Chapter 6 (Annex)
Prioritized Theme and Technology Theme for Research Proposals

R&D Type	R&D Areas for which Proposals will be Solicited	Refer to
Small-start Type (Feasibility study)	**"Realization of a Super Smart Society (Society 5.0)" area** (Program Officer: Akira Maeda) Innovative AI technologies for Sophisticated Integration of Cyber and Physical World (New)	5
	"Realization of a Sustainable Society" area (Program Officer: Hideyo Kunieda) 1. Creation of innovative food production technologies responding to future changes in climate and social demands 2. Enhancement of product durability and usability for resource-efficient society (New)	11
	"Realization of the Most Safe and Secure Society in the World" area (Program Officer: Ken-ichi Tanaka) 1. Realization of a safe, secure, and comfortable town free from hazardous substances hiding in the living environment 2. Self-management of health based on the action mechanism of daily behaviors such as food, exercise and sleep (New)	21
	"Realization of a Low Carbon Society, a Global Issue" area (Program Officer: Kazuhito Hashimoto) "Realization of a low carbon society through game changing technologies"	31
	"Common Platform Technology, Facilities, and Equipment" area (Program Officer: Nobuyuki Osakabe) Realization of common platform technologies, facilities, and equipment that creates innovative knowledge and products	63
Large-scale Type	(Program Officer: Yoshihiro Oishi) Innovative thermoelectric conversion technologies for stand-alone power supplies for sensors (New)	78

6.1 Small start Type

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

About research areas for setting a prioritized theme by JST, National R&D Agency, in JST-Mirai program

JST, the National R&D agency, sets research themes (prioritized themes, hereafter) for the JST-Mirai program (small start type). There are tentatively five areas (sections) for the themes set in fiscal year 2018, the first year of the program, that reflect the Fifth Basic Plan of Science and Technology.

A review of prioritized themes must reflect the purpose of this project to rigorously examine a technologically challenging target that is both economically and socially impactful. The review must also be strategic while paying attention to a wide collection of novel and diverse ideas, be consistent with various policies of the government, and avoid the duplication of prioritized and challenging R&D performed by other National R&D Agencies.

① "Realization of a super smart society"

This research area is set as a transdisciplinary (lateral skewered) area from the viewpoint of creating new values toward the creation of industries and reformation of future society. Specifically, it includes spreading the utilization of networks and IoT not only to manufacturing industries but also to R&D in various other fields and strengthening base technologies (base technologies necessary for building a common platform through the effective utilization of IoT and base technologies that are a core of Japan's strength in creating new values, including advanced measurement technologies) for maintaining and strengthening the competitiveness of Japan as a super smart society. It also includes technologies related to space, such as satellite position measurement, satellite remote sensing, satellite communications, and satellite broadcasting.

② "Realization of a sustainable society"

This is an area that includes stably securing resources and food (stable securing of resources and their utilization through recycling, stably securing food), realization of a sustainable society that responds to super aging and population decrease (formation of a healthy aged society using the most advanced medical technologies in the world, realization of a societal base for sustainable cities and regions, and measures for longer life with efficient and effective infrastructure), improving competitiveness in manufacturing and holding events, and response to biodiversity. It also includes marine technologies that contribute to the sustainable development and utilization of the ocean.

③ “Realization of the most safe and secure society in the world”

This is an area for responding to natural disasters; securing food safety, the living environment, industrial safety and health, and cyber security; and responding to national security problems.

④ “Realization of a Low Carbon Society, a global issue”

This is an area that includes stably securing energy and the efficient utilization of energy (energy-saving technologies, improving the efficiency of reusable energy, and technologies for stabilizing energy utilization with hydrogen and stored energy).

⑤ “Common platform technology, facilities, and equipment”

This is an area set to target common platform technology and cutting-edge research equipment that support a wide variety of research activities. This area makes it possible to open up a new interdisciplinary field, support capabilities of basic science in Japan as a basis for bringing world-leading research results, and contribute to create sustainable science and technology innovation.

6.1.1 “Realization of a super smart society (Society 5.0)” area

Research and Development Supervisor (Program Officer: PO):
Akira MAEDA
(Former Corporate Chief Engineer, Information & Communication Technology Business Division, Hitachi Ltd.)

I. Goal of the “Realization of a super smart society (Society 5.0)” area

As set out in the Fifth Basic Plan of Science and Technology and the Comprehensive Innovation Strategy, Society 5.0 is defined as “a society centered on people that, through the merging of cyber space and physical space, provides goods and services that precisely respond to various needs and potential needs to support both economic development and solutions for social issues and allows people to live comfortable and active lives.”

This area assumes that a “super smart society” (synonymous to Society 5.0) is considered a “society in which things of the real society are incorporated with intelligent software for sophisticated functions (making it smart), and things cooperate to automate societal systems for high efficiency as well as facilitate new functions and services.” The question “how is it different from ”a smart society” or the conventional “information society” referred to as in Society 4.0” may be answered as following: “assuming information technologies is for sophisticated information and data processing in cyber space, a super smart society incorporates intelligence of information technologies into a physical entity, such as electrical power systems, transportation systems, service robots, and similar entities, for them to interact for the expansion of the range of automation and autonomy as the whole system, and possesses a mechanism for sustainable creation of new services and businesses.

In other words, it is believed that in a “super smart society” or “Society 5.0,” cyber space cannot be separated from the real world; software is incorporated into things in the real world and the existing societal systems collaborate by IoT, integrated with real world (hardware) and software to constitute a system or “system of systems.”

Based on this concept, we adopted a prioritized theme for “the establishment of a service platform that enables collaboration between various components and creation of new services, in FY2017. In FY2018, we placed a particular focus on "a technology that secures real-time performance and reliability using modeling and simulation to realize the function to control objects and systems in the real space with API," and added a prioritized theme of "Modelling and AI for integration of cyber and physical worlds" as a key technology to construct a new service platform that utilizes AI and big data analysis technology.

