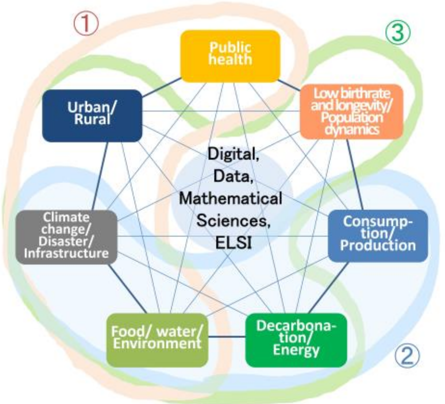

Fig. Three multiple perspectives envisioned for the seven categories and four foundations for solving emerging social issues

In multiple perspective shown ② in Figure, consisting of the categories of "Food, Water and Environment," "Consumption and Production," "Climate change, Disaster and Infrastructure," and "Decarbonation and Energy", these viewpoints are closely related, so solving from one viewpoint may cause new issues from another viewpoint. On the other hand, a single solution may lead to the solution of multiple issues. Therefore, to construct social systems, it is necessary to take multiple approaches and consider their interrelationship. Furthermore, social issues change not only with changes in the natural environment, but also with political, economic, scientific, and technological developments, etc. Therefore, it is more important to construct a social system as a solution to deal with changes than a unique and fixed solution. In other words, we design and construct social systems by quantitatively measuring, observing, and analyzing the interrelationships among the environment, resources, and flows of people and goods, and evaluating discontinuities and uncertainties, etc., and then quantitatively evaluate the systems themselves while assuming the effects of social systems applied to the real world on society, the economy, and the environment, etc. It is important to build a sustainable and resilient social system that solves issues by repeating the loop of feedback to the system.

For example, there is a multifaceted analysis system that not only designs smart agriculture, forestry, and fisheries through digitization of primary industries, but also extracts factors that can become trade-off relationship with human activities, ecosystem conservation and takes into consideration extreme events and outbreaks. Furthermore, we need to construct and realize a social system that can adapt to climate change and changes in social conditions, giving feedback to the original system with the evaluation results utilizing technology of impact assessment and risk management, etc. We believe that designing a mechanism for the cycle of reconstruction and realization through system development and feedback will lead to the realization of a sustainable society.

In this prioritized theme, we aim to solve social issues by finding solutions based on scientific knowledge and technological development for the realization and utilization of sustainable environmental and natural capital and by constructing a sustainable and resilient social system that enables us to give a feedback of impact assessment through the implementation of solutions and applying the results to the real world.

In FY2021, we focused on “Climate change” and “Disasters,” and actively sought R&D proposals paying attention to construction of a social system to prepare for a drastically changing environment and increasingly severe natural disasters, taking into account the relationship between urban and rural areas and public health (see ① in Figure). In FY2022, we added ″Consumption and Production″ and ″Decarbonization and Energy″ to the core focus, placing more emphasis on economic aspects. In FY2023, we plan to focus on ″Low birthrate, longevity and Population dynamics″ and ″Urban and Rural areas″ (③ in Figure). In addition, it is possible to submit R&D proposals from a perspective that goes beyond the multifaceted viewpoints emphasized in each fiscal year.

(2) R&D Supervisor’s policies for proposal selection, and R&D management

① Policies for proposal selection

Rather than R&D proposals that set out to solve social issues as an extension of the development and utilization of science and technology (seeds), <u>we seek proposals for designing social systems that can solve social issues by organizing the science and technology necessary to solve emerging social issues, and then adapt the results to the real world.</u> In particular, we welcome R&D proposals based on original ideas that will have a large impact when they are realized.

In FY2022, we will target at multiple perspective that take into account the relationship between “Food, Water, and Environment” and “Consumption and Production,” as well as “Decarbonization and Energy,” and “Climate change, Disasters, and Infrastructure”. In addition, emphasis will be placed on R&D proposals that include the key concepts of “novel creation of environment” and “maintenance of life and living organisms and utilization of biological resources”.

Specifically, we expect original R&D proposals that can directly contribute to solving social issues in the real world, such as the development of autonomous remote observation technologies with high temporal and spatial resolution; the construction of systems to integrate and utilize collected data; the establishment of forecasting and assessment technologies that take into account climate change, man-caused impact, biological response, and social and economic activities; the development of ICT technology applications that enable labor-saving and high-efficiency; the development of the development of new materials using chemicals and other substances that decompose easily and safely, the development of technologies for measuring material and energy balances from production to distribution and processing, the development of technologies related to ensuring life and biodiversity and to the recycling and regeneration of natural resources by combining these technologies, and the development of technologies to circulate and regenerate natural resources, the construction of sustainable social system that can regenerate our environment, information processing technologies effective for community formation and decision-making, etc. R&D proposals that go beyond the multiple perspective shown ② in Figure are also possible to submit.

When submitting an R&D proposal, please indicate the following points. Even if the proposal is at the conceptional or hypothetical stage, it is acceptable as long as it logically demonstrates what is lacking at the time of the feasibility study proposal and what efforts will be made during the feasibility study period. In addition, since the interrelationships among social issues vary depending on the environmental, social, and economic foundations, even proposals that aim to establish a social system for a specific area should objectively and logically demonstrate the possibility of cross-sectoral development.

a. Based on the interrelationship of focus points, what are the specific social issues that are emerging and that you are trying to solve?
b. Reasons for setting it as an emerging social issue
c. Future society after resolution (vision)
d. What are the characteristics of the emerging social issues when analyzed from the focus category
e. How to solve emerging social issues
f. Trade-offs, synergies, and difficulties in implementing the proposed social system
g. Ethical, legal, and social issues (ELSI) that should be considered to build a new social system
h. The recipients of the constructed social system and the POC that should be achieved (the stage where we can be determine whether practical application is possible)
i. Superiority and uniqueness of the R&D proposal in light of domestic and international R&D trends
j. R&D elements (scientific knowledge, data, mathematical sciences, technology, etc.) necessary to solve the issue, and methods of designing social systems
k. Social and economic impact of the new social system (estimates with evidence) and strategies to increase the ripple effect of the results
・ l. The structure necessary to build the new social system (it is not necessary to have all the teams necessary to achieve the POC when making a proposal. If so, please provide a plan for activities to build the system during the feasibility study period).

In preparing the proposal, a, b, and c should be filled in the Form 2 “1. Vision of the future society you want to acheive,” d, e, f, and g should be the Form 2 “2. Challenges in realizing the vision of a future society,” h should be the Form 2 “3. POC aimed at this R&D,” i should be the Form 2 “4. Technological difficulty level of proposal,” j and k should be the Form 3 “3. Contents of feasibility study,” l should be the Form 3 “4. Team to conduct feasibility study.”

② Policies for R&D management

Establishing a management system to provide appropriate advice and guidance through confirmation of R&D plans, site visits and research meetings etc. by R&D management committee members, we will promote R&D aimed at achieving goals of the theme, with R&D supervisory and the management committee members and R&D implementers working together.

Since the emerging social issues targeted in this area are important not only in Japan but also internationally, we will disseminate the activities and results of R&D projects not only domestically but also internationally, and actively promote network building that is effective for understanding, developing, and expanding the results.

Furthermore, we will not limit ourselves to technological development research that is an extension of the current seeds, but will take on the challenge of solving social issues in the real world through the construction of a new sustainable and resilient social system. Since "solving social issues" is the main focus of this area, during the feasibility study period, please consider R&D elements, initiatives, and system enhancements that should be added to construct a social system.

In addition, this area emphasizes the ability to plan for solutions, the ability to execute and realize plans, and the ability to involve diverse stakeholders, which are necessary for solving social issues in the real world. From the feasibility study period, please materialize not only R&D, but also the concept of full R&D project and POC in cooperation with potential leaders of social solutions, such as companies, governments, NPOs, and NGOs. The program will also provide support for finding and matching new collaborators who become necessary during the feasibility study period, by the R&D supervisory and management committee members.

In the stage-gate evaluation for the transition from feasibility study to full R&D project, we expect to confirm the degree of achievement of the feasibility study goals, the prospect and specificity of solving social issues in the real world, the size of impact, and the implementation structure, based on the R&D plan that was thoroughly reviewed and revised for its feasibility during the feasibility study period.

③ R&D period, timing of Stage-gate evaluation, and R&D costs

For FY2022, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2024) and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period. Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2024.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period.

After adoption, we will flexibly allocate the budget according to the R&D content.

6.3 Society Optimized for Diversity

R&D Supervisor (Program Officer: PO):
WAGA Iwao
(Senior Fellow, NEC Solution Innovators, Ltd.)

I. Goal of the Mission Area

In recent years, society has been optimized to respond to the economic growth and expansion and population growth. In addition to division and disparity in the society, mental problems have become more serious, and the modern society is now at a turning point. Furthermore, the spread of the new type of coronavirus infection has brought social unrest, accelerating the trend toward reconsidering the way our society should be. Against this background, the Sixth Science, Technology and Innovation Basic Plan clearly outlines a policy of change toward “a society in which the diverse happiness (well-being) of each individual can be realized”. In addition, interest in wellbeing is growing worldwide. The Great Reset, the global agenda for the next World Economic Forum Annual Meeting in Davos (the Davos Forum), scheduled to be held in the summer of 2022 (postponed from the previous year), refers to the need for “a shift to an economic system that prioritizes our collective well-being,” and corporate executives in Japan and abroad are taking steps in this direction. On the other hand, various surveys and reports show that the level of happiness in Japan ranks low among developed countries and is trending downward. However, conventional approaches centered on subjective evaluation methods may not be able to understand the actual situation precisely in a timely manner, so an approach based on scientific evidence is required.