On the other hand, when using AI and big data analysis technology, problems are becoming clear in applying the current mainstream technology of deep learning using big data to real-world objects and existing social systems. The problems include a difficulty in explaining the recognition and inference results, which hinders collaboration with human beings, exceptional events that make collecting big data difficult, a difficulty in application to changing environments, and a lot of time for learning, which precludes real time processing. Solving these issues is vital to “highly converge the cyber and physical spaces” which is one of the key elements of Society 5.0.

Based on this awareness of issues, we have adopted a prioritized theme of “Innovative AI technologies for Sophisticated Integration of Cyber and Physical World” for this fiscal year. We have reshaped and expanded the FY2018 prioritized theme of "Modeling and AI that connects the cyber and physical worlds " into a wider theme for FY2019 theme by adding the technical theme setting of "collaboration and convergence of modeling and AI" and problem solving with the utilization of AI technology in the real world, and have adopted it as a new prioritized theme again.

Under this theme, researchers are requested to clearly determine specific application targets and technical issues to realize them. In addition, an approach that integrates and combines technologies from a wide range of fields is needed to solve these issues. Furthermore, collaboration between academia and industry is also a key. We expect many researchers to propose R&D proposals in line with the purpose of the theme.

II. Prioritized theme

Innovative AI technologies for Sophisticated Integration of Cyber and Physical World

New

Theme manager
Takashi WASHIO
(Professor, Institute of Scientific and Industrial Research (ISIR) Osaka University)
* A theme manager who assists the R&D management of the Program Officer is to be assigned to this prioritized theme.

(1) About the theme

As stated in R&D policies for the “realization of a super smart society” area, Society 5.0 is defined as a society in which cyber space and physical space merge at a high level to allow people to live better lives. This research area takes this definition as a society in which cyber space and physical space merge, or software is incorporated into real-world goods, for their collaboration and cooperation to realize a mechanism that facilitates the realization of new functions and services. For “the high-level merger of cyber space and physical space,” a cycle needs to be repeated in which such feedback is performed as responses to complex and constantly changing situations in the real world (physical space), judgement and optimization based on data collected by sensing, and control, manipulation, and working on the real world. Subjects in the real world include energy and transportation, the whole cycle of manufacturing, various social systems including prevention and reduction of damage from disasters (the leading 11 systems of Society 5.0), and people engaged in them. In addition, the subjects also include constituents of systems, for examples taken from manufacturing, designs of plants and goods dealt with in the concept of digital twins promoted in so-called Industry 4.0, and control and maintenance mechanisms using IoT. This also applies to other social systems.

Meanwhile, AI/machine learning technologies have made remarkable progress in recent years to rapidly expand their scope of applications. So-called big-data approaches are powerful. On the other hand, it has been pointed out that the results of deep learning can be black boxes that are difficult for people to understand, that responses to irregular case, such as failures, are inadequate, and that adapting operations to a changing environment real time is not easy. Solving these issues is considered vital to realize Society 5.0 and the advanced cyber and physical convergence.

Aiming to solve various problems manifested in applying AI technology to the real world, we have selected a prioritized theme "Innovative AI technologies for Sophisticated Integration of Cyber and Physical World" for this fiscal year. This prioritized theme shares the awareness of problems with a FY 2018 prioritized theme of “Modeling and AI that connect the cyber and physical worlds” and is created by reorganizing and expanding the FY 2018 prioritized theme.

This FY2019 prioritized theme aims to develop innovative AI technologies that solves various issues in practical application of AI technology toward realization of the system and application assumed in Society 5.0. The innovative AI technologies include those capable of guaranteeing user-side independence and acceptability by explainable AI, securing safety and reliability, adapting changes, and securing an execution speed and accuracy in environments that require real-time performance, etc.

More specifically, we expect the following research contents:

[1] Realization of explainable AI combining inductive type and deductive type

[2] Construction of learning mechanisms, such as additional learning and online learning that can respond to changing events

[3] Realization of learning from a small quantity of data by incorporating a model representing the prior knowledge of the real world

[4] Extraction of a model structure from trained neural networks

[5] Establishment of a system development technology that guarantees operation and reliability

[6] Development of a learning algorithm to integrate and fuse individual learning results in a distributed environment

[7] Radical power saving and speeding up by upgrading the learning algorithm

These are just examples. Any other AI technology may be proposed that meets the purpose of the theme to aim for the advanced cyber and physical convergence.

Under this theme, the researchers are requested to keep in mind specific application targets (use cases) for a new value realized by it and promote research, while drawing up a scenario for achieving this theme. The researchers must propose not only the R&D of novel technologies, but also a scenario (hypothesis) for achieving this theme, i.e., to what kind of field is the technology applied to realize what value, before their themes can be adopted.

* Implementation in society is not essential at completion of full-scale research. A goal is set at a stage when a business firm can judge its practicability (POC).