In this mission area, we define well-being as a state of vibrant happiness in which each individual can be mentally and physically satisfied.We will work on creation of the science and technology to realize it, and to disseminate the results throughout society to promote the creation of new services. Specifically, we will multilayer the knowledge and techniqueste of natural sciences and technology on the wisdom of the humanities and social sciences, which have led well-being research, and will quantitatively understand the optimal state for each individual with a complex analysis that utilizes advanced information technology from the data obtained with sensing technology, which is the source of Japan’s international competitiveness. At the same time, we will try to develop methods to lead individuals, groups, and society to an optimal state of well-being by making full use of intervention methods based on convergence of knowledge. Considering the growing influence of digital technology omnipresent throughout our society, we aim to accelerate the transition from a society optimized for economic growth to a society optimized for the individual, focusing on people's diversity and happiness, without leaving anyone behind.

We expect our R&D projects to address social issues related to the maintenance and improvement of well-being along with this perspective. We welcome R&D proposals from many individuals who are expected to play an active role in academia and industry in order to obtain a desirable future and society through back casting, with the expectation that world-leading research areas will flourish in Japan.

This mission area aims to realize this goal through four steps (see figure). In FY2021, the first year of the area, we called for R&D proposals, focusing on the development of technology to measure the various factors that constitute individual well-being and to visualize dynamically changing conditions, with the aim of realizing a society that can realize well-being. These foci are globally recognized as important factors in well-being application but not yet solved by scientific and technological approach.

In FY2022, we set ”Assistance and Evaluation for Enhancing Human Relationships” as the theme to focus on the connection between individuals or within a group and relationships in society, which is considered an important factor for realization of well-being. In this mission area, where people are the subject of research and development, we believe it is important to emphasize diversity in both the management and R&D teams. We also believe that creating an environment in which researchers can concentrate on their research, while promoting research and development in cooperation with those involved in the management of the area and researchers, in necessary. In addition, we strongly request that R&D projects should be planned from the perspective of diversity, and that ethical, legal, and social considerations should be considered.

Fig. Roadmap to the goals of this mission area

II. Prioritized theme

Assistance and Evaluation for Enhancing Human Relationships

(1) Goal of the theme

(Background)

The acceleration of social change has brought to the fore issues related to social relationships, such as isolation and division. In addition, the way we communicate and build relationships with others is changing dramatically with the promotion and spread of telework and online classes in the COVID-19 pandemic. Under these social conditions, it has become increasingly important for individuals to be interconnected with others and to support each other in mutual understanding, and for people and society to lean on each other. Such social adaptation is considered to be closely related to abilities such as “social and emotional skills (※),” which includes diverse elements such as communication skills, self-control, and cooperativeness, as well as physical and mental health, which are components of well-being. These abilities are required as important capabilities for diverse individuals to be connected and to actively participate in a community. These abilities are cultivated in social groups and are enhanced in interactive relationships with others, but there are concerns about the impact of accelerating digitalization and the transformation of interactions with others. In addition, methods to assess these abilities based on scientific evidence or methods to effectively develop them have not been established. Furthermore, it has been pointed out that it is important to intervene in individuals in their early stage of life, such as in infancy and before school age, in order to acquire and improve these abilities, but it is not easy to intervene in these younger generations. In addition, many issues remain to be addressed in R&D when environmental factors that can influence the development of young people, such as adults in the home and community, are considered as the target.

※Social and emotional skills: skills involved in achieving goals, working with others and managing emotions, which are developed through learning and have an impact on an individual's life and ultimately on the social economy (OECD Report in 2015 “Skills for Social Progress: The Power of Social and Emotional Skills”).

(Goal)

The goal of this theme is to develop technologies lead to new products and services to support social adaptation in which diverse individuals build better social relationships through interactions that connect them to each other. For this goal, we will promote the growth and development of social and emotional skills through the integration of conventional developmental psychology and cognitive science with brain science, physiology, and information engineering, thereby realizing a society in which everyone can actually feel well-being.

(2) R&D Supervisor’s policies for proposal selection, and R&D management

① Policies for proposal selection

This theme does not require social implementation within the R&D period, but it does call for proposals that describe the way for technological development and its deployment that will contribute to solving specific social issues through product, service development or institutionalization. Please consider the R&D concept with its final outcome in mind.

(Regarding R&D subjects)

For R&D proposals, please set up a specific situation in which people are connected to each other, including cyberspace, as a place for interaction between individuals and others. As the target of the interaction, applicants are required to set up a variety of people who can be assumed to be involved in the situation. We seek to develop technologies to appropriately measure and evaluate Social and Emotional Skills, and to extend, develop, and grow social and emotional skills in the situation. Besides, the proposals for other abilities and skills that lead to social adaptation through interaction with others will be also eligible.

(Regarding required technology)

Individual technologies do not have to include unconventional and novel elements. Under the concept of practical application, we are also looking for initiatives that skillfully combine existing technologies such as digital devices, sensing technologies, and algorithms such as machine learning, or that utilize elemental technologies in unconventional combinations to overcome conventional technological bottlenecks. These technologies include the development of institutional design for groups and organizations. In addition, as long as the R&D of technologies target at people, we actively seek R&D proposals based on convergence of knowledge that integrates disciplines by incorporating analytical methods of the humanities, social sciences, and natural sciences. However, the superiority of the proposed technology over existing technologies and, in particular, its international competitiveness, must be stated in the proposal.

When proposing R&D, please keep the following points in mind.

(Regarding diversity)

In this area, emphasis will be placed on the perspective of diversity in terms of gender, age, region, etc. In your R&D proposal, please be sure to indicate which perspective of diversity you have adopted, both in terms of the structure and the content of the R&D. In particular, it is necessary to consider the balance of gender, age, region, etc. in the content of R&D. Please be sure to describe how biological, socioeconomic, or psychological differences were taken into account in the research methodology and plan, while targeting a variety of individuals.

(Regarding interdisciplinary collaboration)
Although emphasis will be placed on R&D proposals for collaboration in different fields of humanities, social sciences, and natural sciences, only one of these fields is acceptable at the time of proposal. If only one of the fields is selected, please describe in detail what you expect from the different fields from the viewpoint of strengthening the R&D proposal.

(Regarding addressing ethical, legal, and social issues, etc.)
In the case of the prioritized themes in which people are the subject of research and development, consideration of privacy, respect for the will of the individual (freedom of choice, free will to consent or withdraw consent, etc.), physical and psychological effects, ethical issues, and institutional issues in the management and use of acquired data are assumed. Please consider thoroughly the measures for solution to the issues and include this information in your proposal. We also welcome proposals that involve stakeholders such as communities and residents related to the targeted social issue. Proposals may also include how to resolve these ethical, legal, and social issues in order to achieve the goal of the theme and realize social implementation. If so, please describe the specific research and research structure, as well as the R&D costs (including a breakdown) associated with the research in the R&D proposal. For details on R&D costs, please refer to “③ Period and R&D costs”.

② Policies for R&D management

At the R&D management committee, we will establish a management system that can provide appropriate advice and guidance through the reviews of R&D plans and site visits, study groups, and so on. The R&D management committee, including the R&D Supervisor, the R&D management committee members and the R&D practitioners work together to promote R&D, aiming to achieve the goal of the prioritized theme.

While organizing an environment in which researchers can concentrate on their research and development, we will build a system that can provide a support they need in a timely manner, especially in the interdisciplinary collaboration and promotion of social implementation. In addition, research evaluation will be conducted from the viewpoints of social impact, science and technology, etc., based on the evaluation criteria set forth in this program. In addition, it is assumed that the program will provide necessary support for ethical, legal, and social issues in R&D targeting at human subjects as an area.

Furthermore, after the adoption of the proposal, it is assumed that the collaboration among the adopted research and development projects will be strengthened and the system will be expanded to achieve the thematic goals. To achieve the goals of this mission area, the R&D Supervisor, the members of the R&D Management Committee, and the researchers of the R&D themes will closely share information and constructively exchange opinions on the points to be strengthened in each R&D theme, and will also promote activities to incorporate outside opinions through public events.

③ R&D period, timing of Stage-gate evaluation, and R&D costs

For FY2022, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2024) and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period. If the R&D proposal also covers research to solve ethical issues, a separate evaluation will be conducted after the proposal is selected, and the R&D cost will potentially be increased. Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2024.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period.

After adoption, we will flexibly allocate the budget according to the R&D content.

6.4 Low Carbon Society

R&D Supervisor (Program Officer: PO):
HASHIMOTO Kazuhito
(President, National Institute for Materials Science)

I. Goal of the Mission Area

It is a global issue to build a “low carbon society,” in which the emission of greenhouse gases, especially carbon dioxide (CO_2), which is a cause of the global warming problem, should be suppressed. The “Paris Agreement,” adopted in the 21st session of the Conference of the Parties of the United Nations Framework Convention on Climate Change (COP21) held in December 2015, called for the parties to limit the temperature increase to less than 2°C compared to pre-industrial levels and to pursue efforts to limit it to 1.5°C. In correspondence with this agreement, the government of Japan set forth a target, “to reduce greenhouse gas emission in fiscal year 2030 by 26 % compared to fiscal year 2013,” in December 2015; to attain this target, the Global Warming Prevention Headquarters has determined to make steady efforts.

In addition, the “The Long-Term Strategy under the Paris Agreement” (Cabinet Decision in June 2019; hereinafter referred to as the “Long-Term Strategy”) proclaims a “decarbonized society” as the ultimate goal, aiming to accomplish it ambitiously as early as possible in the second half of this century, while boldly taking measures towards the reduction of GHG emissions by 80% by 2050. In addition, the “Environment Innovation Strategy,” compiled by the Council for Integrated Innovation Strategy in January 2020, lays out a roadmap for establishing innovative technologies and implementing them in society to achieve the greenhouse gas emission reduction targets set forth in the Long-Term Strategy, and in October 2020, former Prime Minister Suga announced that Japan will aim to reduce greenhouse gas emissions to net-zero by 2050 (realization of carbon neutrality).

To attain this target, we need an innovative technology based on a completely new concept and science, in other words, the creation of “game changing technology.” For the creation of a game changing technology, completely new proposals made by researchers in different fields are also important, in addition to the challenging proposals that may result from the integration, utilization, and/or development of the forefront research methods by researchers in this field.

To promote the creation of a game changing technology based on the proposals for prioritized themes we called for from the general public as well as on the interviews with experts in relevant specific fields and other fields, we, in our R&D management committee, examined the prioritized theme for FY2022. As a result, we came to a decision that it was extremely important to make continuous efforts to develop innovative technology; thus, the prioritized theme was set as a continuation from FY2021, “realization of a low carbon society through game changing technologies.”

By creating game-changing technologies, which are innovative technologies based on completely new concepts and science, and implementing the results in society in collaboration with JST's other projects and the efforts of other ministries and agencies, we aim to contribute to the realization of a low-carbon society that will drastically reduce CO_2 emissions while satisfying the service demand expected in 2050.

II. Prioritized theme

Realization of a low carbon society through game changing technologies
(1) Goal of the theme

We aim to create a game changing, innovative technology based on a completely new concept and science, and cooperate with other JST projects, endeavors by governmental bodies and others to implement our achievements in the society, satisfying the demands for services that are expected to be present in 2050 and contributing to the realization of a low carbon society where CO_2 emissions are drastically reduced.

As mentioned above, the “Plan for Global Warming Countermeasures,” a cabinet decision in the year 2016, set up a target as the strategic objective with a long-term target in view; that is, “to pursue efforts to reduce the emission of greenhouse gas by 80 % by the year 2050.” To attain this target, it is “essential to create the innovation that realizes a drastic reduction in the amount of emissions in the whole world, including those technologies that are not a continuation of any conventional reduction technology;” therefore, it is one of the roles our country should play to strongly promote the mid- and long-term R&D in the field of energy and environment for realizing innovation in the reduction of CO_2 emission with wisdom gathered from the industries, academes, and governmental bodies and spreading the outcome to the world. This is also the concept included in the long-term strategy and “Progressive Environment Innovation Strategy” determined in January 2020. The concept of the creation of a game changing technology addressed in this mission area agrees with these strategies and we will promote the R&D that are closely connected to the public interest.

Furthermore, we, considering the R&D funds from the government and also the impact on the society, expect that the point of view of “the cost engineering of a low carbon technology” should be included in the proposals in this mission area. This is for the rational forecast of the technology development at the time of a low carbon technology and system being introduced in the society in the future and also for the assessment of the effect on reducing the amount of CO_2 emission; this is also an important viewpoint for attainment of the target by the year 2050, namely, the 80% reduction of greenhouse gas emissions. We hope that, with respect to the low carbon technology and system within the scope of the issues in the proposals, examinations should be made from the perspective of the cost, on the timing of the establishment of a technology as well as the timing of its industrialization, on the outlook for the market size, and on other aspects; in addition, we also hope that certain measures (scenarios) for the solution of these issues should be presented.

As for the point of view of the contribution to the international society, we can also assume, for instance, that we should use excellent technology to advance the endeavors or any other effort in cooperation with willing developing countries or any other country, such that our country may use its technological ability to play a core role in reducing the amount of CO_2 emissions around the globe. In the world of industries, the Japan Business Federation (Keidanren) has compiled the “Commitment to a Low Carbon Society” (formulated in January 2013, revised in April 2019) and established the “Development of Innovative Technology” as one of the mainstays in their plans, stating that “we also make use of the cooperation among industries, academes, and governmental bodies to proactively cope with the development and practical implementation of the innovative technology in a mid- to long-term period.” We can expect that we, apart from contributing to corporations in reducing their CO_2 emissions to attain the target of reduction, may be on the direct path to the enhancement of the industrial competitiveness of Japan only if an innovative technology is created to contribute to the solution of any bottleneck issues that hinder the low carbon application aimed at in this mission area, and the technology is transferred to corporations.

Fig. 1 shows an overview of this mission area.

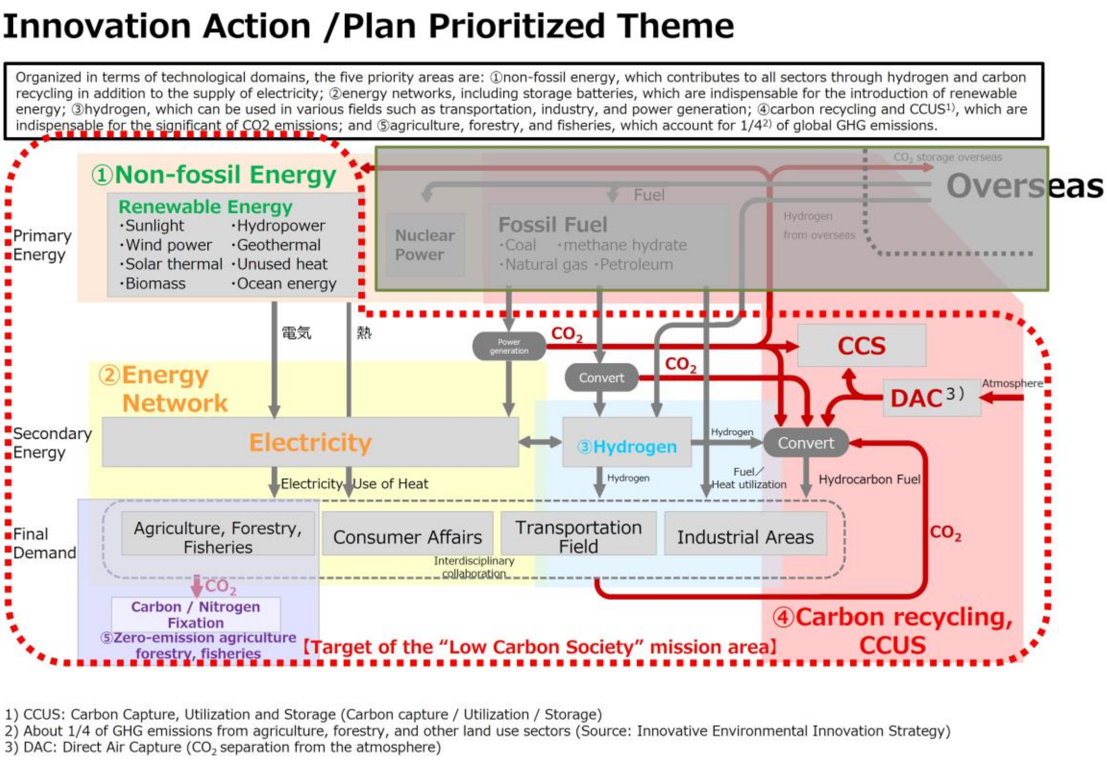

Fig. 1 An overview of the “Low Carbon Society” mission area
(Correspondence between the targets of the low-carbon society mission area and the sub-themes set in the Innovative Environmental Innovation Strategy)
Source: "Innovative Environmental Innovation Strategy" (January 21, 2020) by the Integrated Innovation Strategy Promotion Council

We classified the fields of the technologies in relation to low carbon emission into three Technology-Field; then, based on the analysis of the contents in the prioritized themes called for from the general public as well as on the “bottleneck issues” (the technological issues in implementing achievements in the society) presented thus far, we reset our bottleneck issues to call for more R&D proposals for solving those issues.

Technology-Field	Classification	Bottleneck Issue
①Water electrolysis and fuel cells	R4-B1	Hydrogen production by water electrolysis without noble metal electrocatalysts using neutral aqueous solution
	R4-B2	Hydrogen production by water electrolysis using seawater without chlorine evolution

	R4-B3	Electrolyte membrane for fuel cells of wide operation range and high durability
	R4-B4	Electrocatalyst and catalyst layer for fuel cells of wide operation range and high durability
②Biotechnologies	**R4-B5**	Development of low-carbon technologies through efficient use of new biological resources and biological information
	R4-B6	Technologies for improving biomass productivity with minimum resource input
	R4-B7	Synthetic biological technology and innovative bioprocess technologies for designing cells with high productivity for useful substances
③Other(Solar energy conversion, semiconductors, etc.)	**R4-B8**	New concept solar cells using nanostructures and unused energy
	R4-B9	Artificial photosynthesis aiming for dramatic improvement in efficiency
	R4-B10	3DIC heat dissipation technology
	R4-B11	Process and device technologies for 3D integration of next-generation oxide semiconductors
	R4-B12	Development of technology for practical application of CMOS using 2-D layered materials
	R4-B13	New approaches for realizing a Low-Carbon Society

*Technology-Field" here refers to those in sub-classification of the bottleneck issues.
* For a description of individual bottleneck issues, please refer to (3) Explanation of Each Bottleneck Issue.
* Describe the names of the prioritized themes, Technology-Field numbers (① – ③), Classification of Proposals (R4-B1 – R4-B13), and the names of the bottleneck issues in the "application to prioritized themes" on the cover sheet of the R&D Proposal Document (Form 1).