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

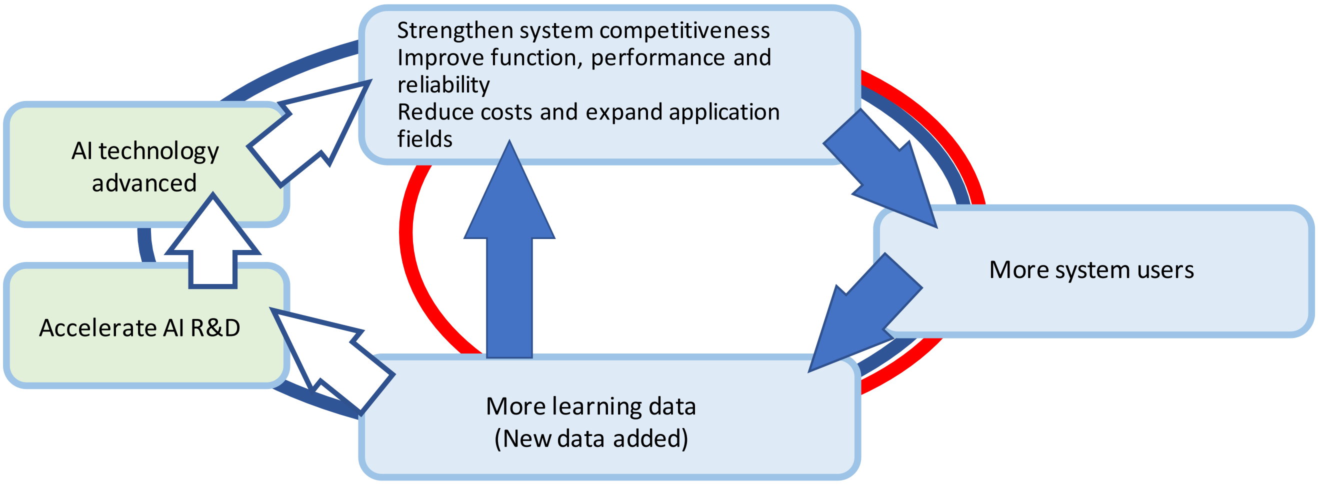
① Policies for proposal selection

Under this theme, researchers are requested to promote R&D under the supervision of the Program Officer and the theme manager.

Proposals are called for AI technologies that can safely and securely operate in the constantly changing social system of Society 5.0, in which people and modelling/simulation technologies and AI/machine learning technologies are included.

Every proposal is required to describe to what specific system and application and service a technology will be applied, how to create value (social and economic impacts) through its application, and a future image should be conceived. Then researchers are requested to identify the technical issues that are the bottleneck for application and clarify the means to solve them.

In order to aim for the sustainable technological development and implementation of AI in application of AI, while the IoT environment is dramatically evolved by the service in of the 5th generation communication (5G) etc., we focus on [1] exploring new areas of application of AI, or [2] applying AI to objects and systems for which Japan has an advantage. The following diagram, provided as an example, depicts our expectation that identifying areas in which AI produces great value and focusing on these areas to promote R&D increases the number of users of the system and thereby the volume of learning data, which promotes the continuous evolution of AI, allowing us to survive the intensifying international competition. "Improving the accuracy and reliability of AI by increasing the amount of learning data," as shown in the diagram below, and for some areas of application, "enhancing the accuracy and reliability of AI by co-evolving the collaboration between AI technology and field workers to improve both AI technologies and field workers" are important for the sustainable technological development and implementation of AI. Besides the above-mentioned methods, we expect researchers to consider more effective methods for the sustainable technological development and implementation of AI in a flexible manner.



We request the researchers to clarify POC through the full-scale research period, create an R&D plan for achieving it, and draw up a scenario for realizing the future vision as far as possible. If social and economic impacts and the scenario are unclear, we request them to conduct a feasibility study to clarify them and establish a concrete vision of the future.

(About technologies)

We welcome proposals on innovative AI technology development aimed at advanced cyber and physical convergence based on specific use cases and scenarios. Besides the items 1 to 7 listed in (1) "About the theme," we expect the researchers to forward challenging proposals based on new ideas.

(About team composition)

It is not necessary to initially form a team that covers the whole plan. Proposals that include building a team system during a feasibility study are acceptable. In such a case, clearly describe the following in the proposal documents:

- What researcher(s) do you want to collaborate with to perform research?
- What activities do you plan to carry out in collaboration?

There may be cases in which JST advises collaboration between proposing researchers based on the collaboration plan in a proposal document after selection or adoption.

② Policies for R&D management

A feasibility study is positioned as preparation for full-scale research, which is conducted for five years in principle. A feasibility study has a period of two and a half years, in principle (up to end of fiscal year 2021).

A feasibility study is presumed to take on the following specific research:

- Verify the social/economic impacts that the research will bring about in the future and its scenario.
- Specify technological development targets and a research plan by verifying technological feasibility.
- Proceed to form an effective team including AI/model researchers and business firms, as required.

Furthermore, the premise for a shift from a feasibility study to full-scale research is not only selection and concentration but also a bold re-composition of the research team, including reorganizations of sub-teams within a project team. A project (R&D project) may proceed to full-scale research sooner, depending on research progress.

③ R&D period and costs

For the R&D themes initiated in FY2019, a feasibility study should be planned with a period of up to two and a half years and a total cost of up to JPY 35 million (direct costs) for the whole feasibility study period.

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.

After adoption, we will flexibly allocate the budget according to the research content.

6.1.2 “Realization of a Sustainable Society” area

R&D Supervisor (Program Officer: PO)
Hideyo KUNIEDA
(Senior Advisor, JST/Councilor, Nagoya University)

I. Goal of the “Realization of a Sustainable Society” area

"The Quest of a Sustainable Society" is an ultimate goal not only for Japan, but also for the whole of mankind. The world has turned its direction of development towards a sustainable society regarding economic development only. It is also expressed in the Sustainable Development Goals (SDGs) of the United Nations. We now face the necessity to increase the quality of life and at the same time realize sustainable development of society.

A review of the current situation of Japan finds a slow economy over the last 20 years or longer. The economy has remained slow in a changing global environment undergoing climate change and globalization for more than 20 years. Many industries, including the manufacturing industry, in which Japan has enjoyed advantages, are found to show signs of declining international competitiveness. In addition, a population decrease faster than that of other countries has begun to decrease the population of productive laborers in Japan and to increase the number of seniors who need social support. It is a fact that the sustainability of people’s lives is at risk. This research area takes maximum advantage of science and technology to flexibly adjust changes in “environment,” “society,” and “economy” and aim for realization of a higher-quality and more mature society.