【Example of the description】

Prioritized theme	Realization of a low carbon society through game changing technologies ① R4-B1: Hydrogen production by water electrolysis without noble metal electrocatalysts using neutral aqueous solution

* Individual bottleneck issues are not necessarily independent and maybe interrelated, thus it is expected that an R&D proposal may relate to multiple bottleneck issues. In that case, select the bottleneck issue to which the technology is most strongly related or " ③ R4-B13: New approaches for a low-carbon society" to be submitted.

(2) R&D Supervisor's policies for proposal selection, and R&D management

① Policies for proposal selection

There are, roughly classified, two types of approaches to solve the global warming problem; that is, "measures for applicability" and "measures for mitigation." The former indicates the adjustment of the state of nature and/or the society to reduce the influence of the warming, whereas the latter indicates the suppression of the emission of greenhouse gas per se. For the measures for mitigation, the expectation is high with respect to the contribution by scientific technology; we, in this mission area, we look forward to R&D proposals aimed at creating a game changing technology that contributes to the realization of a low carbon society based on measures for mitigation.

Please note the following points when submitting R&D proposals.

(About the proposals to expect)

We select proposals by following the requirements listed below to adopt the issues that meet the concept of this program (the verification of the concepts based on innovative R&D).

・To be able to make a great contribution to the reduction of CO_2 emission (beyond the point of view of science)
・To propose a technology required by corporations that will undertake the burden of its implementation in the society
・ To propose innovative research that ought to be managed by universities, colleges, and/or other academic institutes

(Evaluated items and norms)

The selection will be based on the criteria described in “Chapter 2, 2.9 Selection viewpoints,” but in this mission area, we put an emphasis on the quantitative representation of contribution of the technology to be evaluated, including the potential amount of CO_2 reduction throughout the process in which this technology is used, to the realization of a low carbon society around 2050.

② Policies for R&D management

Establishing a management system to provide appropriate advice and guidance through confirmation of R&D plans, site visits and research meetings etc. by R&D management committee members, we will promote R&D aimed at achieving goals of the theme, with R&D supervisory and the management committee members and R&D implementers working together.

JST, since year 2010, has been continuing "Advanced Low Carbon Technology R&D Program" (ALCA). In the ALCA, we have adopted "the Small Start & Stage-Gate method" as a program that is specialized for the R&D to realize a low carbon society. This method is an endeavor for adopting a large number of relatively less budget-consuming issues when we adopt them (small start), and, once they have successfully passed our stage-gate assessment, we expand the scale of the research by placing focus on them.

Besides this, we have more endeavors such as cooperating with the Ministry of Economy, Trade and Industry and other governmental bodies in relevant programs and projects etc., providing the measures for accelerating R&D aiming at the implementation of the achievements and transferring it for practical applications in the society in around year 2040.

In this mission area, we follow the principles of the ALCA management and advance the R&D with more challenging targets, aiming to contribute to the significant reduction in greenhouse-gas emission by around the year 2050. In addition, we, as part of the ALCA, will advance R&D programs with the same goal, i.e., the realization of a low carbon society, aiming at synergy effect (Fig. 2).

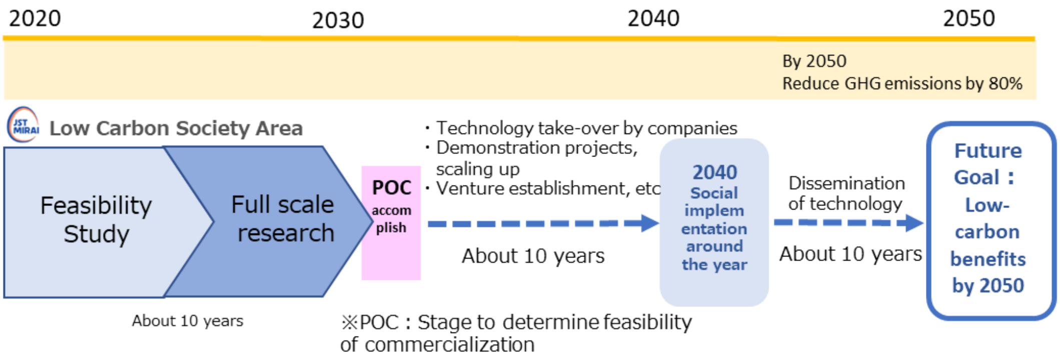

Fig. 2 A roadmap for the realization of a low carbon society

Furthermore, in this mission area, when a large impact is estimated on the society and/or the industrial world based on the solution of a bottleneck, we can expect a rapid implementation and/or application in the society and/or the industrial world; therefore, even if the period of a feasibility study is incomplete, we will proactively examine the transfer to full R&D project. Moreover, if the R&D Supervisor determines the necessity for the maximization of the social and/or economic impact, we may integrate two or more R&D issues and reorganizing research teams, etc.

(Assumption on where achievements are applied)
In this mission area, the challenging R&D are advanced for the solution of the bottleneck issues stated above; therefore, some of the technologies included here may take years to be applied to a practical use. This is why we start cooperation at early stages with other programs at JST and programs provided by other governmental bodies; besides the transfer of the achievements to the industrial sector, we will examine transferring the issues requiring further endeavors to other R&D programs that are closer to a practical application.

(Cooperation with relevant programs)
We will promote the cooperation with, among the pilot research programs of NEDO, “Untrodden Challenge 2050” started in 2017. Cooperation begins in the evaluation process. To create innovative R&D for the realization of the low carbon society in the year 2050, JST promotes solutions of the bottleneck issues by mainly focusing on the fields of academia, whereas NEDO aims to solve the issues, viewing the needs of the industrial world, mainly based on cooperation between the industries and academic institutions.

③ R&D period, timing of Stage-gate evaluation, and R&D costs

For FY2022, a feasibility study should be planned with a period of up to four and a half years (up to end of FY2026) and a total cost of up to JPY 60 million (direct costs) for the whole feasibility study period. In this mission area, the initial budget is small (small start), and after the stage-gate evaluation, the budget is prioritized. In consideration of the purpose of the small start, we may request a review of the budget plan after the adoption.

The period of the full R&D project at the proposal phase is five years at the maximum; the upper limit of the R&D cost in your plan must be JPY 380 million (direct costs) in total, covering the whole period. The period and the budget for the full R&D project are determined based on the stage-gate evaluation of the feasibility study.

After adoption, we will flexibly allocate the budget according to the R&D content and stage-gate evaluation.

(Stage-gate evaluation)

In the case of the assessment at the stage-gate, we assess whether research is heading for the realization of a low carbon society in the future or, namely, if a proposal contributes to the targets in this mission area. The assessments at the stage-gate are not merely the means for “sifting out proposals” but rather “for the correct awareness of the direction of excellent research and, at the same time, for its effective enhancement and growth.” Therefore, this is a method of fostering the technologies that may have a great contribution to the reduction in CO_2 emission in the future.

In this mission area, the transition to “full R&D project” is carried out in FY2027 in principle.

In this mission area, there are two types of stage- gate evaluation, one for evaluating the progress of research (achievement of milestones) in feasibility study, and the other for evaluating whether the project can proceed to full R&D project. Each project needs to receive the stage- gate evaluation for milestones at least once prior to the stage- gate evaluation for the transition to full R&D project. The timing of the milestone and stage- gate evaluation will be decided after the adoption, by taking interviews with the responsible R&D management committee members. Depending on the progress as a result of stage- gate evaluation, the early transition to the full R&D project will be also considered. In the phase of full R&D project, we, being well aware of “the possibility of the contribution to a low carbon society,” take management to accelerate the R&D for the implementation in the society.

(3) Description of each bottleneck issue

① Water electrolysis and fuel cells

R4-B1 to B4 Sustainable production using renewable energy and efficient utilization of hydrogen by water electrolysis and fuel cells, respectively.
R4-B1 Hydrogen production by water electrolysis without noble metal electrocatalysts using neutral aqueous solution
R4-B2 Hydrogen production by water electrolysis using seawater without chlorine evolution
R4-B3 Electrolyte membrane for fuel cells of wide operation range and high durability
R4-B4 Electrocatalyst and catalyst layer for fuel cells of wide operation range and high durability

In order to realize a low-carbon society, Japan needs to drastically reduce carbon dioxide emissions (80% reduction in greenhouse gas emissions by 2050). Hydrogen has attracted much attention as a clean energy carrier for a long time as it contains no carbon and emits no carbon dioxide (CO_2) when it is used.

Currently, hydrogen is produced from fossil fuels such as petroleum, natural gas, and coal, and it cannot be called as a clean energy because CO_2 is produced as a by-product of hydrogen production. By applying Carbon Dioxide Capture and Storage (CCS) technology to the generated CO_2, hydrogen is treated as a “CO_2-free” energy (blue hydrogen).