The prioritized theme of this research area takes into account ideas from applied proposals and discussions with experts in various fields to aim for the goal of improving the natural environment (ecosystem services) and the human well-being / maximizing benefits for future generations.

In FY 2017, the following prioritized themes have been chosen: “Innovation in manufacturing for new process of sustainable resource circulation” and “Improving intellectual capability to enhance 'a Socially Active Life' for overcoming the reducing labor force.” In FY 2018, a new theme, the “Creation of innovative food production technologies responding to future changes in climate and social demands” has been added to the above two themes.

In this fiscal year, we will make the second public call for “Innovative food production technology” and call for R&D proposals for the prioritized theme newly established in 2019 “Enhancement of product durability and usability for resource-efficient society.”

To realize a sustainable society, the expansion of layers for future-oriented researchers and practitioners is believed to be necessary. Various research fields and stakeholders need to tackle the future as a single, united team. For that reason, this area actively takes on the appointment of young researchers and the construction of multidisciplinary research systems.

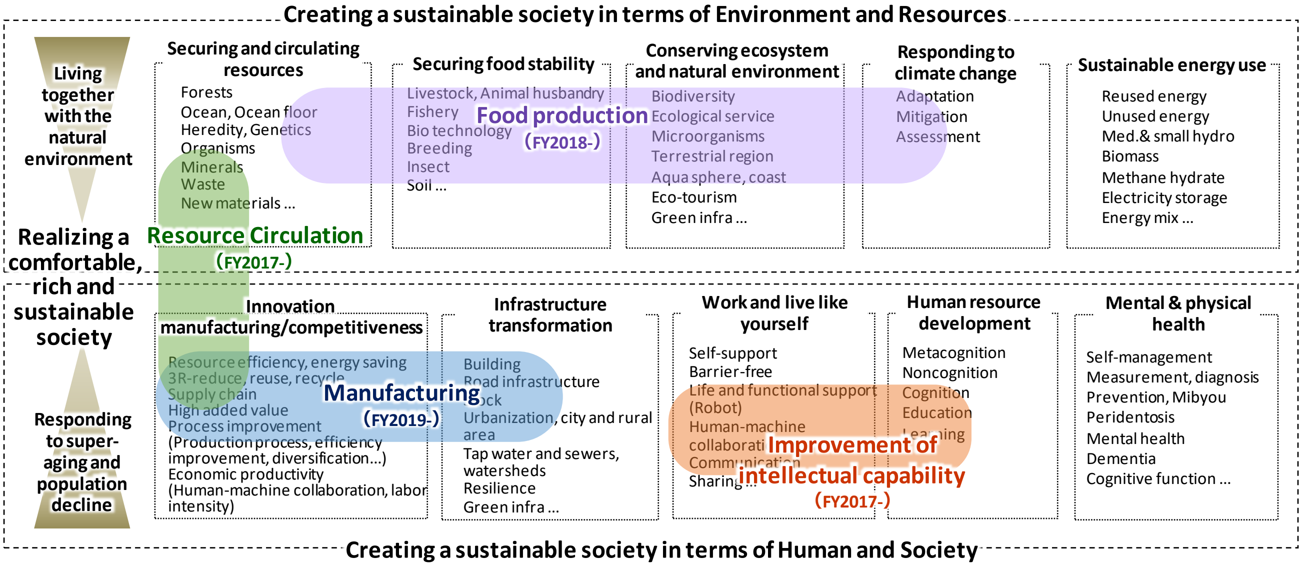


Fig. 1: Designing process of the prioritized themes for the “Sustainable society” area

1. Creation of innovative food production technologies responding to future changes in climate and social demands

(1) About the theme

This prioritized theme aims to establish technologies for stable and sustainable food supply in response to environmental changes in nature and society, including climate change, resource exhaustion, and variations in land use and population distribution. Especially, the call in FY2019 sets a focus on the creation of innovative technologies for animal protein production, beyond simply making existing livestock and aquaculture more efficient.

Population explosion and improved living standards in developing countries are predicted to increase food demands of the world 1.55 times[1] in 2050 from that of 2000. There are concerns that the supply and demand may become tight, coupled with its increased use other than food (biofuel etc.). A significant increase in cultivated land area is unlikely, in addition to the slower growth in yield per unit area. This sense of crisis is emphasized worldwide as one of the goals of the United Nations SDGs, "Goal 2. NO HUNGER." As economic affluence raises the consumption of animal proteins such as meats and seafoods, demands for meats are predicted to increase greatly (1.8 times in 2050)[2] as larger than that of agricultural produce. On the other hand, the production efficiency is quite low in the current production systems such as farming, livestock, and aquaculture, for example, 10 kg or more feed is necessary to get 1 kg beef meat. In addition, fertilizer residues and agricultural waste threaten long-term sustainable production systems. Therefore, there is a strong demand for jump-up in the sustainable production technologies.

Against such backgrounds, this prioritized theme set out to the realization of affluence through food, the creation of a new food industry, and the eradication of hunger from the world, through R&D of innovative technologies for animal protein production revolutionarily improving the sustainability of food production system.

(2) Program Officer's policies for proposal selection and R&D management

① Policies for proposal selection

The call in FY2019 continuously focuses on food as a source of animal protein to invite R&D proposals of innovative production technologies responding to changes in society and the natural environment.

Propose solutions centered on innovative science and technology upon presuming realistic future environmental changes in nature and society and specifying bottlenecks (science and technology aspects and social implementation aspects) in food production technologies as prerequisites.