While there are high expectations for real CO_2-free hydrogen (green hydrogen) obtained by water electrolysis using electricity produced by renewable energy such as solar and wind, there are a wide range of issues to be addressed, including cost, efficiency, response to the load fluctuation, and life. Since they are contradicting factors, strategic research and development are required. For example, alkaline water electrolysis, which is currently used for large-scale water electrolysis because of its low cost, has remained challenges for adapting to fluctuating power by renewable energy and the improvement for hydrogen production efficiency. On the other hand, polymer membrane water electrolysis, which is highly adaptable to frequent start-and-stop, is more suitable for blue hydrogen production by fluctuating renewable energies, but expensive noble metal electrocatalyst should be used with current acid-type electrolyte membranes and the development of novel materials which allow the electrolysis operation without noble metals is needed so that cost reduction can be achieved. In addition, to produce hydrogen on a large scale and sustainably, it is particularly important to produce hydrogen by electrolysis from seawater that is abundant but currently not used. When seawater is electrolyzed, chlorine gas, which is toxic and deteriorate equipment and environment, is preferentially evolved at the positive electrode. Therefore, the establishment of seawater electrolysis technology that does not generate chlorine is required.

By supplying hydrogen produced and stored in this way to fuel cells, it can be converted into electricity when needed. Although fuel Cell Vehicles (FCVs) and stationary cogeneration systems using Polymer Electrolyte Fuel Cells (PEFCs) with proton-conducting polymer membranes, that can be compact and lightweight and allow quick start and stop are commercially available, there are many issues such as the improvements of performance and durability and the cost reduction to be solved before the full-scale spread of fuel cells. The applications of PEFCs for commercial vehicles such as trucks, buses, and construction vehicles, train, and ships are expected to have significant effects on reducing CO2 emissions from diesel engines, expanding the use of hydrogen, and the cost reduction of PEFCs. For such PEFC for heavy loads to be realized, it is essential to develop materials (electrolyte membranes and electrode catalysts) that can maintain both high performance and durability under very wide ranges of temperature and humidity.

Based on the above, we are looking for the following technologies that can solve these bottleneck issues.

- Hydrogen production by water electrolysis without noble metal electrocatalysts using neutral aqueous solution
- Hydrogen production by water electrolysis using seawater without chlorine evolution
- Electrolyte membrane for fuel cells of wide operation range and high durability
- Electrocatalyst and catalyst layer for fuel cells of wide operation range and high durability

② Biotechnologies

R4-B5 Development of low-carbon technologies through efficient use of new biological resources and biological information

Several microorganisms such as E. coli and yeast are widely used in bioproduction, but the bioindustry desires innovative microorganisms that are easier to use and it is explored worldwide. In addition, only about 1% of microorganisms has been cultured using conventional microbial culture technologies, so uncultivated microbial resources exist. Recently, huge biospheres have been found in the deep subsurface and deep sea, revealing one unknown microbial community after another, and it can be said that enormous biological resources remain untapped. Furthermore, Japan is rich in endemic plant species, and new discoveries of a wide variety of phytochemicals and biosynthetic genes are expected to be developed for the production of useful substances. These discoveries have been enabled by recent breakthroughs in genetic information analysis, such as metagenome analysis and long-read analysis. It has become clear that there are many genes whose functions are unknown (dark matter), such as gene sequences and non-ATG initiation proteins that cannot be annotated with the current information. In addition, the analysis of proteins by mass spectral analysis and structural analysis is also progressing rapidly along with computational science using AI and other methods. There is a great potential in the search for molecules with new functions and the development of production processes that utilize the unknown biological resources and biological information obtained through the above-mentioned analysis.

However, it takes an enormous amount of time and effort to discover new bioresources and biological information and to understand their functions, so there is expectation for technologies that enable us to analyze the functions of unknown genes and visualize gene interaction simultaneously as well as new technologies that can utilize the discovered new bioresources and biological information. In this context, we are calling for the development of technologies to efficiently search for new bioresources and biological information that will contribute to low-carbon society, and technologies that will lead to low-carbon society through the production of new materials and energy by utilizing the obtained bioresources and biological information. Specifically, we expect the following examples of proposals

- Exploration and utilization of useful new microorganisms and biomolecules that innovate conventional bioproduction. For example, microorganisms that can store an overwhelmingly large number of products inside the cell, microorganisms that selectively expel products from the cell, microorganisms that can easily capitalize on C1 compounds such as CO_2 and formic acid, microorganisms that can grow on inexpensive culture media like on eutrophic media, microorganisms and biomolecules that can maintain growth and production regardless of high or low temperature
- Technology and its application to search for new plant resources and plant-derived gene clusters that contribute to low carbon emissions
- Technology that can be easily incorporated into consortia and cellular modifications using macro information such as satellite information and ecosystems
- Methods for the elucidation of unknown gene function and quick analysis of gene function, and the use of such methods. Elucidation of unknown genome function from analysis of large amounts of phenotypic information and its use. Technology to facilitate large-scale modification of genomes.
- Development of highly efficient gene transfer to plant cells and plant body regeneration. Development of diverse material production technologies through synthetic biology and metabolic design of plant cells.
- Bioinformatics for the discovery and analysis of new biological resources that contribute to low carbon emissions
- Microorganisms and biomolecules with energy-creating functions that efficiently store and release necessary energy, capacitor functions, and robustness to avoid stress

R4-B6 Technologies for improving biomass productivity with minimum resource input

The methods for increasing the amount of biomass production of plants contributing to CO_2 reduction include the expansion of the habitat and productivity increment and enhancement. In either case, it is understood that the effective measures here include the feasibility of the culture with a small amount of water and nutrients and the development of plants that can sustain their yields and growth in various unsuitable environments by being extremely durable against environmental changes, and resistance against disease and vermin; however, there is no technology for any drastic solution yet. Furthermore, investing in water, nutrients, and other resources means, in other words, investing in energy; moreover, suppressing such energy investment is important from the viewpoint of energy efficiency per yield. Moreover, the states of the growing of plants are largely different depending on the difference in the soil; the difference in microbial florae may be regarded as one of the important factors to make such difference, but its clarification and its efficient control are among the issues in the future. Abiotic development such as information analysis and programs to realize these breeding is also important.

With these considerations, we are calling for proposals for the development of revolutionary plant thremmatology for growing plants even with extremely little amount of resource investments to obtain plants that are robust against the environment, for instance, such as the following:

- Development of breeding techniques by promoting the intake of substances into plants and/or the transfer in plants and enabling the use of a nitrogen source that cannot be used up until now, by adding a new metabolic pathway
- Development of technology to realize optimum design and/or breeding so that we can maintain the balance of a plant at a high level as a whole by way of some link to photosynthesis, metabolism, hormone,
- Development of technology to use microorganism agents by isolating and identifying those symbiotic microorganisms that contribute to the acceleration of growth and improve resistance against diseases and vermins, based on the understanding of the interactions with the microorganisms cohabiting with plants and the chemical compounds that can control environmental microorganism groups
- Research on identifying the optimal composition of microbial florae for excellent culturing fields; development of technology to cultivate plants that maximizes the functionality of microbial floras to establish the use of microorganism in technology to increase the production of plant biomass resources for practical use; and R&D on using genome information to modify plants.
- Information analysis with respect to the plants and soil in culturing fields, and development of data-based breeding prediction modeling program
- Development of innovative methods of producing low-energy biomass resources from the viewpoints of engineering with respect to the plants

R4-B7 Synthetic biological technology and innovative bioprocess technologies for designing cells with high productivity for useful substances

When you introduce a bio-process to the production of a substance and, thus, reduce the energy required for the production, you can expect a reduction in CO_2 emission. When you aim for the generalization of bio-processes and scaling them up, and when you advance omics analysis, system biology, flux analysis, genome editing, and genome synthesis technology, then you can introduce an artificial metabolic pathway in microorganisms and impart a new ability to produce the substance. These kinds of researches are expected to develop technologies to synthesize chemical products from a variety of sugar sources and low molecular weight gas such as CO_2 and methane. The production of substances from CO_2 by photosynthetic microorganisms is also expected.

However, even if a pathway is introduced, it has been frequently observed that we cannot attain any sufficient productivity because of factors such as the short duration, the absorption into redundancy, the failure to attain the expected degree of effectiveness, the deterioration of the growth speed caused by some disorder in the balance of metabolism in cells or of energy, oxidation, and reduction resulting from the alteration and/or introduction of the pathway. In addition, it is necessary to reduce the amount of energy input for the production of the substance; for this purpose, it is necessary to develop a new method after determining the functions of autotrophic microorganisms. Furthermore, there is another issue: target products present toxic characteristics and, thus, their productions are not feasible. There is also a hurdle to overcome in large-scale cultivation: unlike in the laboratory, tends to have low productivity.

In order to solve these issues, we are calling for proposals on developments contributing to the synthetic biological technology for the designing of cells to realize the overall optimum production of substances by, for example, combining an artificial metabolism pathway with reduced energy and power supply systems. The development of optimal microbial and cellular designs for large-scale culture is also open to the public. For instance, we are expecting the proposals such as the following.