In the FY2018 call for this prioritized theme, we have adopted four projects aimed at culture

1 Estimates of the Ministry of Agriculture, Forestry and Fisheries "World food supply and demand outlook in 2050" (June 2012)

2 United Nations Food and Agriculture Organization (FAO) Report "World Agriculture Towards 2030/2050" (June 2012)

production of meat by applying regenerative medicine technology and three projects aimed to fundamentally change aquaculture methods using probiotics and developmental engineering.

In the call for FY2019, we particularly seek for proposals for innovative technologies on animal protein production which are not simply the extension or improvement of conventional methods, and with high novelty and efficiency exceeding the 2018 projects' approaches. Such technologies include unprecedented methods of food production (for example, culture production of meat and seafood), a livestock or fishery system that dramatically improves its sustainability (for example, feedstuff production based on novel ideas), and other technologies required to create a high-impact food industry (for example, innovative technologies targeted at other than livestock and fisheries). We also strongly expect proposals from newcomers beyond conventional research fields.

The overview of R&D themes adopted in FY2018 is available on the website of JST-Mirai Program (https://www.jst.go.jp/mirai/jp/program/sustainable/).

Be sure to include following elements in proposal documents. The description is keenly expected to be as specific and quantitative as possible.

- Specific image of social implementation and how great realistically presumed social and industrial impacts would be
  - no need to be restricted to Japan.
- Bottlenecks that would be a barrier when realizing the aforementioned "image of social implementation" and those are difficult to solve at present
  - multifaceted examination, not only in scientific and technological aspects, is necessary for social implementation.
  - restriction to one bottleneck is not necessary. In case of multiple bottlenecks, describe prioritized key bottlenecks.
- POC (proof of concept; a stage for the society and industries to be able to judge practicability) aimed to be achieved at completion of full-scale research
  - it is necessary to clearly show innovative science and technology to solve the aforementioned "bottlenecks"
- Goal for the feasibility study that should keep achieving the POC in mind and perform confirmation, verification, and construction as a stage before full-scale research

  To check the feasibility of the POC, the feasibility study presumes the following contents to be included as required and requires a goal that meets the contents.
  - checking feasibility in the aspect of science and technology, including theoretical verification of technologies at the stage of idea and detailed examination of necessary component technologies.
  - checking feasibility at social implementation including research on bottleneck dissolution toward social implementation (for example, social permissibility)
  - checking social and economic impacts including detailed surveys of social and industrial needs and maximization of the impacts
  - checking a research team composition for full-scale research including R&D team formation by business firms or academia for maximizing impacts

Food production using genome engineering is also applicable, but it is imperative for researchers to consider how the food produced by the technology will be socially accepted domestically and/or abroad, and describe how the R&D targets and goals are set/optimized.

(R&D projects to be excluded)

- Projects mainly for eliminating bottlenecks after food production, such as food processing, storage and transportation are excluded.
- Upgrading/increasing value of food for market development are not included.
- Because the purpose is to solve key bottlenecks with innovative science and technology, projects mainly aimed at mere expansion of the targets of existing technologies, mere improvement of the efficiency, scaling up and labor-saving of production, enlightenment, diffusion and multi-point development are excluded.

(Items for special consideration)

It welcomes challenging research proposals and newcomers from other research fields that have not yet being involved. Even a research plan at the idea stage or a lower TRL study could be proposed, if the proposal objectively and specifically shows a plan in the proposal concerning what is lacking and how to overcome it during the feasibility study.

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 meetings, site visits, study groups, etc., and the R&D management committee, including the Program Officer, and the R&D practitioners work together to promote R&D, aiming to achieve the theme goal.

This prioritized theme considers active mergers of different fields beyond conventional scientific fields effective, because it aims for marked sustainability and stabilization of food production on the premise of creating innovative science and technology. Moreover, collaboration among business firms, society, and academia is keenly expected as it needs to lead strong social demands in the future. And for those reasons, collaboration with related domestic programs is included in promotion of R&D maximizing the outcomes.

In addition, this prioritized theme is assumed to be quickly applied to society and industry once the bottlenecks are eliminated and significant impacts on society and economy are revealed. Therefore, shift to full-scale research is positively reviewed even during a feasibility study period. If deemed necessary by the Program Officer to maximize the social and economic impact, we may combine and integrate multiple R&D projects and improve R&D plans (including team formation, budget review, cancellation), regardless of the stage of the project (at the time of adoption or during research).

③ R&D period and costs

For R&D initiated in FY2019, a feasibility study should be planned with a period of up to two and a half years and a total cost of JPY 10-40 million (direct costs) for the whole feasibility study period.

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.

After adoption, we will flexibly allocate the budget according to the research content.

2. Enhancement of product durability and usability for resource-efficient society

New

(1) About the theme

This prioritized theme elucidates the principle of complex phenomena of fatigue and deterioration for composite materials that are expected to expand in the global market, and the mechanism leading to damage and breakage, establishes technology to accurately evaluate the life (remaining life) of products, and thereby promotes the continuous use and reuse and minimum resource utilization by highly optimized design, and achieve material design for longer life and highly functional products.

The technology that minimizes the amount of materials used while maintaining product functions not only directly leads to cost reduction but also leads to the effective use of resources and the minimization of transportation costs (energy saving), which forms a foundation for manufacturing. In particular, for structural members and strength members that require a particular strength, R&D has been promoted with emphasis, supported by social and economic demands, such as intensifying international competition for resource saving and energy saving. In particular, composite materials that combine the properties of multiple materials with high strength and light weight draw attention and are being developed and used. Given the heat resistance and formability (shape) of composite materials, their application to manufacturing in new areas that could not be achieved with conventional materials is expected. Now that the values are changing greatly “from disposal to circulation and from ownership to sharing,” the heat resistance and formability of composite materials have the potential to promote their wide use for creating new products that can be used continuously or reused, which anticipates the need of the times.