- The development of high-efficiency ATP and/or reduced power regeneration systems that can be introduced commonly to a variety of microorganisms
- The technology to use the functions of autotrophic microorganisms, including the ability to supply electrons, the ability to supply chemical energy, and the ability of carbon fixation
- The establishment of a method that can realize an efficient creation of artificial enzymes necessary for artificial metabolism pathways
- The establishment of a rational method of designing genetic circuits that can produce even highly toxic substances with enhanced yields and energy efficiency
- The development of the designing tools for synthetic-biological designing by using the above-mentioned ways
- The development of the platform host cells suitable for synthetic-biological developments
- The development of robust microbial optimal for large-scale culture
- The new process development to easily connect / link both biological and chemical processes

③ Other (Solar energy conversion, semiconductors, etc.)

R4-B8 New concept solar cells using nanostructures and unused energy

The theoretical maximum conversion efficiency of a single junction solar cell is about 30%. This is because ordinary solar cells cannot absorb light with energy lower than the bandgap, and excess energy is lost as heat in the case of light with higher energy. On the other hand, quantum dot solar cells can form an intermediate band within the band gap, and it has been pointed out that most light energy can be converted into electricity. Therefore, intermediate band solar cells are expected to theoretically achieve efficiencies of 60% or more in a concentrating mode. However, the conversion efficiency obtained is low, and it is necessary to optimize the intermediate band materials and the formation method of quantum dots, and the solar cell structure, in addition to fundamental studies including the validity and feasibility of theoretical models. In this category, we are inviting for challenging R&D proposals aimed at realizing solar cells with unprecedentedly high conversion efficiency through the design of solar cells using new concepts such as quantum effects and photon management, the development of materials, and cell structures based on these concepts. There are no restrictions on the materials, but the R&D proposals must demonstrate the advantages over conventional solar cells, as well as specific fabrication methods and efficiency targets. Combinations of conventional technologies, such as the combination of photovoltaic and thermal power generation, are not eligible for application. For example, R&D proposals such as the following are expected.

- High-density quantum dot system fabrication technology that achieves long carrier life and high efficiency solar cells
- Development of ultra-high efficiency solar cells utilizing new phenomena such as multi-exciton generation and hot carriers
- Development of ultra-high efficiency solar cells by photon management using photonic crystals and plasmons
- New theoretical proposal for ultra-high efficiency and its experimental practice
- Development of an unprecedented new solar cell that dramatically increases efficiency by using light and heat simultaneously

R4-B9 Artificial photosynthesis aiming for dramatic improvement in efficiency

Artificial photosynthesis is an ultimate goal for realizing a low carbon society. The methods to activate stable small molecules such as water or carbon dioxide to convert to the useful substances such as hydrogen or methanol using sunlight, and development of catalysts that promote such converting process are the very important bottleneck issues. Another important issue is the development of fundamental technologies to convert only solar energy into energy carriers with high energy density. Projects concerning hydrogen generation by aqueous photodegradation or photochemical synthesis to produce useful substances such as methanol from carbon dioxide are called for as artificial photosynthesis projects, which are not simply for model study but 100% socially useful. In this case, it is a key to use water as an electron source, without a sacrificial electron donor. In addition, these issues include the synthesis of organic chemical compounds useful for the society, with utilizing the electrons extracted from water, or development of the energy conserving process to significantly reduce the existing synthesis steps. We are expecting comprehensive proposals involving the isolation processes of products at such artificial photosynthesis, for example, such as the following:

- Development of new catalytic materials aiming at efficiency more than double that of conventional
- Design and development high-efficiency oxidative-reductive with suppression of charge recombination and backward electron transfer
- Development of electrodes for electrochemical reaction using photovoltaic power generation
- Development of solar utilization technology to convert ammonia and alcohol into fuel and resources

R4-B10 3DIC heat dissipation technology

While the miniaturization of the semiconductor integrated circuits slows down, there are high expectations for Three-Dimensional Integrated Circuits (3DICs), in which semiconductor chips are stacked vertically, as a means of increasing integration and reducing power consumption.

However, there is concern that the increased power density resulting from 3DICs may lead to reliability failures as device junction temperatures rise. Therefore, it is necessary to develop innovative heat dissipation technology for 3DICs at various hierarchies such as system, device structure, material, and physics, but there is no academic framework yet, which is considered as a bottleneck.

In this project, we invite research proposals related to theoretical investigation of heat dissipation models, exploration and development of materials and material processing, and investigation and proposal of system and device structures. For example, we expect the following types of proposals, but we are open to innovative proposals in addition to them.

- Computational prediction of thermal resistance associated with chip operation
- High thermal conductivity of underfill materials to fill chip junctions
- Exploration for new materials with high heat dissipation by incorporating Material Informatics (MI) and other techniques in search for heat-dissipating materials
- Improvement of processability of carbon-based materials such as graphene
- Consideration of cooling mechanisms (Peltier) in the structure, chip layout using simulation and study of highly efficient heat dissipation with structural materials
- Propose and demonstrate new heat dissipation technologies using nanostructured photonics, etc.

R4-B11 Process and device technologies for 3D integration of next-generation oxide semiconductors

As the amount of data processing rapidly increases and at the same time carbon neutrality is demanded, there are great expectations for 3D integrated devices as a means of making semiconductor devices faster and more energy efficient. Oxide semiconductors such as IGZO, which were once applied to drive circuits for displays, are attracting attention as a promising technology for 3D integrated devices because of their ability to form high-quality transistors at low temperatures in the multilayer wiring layers of semiconductor integrated circuits.

However, unlike the case of display applications, a high technological level is also required as an elemental technology to achieve nanoscale integration. The materials, processes, and device technologies for this purpose have not yet been established, and equipment and device manufacturers have been unable to immediately proceed with research and development, which is considered as a bottleneck.

In this project, we invite research proposals on materials exploration, process development, and integrated device applications for the application of 3D integration of oxide semiconductors at the nanoscale. For example, we expect the following proposals, but are open to innovative proposals in addition to them.

- Exploration of oxide semiconductor materials with excellent mobility, reliability, and processability, and development of deposition processes
- Integrated device technology based on hybrid structure with Si CMOS
- Development of technology that can reduce cell area and increase cell density by creating a 3D structure
- Development of monolithic 3D integrated device technology
- Solving issues for practical application, such as miniaturization process and reliability

R4-B12 Development of technology for practical application of CMOS using 2-D layered materials

As channel materials for sub-nm generation CMOS, there are high expectations for new 2D layered materials such as graphene and transition metal chalcogenides (MX2), which are different from conventional Si.

However, the elemental technologies to meet the requested specification such as practical performance, the level of integration, and reliability for sub-nm generation CMOS have not yet been established, which is considered as a bottleneck.

In this project, we invite research proposals on elemental technologies such as materials, processes, integration, and reliability for the practical application of sub-nm generation CMOS using 2D layered materials. For example, the following types of innovative proposals are expected, but we are open to the other innovative proposals in addition to them.

- Exploration of thin-film high-mobility channel materials on the order of several nm for sub-nm generation CMOS and development of large-area and selective deposition methods
- Development of defect reduction and repairing techniques with uniform, high-quality and large-area deposition in mind
- Development of elemental and integration technologies for gate stacks, a source, and a drain of transistors using 2D layered materials as channels.
- Establishment of reliability technology including elucidation of the reliability degradation mechanism of the above transistors and countermeasures

- Development of new multifunctional devices using two-dimensional layered materials for CMOS applications

R4-B13 New approaches for realizing a Low-Carbon Society

We expect R&D proposals based on new ideas for realizing a low-carbon society except for the sub-themes from R4-B1 to R4-B12.

6.5 Common Platform Technology, Facilities and Equipment

R&D Supervisor (Program Officer: PO):
OSAKABE Nobuyuki
(Deputy General Manager, Business Strategy Planning Division, Connective Industries Division, Hitachi, Ltd.)

I. Goal of the Mission Area

Japan needs to find a way to harmonize its contribution to solving global issues with the domestic structural reform in Japan, which faces the challenges of a declining birthrate, aging population, and declining international competitiveness. The Sixth Science, Technology and Innovation Basic Plan describes the vision of Society 5.0 that Japan should aspire to as “a society that is sustainable, ensures the safety and security of its people, and enables each individual to realize diverse forms of wellbeing,” and to realize this vision, the plan calls for the realization of Society 5.0 through “social transformation with convergence of knowledge” and “a virtuous cycle of investment in knowledge and people”. It is important to promote social change and the creation of “knowledge” in a cycle, and research and development of the fundamental technologies that support it must also be conducted with this cycle in mind.

In order to enhance research capabilities, which are the source of innovative “knowledge”, it is important to promote efficient and effective research and development based on fundamental scientific capabilities and to build an innovative common infrastructure for this purpose. In this mission area, we will focus on the following three priorities: ① development of high-risk, high-impact and cutting-edge technologies and equipment for measurement and analysis, ② development and systemization of applications such as data analysis and processing technologies, and ③ development of technologies that contribute to productivity improvement at actual research sites.

In this mission area, we aim to develop technologies and equipment for measurement and analysis (seen with human eyes) for systemization and instrumentation, and to create unprecedented new value by combining mathematical analysis and simulation (seen by the computer) based on mathematical science and mathematical engineering, which are rapidly being applied and developed these days, and by innovating research methods to acquire convergence of knowledge (Figure 1).

In promoting these R&D, it is necessary for researchers in advanced fields to have the motivation to work for change for society and to open up new research fields while utilizing various types of knowledge. It is expected that researchers will grasp the needs of society and the needs of the research field, share with stakeholders the goals to be realized in the near future, and steadily promote the construction of a research system to realize them.

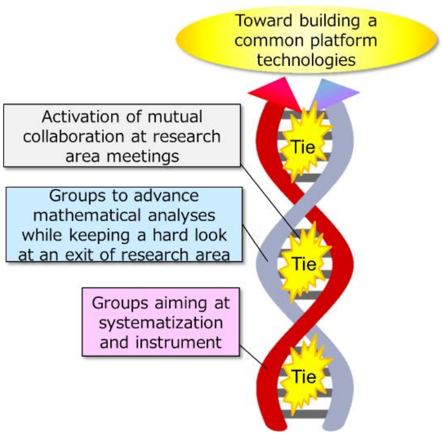

Fig.1 Scheme of Area management

II. Prioritized theme

Realization of common platform technologies, facilities and equipment that create innovative knowledge and products

(1) About the theme

(Background)

In recent years, innovation has been causing frequent shakeouts of existing technologies. The research field is no exception to this tendency. In addition to existing technologies such as the method for analyzing membrane protein molecules and single molecules using cryo-electron microscopy, which won Nobel Prize in Chemistry in 2017, next-generation sequencers and CRISPR-Cas9, etc., innovative new technologies and different kinds of data that varies depending on each measurement device are being developed using mathematical science and mathematical engineering. The data processing is expected to lead to renewal and standardization of research methods, such as the discovery of new facts. Under these circumstances, this mission area has established "Realization of Common Fundamental Systems and Devices for Creating Innovative Knowledge and Products" as a prioritized theme based on the following three priorities.

Priority item1: Development of high-risk and high-impact advanced measurement and analysis technologies/instruments
Priority item2: Development and systemization of applications, such as data analysis and processing technologies
Priority item3: Technology development that contributes to improving productivity of research fields

(Goal)

Based on the above-mentioned priorities, we expect that the fundamental technologies created in this mission area will contribute to achieving either "Goal 1: Improve Japan's R&D capabilities" or "Goal 2: Enhance Japan's industrial competitiveness" by directly contributing to industries and services, as well as by making sure that the system and device themselves become a major business. In this mission area, we also expect that the technology will reach the level where its usefulness can be demonstrated in the actual research sites (i.e., the level where companies can determine whether or not it can be put to practical use).

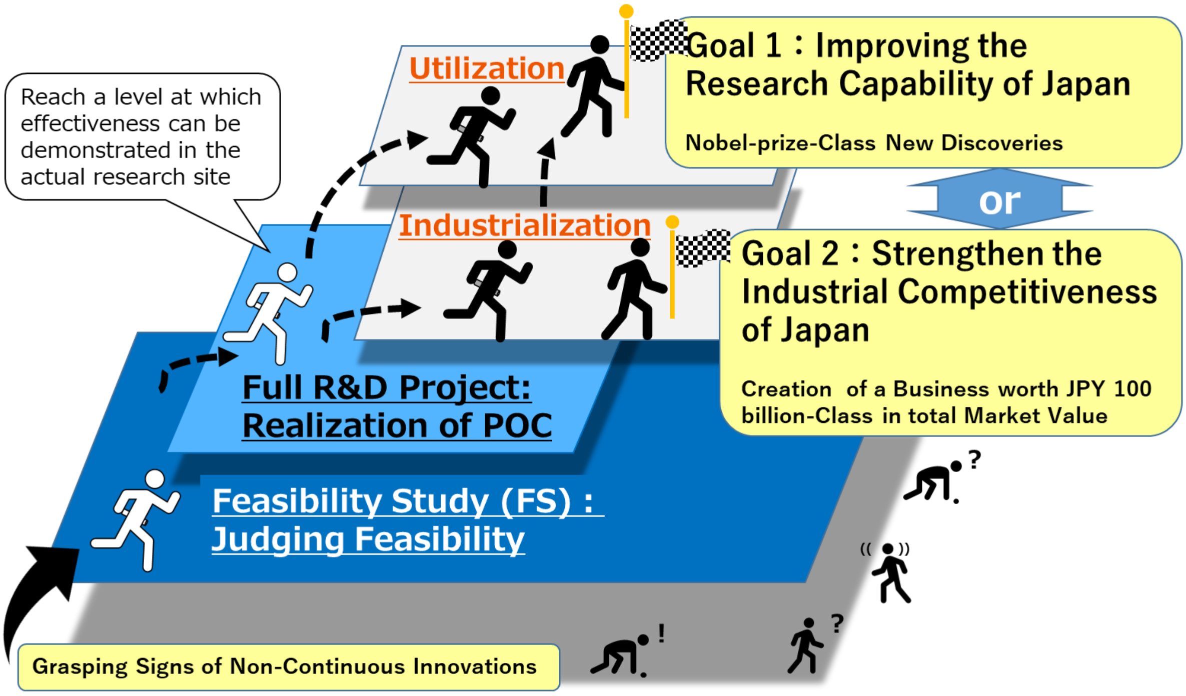

Fig. 2 Conceptual illustration of the goals of the prioritized theme and R&D phase

(2) R&D Supervisor's policies for proposal selection, and R&D management

① Policies for proposal selection

(overview)

Based on the priorities in this mission area, we have been calling for various R&D proposals under 10 sub-themes (see table), which are broad technological areas roughly divided according to research needs. In FY2022, we will continue to call for proposals under the 10 sub-themes.

In addition, in order to indicate the direction of priority in light of recent domestic and international R&D trends, in this year we will continue to call for proposals of "Priority Themes," which we have set and called for since FY2019 (Fig. 3). When submitting a proposal, please enter the appropriate classification in the "Priority Themes" (Y01) or "Sub-Themes" (Category ST01-ST10, see Table 1) (You may select multiple classification from Y01 and ST01-ST10 that match your proposal content). Please note that you do not need to fill in the classification when submitting your proposal via e-Rad. For any R&D proposal, we would like to see as much information as possible in terms of the social impact of solving a problem, clarification of the gap between the current situation of the problem and existing technology to solve it and the policy to fill it, comparison with competitive analysis of international technologies, and whether POC undertakers such as companies participates with high expectations (include the case where they still plan to participate).

The proposal selection will not be conducted independently on a basis of "Priority Themes" or "Sub-Themes," but will proceed by comparing all of them at the same time. As a result of the proposal selection, it is possible that some sub-themes will have more than one selected proposal, and others may have no selected proposals.

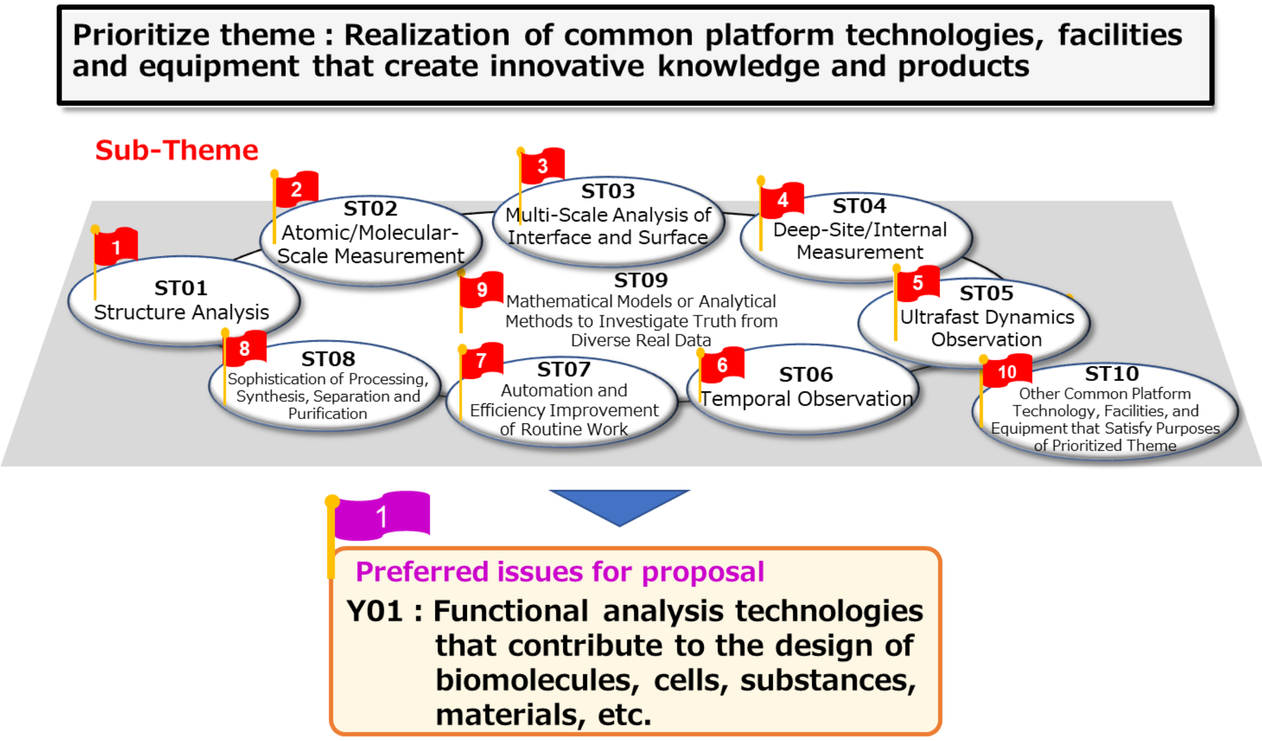

Fig. 3 Preferred issues for proposal and sub-themes in the “Common Platform Technology, Facilities and Equipment” mission area (FY2022 version)

(Preferred issues for proposal)

The following "Preferred issues for proposal" are invited. Perspectives of the call for proposals with a view to Full R&D project are as follows

Classification	Title of preferred issues for proposal
Y01	Functional analysis technologies that contribute to the design of biomolecules, cells, substances, materials, etc.