However, the use of composite materials is now limited to a specific area, and application or widespread use that takes advantage of their characteristics has not progressed yet. For example, Carbon Fiber Reinforced Plastics (CFRP) is expected to be widely used as a structural member or strength member that requires high strength. Unfortunately, a failure to quantify the impact of fatigue and deterioration during the use of CFRP on damage and breakage results in design with extra thickness to secure safety and reliability, which cannot make full use of its benefit of being lightweight. In addition, a failure to accurately evaluate the functions and life left in products and parts that have been used once due to the inability to understand changes in fatigue and deterioration in details precludes quality assurance and prevents the promotion of their continued use or reuse. In other words, the complexity of interface and phenomenon correlation between different materials in a composite material prevents the scientific understanding of basic processes involved in fatigue, deterioration, damage and breakage, of complex phenomena has not progressed, which is a barrier to making the most of the properties, such as high strength and light weight, inherent to the composite materials.

This prioritized theme promotes a scientific understanding of unelucidated phenomena that occur in composite materials, and maximizes the performance and functionality of these materials to bring innovation not only to the manufacturing but also their usage, thereby aiming to contribute to “Improvement of resource utilization efficiency and promotion of sustainable consumption and production forms” advocated in 9 and 12 of the United Nations'

SDGs (Sustainable Development Goals) and realize an environmentally and economically sustainable society in response to the changing needs of society and people.

(2) Program Officer’s policies for proposal selection and R&D management

① Policies for proposal selection

Under this prioritized theme, we request for R&D proposals that scientifically elucidate the process of fatigue and deterioration and the mechanism leading to damage and breakage of the composite materials composed of basic and reinforcement materials by returning to the theory and establish technology that enables highly accurate evaluation of life expectancy to enable the design of longer-life and highly functional products.

The proposals need to be backcast from a concrete application that has a social impact, such as continuous use or reuse, highly optimized design, and feedback on material design. It is imperative to set as POC deepening a scientific understanding of the basic processes of fatigue and deterioration, including unelucidated parts to date, elucidating the mechanism that leads to damage and breakage, and developing a technology that enables highly accurate evaluation of life expectancy.

In the proposal, the above-mentioned research elements should be planned as a series of R&D activities under a clear concept that covers the physical picture in the underlying processes, final evaluation of life expectancy and feedback to the design that maximizes the function of the materials. Multiple environmental factors, such as temperature, water vapor, ultraviolet light and cyclic load, which affect fatigue and deterioration should be considered.

For the elucidation of the life of things, in particular, we request that your proposal should allow life expectancy to be evaluated based on a mechanism elucidated according to the principle, instead of being an extension of conventional methods, using a life simulation model based on statistical processing of destructive test data. For example, such proposal should include the following R&D elements:

- Understanding the underlying processes of fatigue and deterioration
- Multi-scale elucidation of phenomena progressing from micro to macro

We expect that your R&D should aim to contribute to the development of a wider range of products and new materials beyond the combination of specific base materials and reinforcing materials and the combination of specific products and usage environments.

Under this theme, we expect proposals from new fields beyond the existing research ones, and those that require collaboration across the technology areas and fields. We are also looking for challenging proposals that are not an extension of the conventional technologies.

In a feasibility study, the researchers are requested to conduct R&D with an emphasis on the solution of the largest scientific and technological bottlenecks and their feasibility confirmation, which are the key points for a successful POC, start considering a full-scale research and an optimal R&D team organization for a successful POC, and brush up the full-scale research concept.

Please be sure to include the following in the proposal. We strongly expect them to be as specific and quantitative as possible.

- The concrete image of the social implementation that the proposal aims for, and the magnitude of the social and economic impact that is realistically assumed
  - It is necessary to determine specific application areas on which continuous use, reuse, highly optimized design and material design have impact.
- POC that aims to be achieved at the end of full-scale research (a stage where society and industry can determine the possibility of commercialization)
- Concept of full-scale research for achieving POC
  - The full-scale research should be not only a single research, such as observation means to elucidate mechanisms or physical property test, but also a series of R&D processes from physical picture based on underlying process finally to evaluation of life expectancy. The full-scale research should also cover feedback to the design that makes the most of the function of a material.
- Goals and contents of the feasibility study for full-scale research
  - The feasibility study intends to confirm feasibility for achieving POC, and should focus on solving the largest scientific and technological bottlenecks and confirming the feasibility of solving them.