In order to accelerate research on health and medicine, material production, and functional materials, which are facing increasingly intense competition worldwide, there is a need to develop technologies that enable highly accurate integrated analysis of data obtained at various hierarchies in order to clarify the functions of materials and cells under real environment and provide feedback to product design and manufacturing processes.

In this section, we will indicate what is required in the fields of life science, materials science, mathematical science and mathematical engineering as follows.

- ✧ Life Science: In contrast to conventional measurement under conditions optimized for each measurement device, it is important to clarify the functions of biomolecules that continuously change under physiological conditions corresponding to in vivo environment, such as the presence of impurities and measurement under high concentration conditions assuming an intracellular environment. For example, we seek technologies that can analyze the relationship between structure and function of proteins that form diverse structures and express their functions in the cell. In addition, for functional elucidation, it is important to integrate data from different samples and analytical methods at each hierarchy. To achieve it, quantitative, inexpensive, and high-throughput measurement of data at each hierarchy is required, so we expect such technologies as will contribute to it. In addition, we welcome proposals for new measurement systems using various bioresources (clinical samples, seeds, genome information, etc.), as well as proposals for generating new knowledge by combining existing modalities.

- ✧ Materials Science: To achieve carbon neutrality, innovations that fundamentally rethink the manufacturing process of materials are required. On the other hand, the issues to be solved have become more complex, and the trial-and-error process has been increasing at each scale-up, from basic research to practical application, from elementary reaction research to small-lot lab level, pilot level, and mass production level. As a result, the development period becomes longer until practical application. To speed up the process from development to production of functional materials is essential for the survival of not only the materials industry but also the manufacturing industry in Japan. For this purpose, it is necessary to develop a model-based process that can link processes divided into several hierarchies and enable simultaneous processing. In this year we will focus on the transformation of the manufacturing process into a green and sustainable one, and from the viewpoint of research and development with the final product in mind, we expect R&D proposals that integrates the process from R&D to mass production in a high-throughput manner by utilizing information processing technology, data science, etc.
- ✧ Mathematical Sciences and Mathematical Engineering: This time in any of the fields targeted by “Priority Themes,” we are seeking R&D proposals for mathematical analysis methods that enable the integration of measurement and simulation technologies and mathematical models, computational methods, and data analysis techniques methods that efficiently and accurately link multilevel data and multiple life, physical, and chemical phenomena and bring them closer to realistic solutions. In addition, it is expected that data-driven mathematical model building techniques and new dynamic information processing methods that estimate and mathematically model the nonlinear dynamics of the system that produced the data and extract the underlying laws based on multidimensional and noisy spatiotemporal data obtained from actual research sites will be applied to great improvement in the efficiency and performance of complex data analysis, spatiotemporal structure analysis etc. Based on original mathematical methods, we expect proposals from mathematical scientists and engineers with flexibility and versatility to enable mathematical model analysis and mathematical data analysis through close discussions with experts in various fields, not only in the life science and materials science fields, but also, for example, in energy and agriculture from various angles.

In addition, based on the current status of measurement and analysis technologies and instruments in each field, we will provide examples of the necessity and required performance of “functional analysis technologies that contribute to the design of biomolecules, cells, substances, materials, etc”.

- ✧ Omics analysis technology: Proteomics focusing on mass spectrometry needs further improvements in quantitativeness, sensitivity, and throughput etc. If we develop new proteomics technologies that enable the analysis of diverse structures and achieve quantitativeness, sensitivity and throughput; quantitative improvement using labeling and pretreatment; expansion of measurement targets by enhancing ionization efficiency of peptides; development of methods to identify protein structures after translation and modification using mathematical and informatics science; and new measurement methods using fluorescence and antibodies that are not dependent on mass spectrometry, etc., we can expect major progress in life science. In addition, we welcome proposals for technologies that can read longer strands on conventional DNA sequencers and pretreatment methods that simplify and speed up the analysis.
- ✧ In vivo protein structure analysis technology: The relationship between protein misfolded aggregates and intracellular phase-separated structures and nerve cell toxicity is drawing

attention. There is a need for technologies to analyze the process of aggregate formation, the interaction between proteins and low-molecular-weight compounds, and the biomolecular structure and function within phase-separated structures. For example, technologies that enable observation under physiological conditions with sufficient resolution (less than msec, less than μm) and diffusion velocity of less than 0.01 μm2/sec, and technologies that integrate the obtained image information with various omics data are expected to clarify the in vivo functions of proteins, leading to new drug discovery and development of diagnostic methods.

- ✧ Substance production technology: Substance production methods that control cellular metabolism are drawing worldwide attention. If there is a method that can obtain more data than now by one digit, it is expected to greatly promote research by utilizing AI, mathematical science, and mathematical engineering, which are advancing day by day. For example, we require a technology for high-speed evaluation using optical measurement instead of conventional metabolomics based on liquid chromatography and mass spectrometry.
- ✧ Catalyst technology: Green and sustainable manufacturing requires compact, decentralized, and on-site manufacturing processes that utilize renewable energy, bio-resources, and other resources. To realize it, we need new synthesis methods that break away from thermodynamic equilibrium, such as synthesis processes using new catalytic reactions, new operando measurement technologies that can measure and analyze dilute active species, new measurement technologies that can analyze reactions in soft systems such as solution, and computational science to understand the nature of phenomena. In addition, to enable materials and process design in anticipation of mass production, we are seeking proposals for not only data-driven research, but also technologies to increase R&D throughput by measurement and analysis in an integrated way: supplementing and integrating physical models with phenomena that are difficult to observe directly.

(Regarding the 10 “Sub-Themes”)

Excellent R&D proposals suitable for the sub-themes will be considered for adoption, regardless of their relationship to the “Prioritized Themes”.

List of “Sub-Themes(continued)”

Classification	Sub-theme	Overview
ST01	Structure Analysis	Development of fundamental technology for structural analysis of materials with complex structures
ST02	Atomic/Molecular-Scale Measurement	Development of methods for measuring various objects at the atomic and molecular scale
ST03	Multi-Scale Analysis of Interface and Surface	Research and development for meso-scale and macro-scale analysis
ST04	Deep-Site/Internal Measurement	Development of techniques to measure deep and internal structures and internal phenomena of materials
ST05	Ultrafast Dynamics Observation	Research and development to dramatically improve the temporal resolution of existing measurements as a technique for observing ultra-short time phenomena, such as transition states in chemical reactions
ST06	Temporal Observation	Research and development for high-impact temporal observations that are highly needed in individual fields and research subjects
ST07	Automation and Efficiency	By automating and streamlining tasks that are already typified in the actual research site, we aim to dramatically

	Improvement of Routine Work	improve and accelerate research productivity and reach the desired results in a shorter time.
ST08	Sophistication of Processing, Synthesis, Separation and Purification	Research and development of advanced processing, synthesis, separation, and purification technologies, which are technologies for generic purpose in the actual research site
ST09*	Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data	Development of mathematical and analytical methods to describe and extract "essential information" that contributes to the predictability of desired properties and performance, and new mathematical methods that could lead to fundamental reform of measurement techniques
ST10	Other Common Platform Technology, Facilities, and Equipment that Satisfy Purposes of Mission Area	Research and development proposals that create fundamental technologies that you believe are necessary "now" in the actual research site and that match the purpose of the mission area.

※An appropriate budget size should be allocated according to the content of the research and development, because the planning for ST09 (construction of mathematical models and analytical methods to pursue the truth from a variety of real data) does not necessarily involve experiments.

② Policies for R&D management

In this mission area, in order to promote challenging research and development that will have a high impact on research activities with the aim of creating innovative knowledge and products, we will put emphasis on adopting innovative ideas by leveraging diversity of R&D system. For example, we will actively promote the interdisciplinary fusion that are not bound by conventional academic fields, the participation of young researchers, and the active collaboration between companies and academia.
※In this mission area, the principal investigator of the adopted proposal will be advised by the theme manager (see below).

Theme Manager

Life Science

SATO Taka-aki
(Senior Fellow, Director, Life Science Research Center, Technology Research Laboratory, Shimadzu Corporation/Director, Center for Precision Medicine, University of Tsukuba)

Material Science

Hiroshi OKAJIMA
(Project General Manager, R&D and Engineering Management Div., Advanced R&D and Engineering Company, Toyota Motor Corporation)

Mathematical Science

Kazuyuki AIHARA
(University Professor, Office of University Professor, The University of Tokyo)

③ R&D period, timing of Stage-gate evaluation, and R&D costs

For FY2022, a feasibility study should be planned with a period of up to two and a half years (up to end of FY2024), and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period. Every researcher is required to undergo a stage-gate evaluation for transition to a full R&D project at the time designated by the R&D Supervisor before the end of FY2024.

A full R&D project should be planned with a period of up to five years and with a total cost of up to JPY 570 million (direct costs) for the whole period.

After adoption, we will flexibly allocate the budget according to the R&D content.