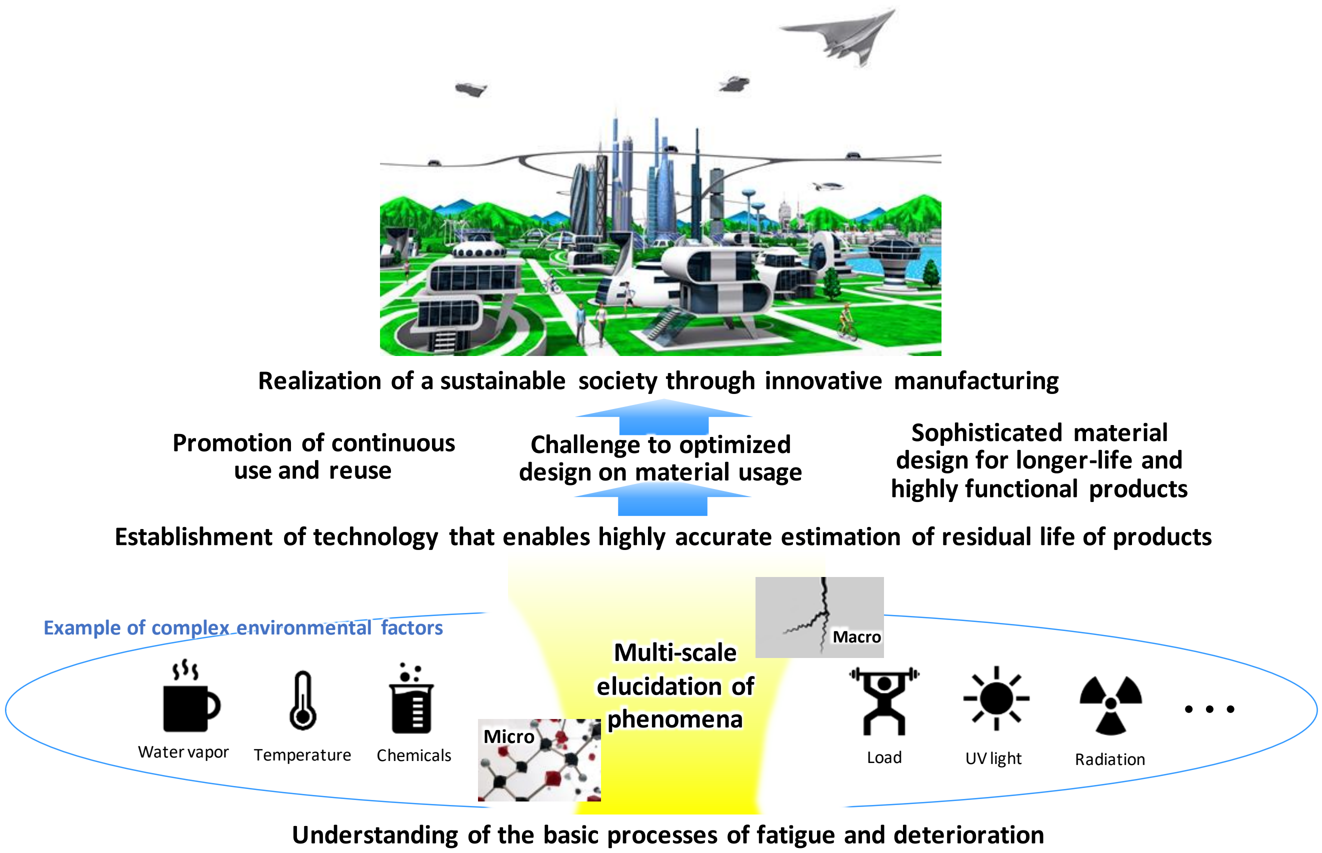


Figure 1: The whole image that this prioritized theme aims

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 meetings, site visits, study groups, etc., and the R&D management committee, including the Program Officer, and the R&D practitioners work together to promote R&D, aiming to achieve theme goals.

This prioritized theme is expected to be rapidly applied to society and industry at a stage where a significant impact on society and economy is expected. If this happens, the researcher should actively consider the transition to a full-scale research even in the middle of the feasibility study. If deemed necessary by the Program Officer to maximize the social and economic impact, we may combine and integrate multiple R&D projects and improve R&D plans (including team formation, budget review, cancellation), regardless of the stage of the project (at the time of adoption or during research).

③ R&D period and costs

For the R&D initiated in FY2019, a feasibility study should be planned with a period of up to two and a half years and a total cost of JPY 10-40 million (direct costs) for the whole feasibility study period.

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.

After adoption, we will flexibly allocate the budget according to the research content.

6.1.3 “Realization of the most safe and secure society in the world” area

Research and Development Supervisor (Program Officer: PO):
Ken-ichi TANAKA
(Senior Engineer, Mitsubishi Electric Corporation)

I. Goal of the “Realization of the most safe and secure society in the world” area

Our society is changing every day. We always need to explore how to improve “Safety and Security” with the social changes.

This research area is expected to deliver POC which provides “safety and security” to the society by various kinds of services and researches necessary for services. Above all, the most important thing is the continuity of the activities utilizing research results. To provide continuous services, it is necessary to design a clear business model and realize a good economic cycle. For this purpose, we would like to positively seek proposals concerning services to search for comfort and pleasure in addition to positive factors without adhering to the image of reducing/eliminating factors that have been found negative in association with such a keyword as “safety and security.”

In FY2019, a new application for the prioritized theme “Creation of a humane* service industry” aimed at securing daily safety and security set in fiscal 2017 has ended (* “Humane” has the meaning of humanitarian and humanistic or making people lofty). In response to the end, we have set a prioritized theme focusing on daily actions which becomes the basic of health, such as food, exercise and sleep, i.e. “Self-management of health based on the action mechanism of daily behaviors such as food, exercise and sleep." We will call for proposals under the two themes, including the prioritized theme for FY2018 “Realization of a safe, secure, and comfortable town free from hazardous substances hiding in the living environment.”

For the prioritized theme “Realization of a safe, secure, and comfortable town free from hazardous substances hiding in the living environment,” we will call for proposals focusing on the atmosphere based on last year's selection and adoption results.

For details of the theme under which proposals are called for in FY2019 and the relationship with the prioritized themes to date, please refer to the schematic below.

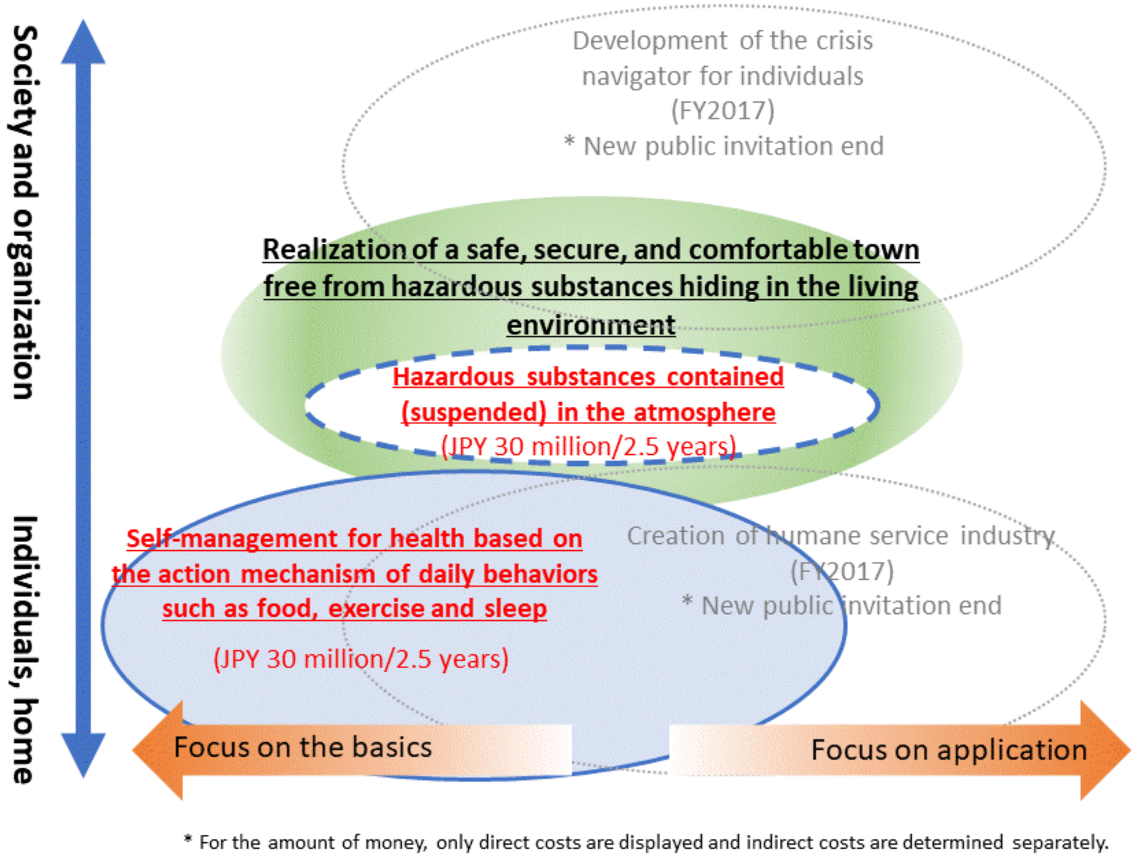


Figure 1: Positioning prioritized themes for “safety and security” area (outline figure)

1. Realization of a safe, secure, and comfortable town free from hazardous substances hiding in the living environment

(1) About the theme

Under this prioritized theme, we conduct R&D to detect and remove minute amounts of hazardous substances hiding in the living environment in a wide area so that all the people living there can enjoy security and comfort without exception.

The air and water from which we are receiving benefits as a matter of course are shared with many people in the wide space of the city. On the other hand, air and water are known to contain minute amounts of hazardous substances[3] that cause health problems, such as viruses, pollen, chemicals, etc. Once heavily polluted by them, it will adversely affect the health of many people.

Our familiar living environment includes the surrounding air and water. To realize a safe, secured, and comfortable town, air or water-related measures taken by individuals, for example, wearing masks or installing a household water purifier, may be effective. However, given an ideal future society, reducing the burden on individuals as much as possible and eliminating anxiety are what the national R&D institute must do.

In recent years, air purification, in particular, has attracted people's attention and various ideas are presented around the world, although their scientific validity needs to be verified. For example, in China, where air pollution caused by PM 2.5 and so on is getting worse, the news that the world's largest 100 m high clean air tower was put into operation became a topic in recent years. In addition, the future drone "UrbanCONE," which was applied for the Electrolux Design Lab 2014 and won the third place, has floated in the air as if it is in the water and presented the concept of purifying the pollutants in the air. Besides the removal of pollutants, such as PM 2.5, etc., much research has been conducted on measures against hay fever, which is a national disease, and methods to control the epidemic of seasonal influenza virus, which affects more than 10 million people every year. On the other hand, this research area still has problems to be solved, for example, effective means for detecting and controlling viruses suspended in the atmosphere have not yet been established and it takes time to detect viruses from human body that cause a new type of infectious disease, such as a new stain of influenza virus.

Under this prioritized theme, we aim to improve the whole town where many people come and go, that is, their living environment, by science and technology as part of the goal of the "Realization of the most safe and secure society in the world" area, which aims to realize a society where everyone can feel that they are protected together.

[3] Hazardous materials in this prioritized theme generally assume causal substances that have a direct adverse impact on humans, more broadly than those set forth in various laws and regulations.

(2) Program Officer’s policies for proposal selection and R&D management

① Policies for proposal selection

Key points for 2019
- **In 2019, we call for proposals on “Hazardous substances contained (or suspended) in the atmosphere.”**
- **About two proposals are to be adopted.**

The hazardous substances subject to R&D in this prioritized theme are the substances generally assumed to adversely affect the humans directly, which are broader than those set forth in various laws and regulations. These hazardous substances are now found in the Japanese living environment, whether manifest or potential. Since the JST-Mirai Program targets themes with a high socio-economic impact, we mainly target viruses, pollen, chemical substances, etc. in the air for this fiscal year. More specifically, these themes include R&D involving quick and high sensitive detection from the atmosphere and removal so as not to adversely affect human health, or R&D involving quick detection of and response to hazardous substances from the human body, excluding R&D aimed at prevention and treatment by medical treatment. We will promote these R&D themes to realize a secure, safe and comfortable town. The researchers are requested to clarify a path toward social implementation, for example, who will perform POC, in consideration of the establishment of policy regulations for dealing with hazardous substances as needed.

The researcher making a proposal should first identify hazardous substance(s) with reference to the above, and clearly describe how to deal with them, including a 2030 social implementation image. Clarifying the advanced science and technology required to handle such hazardous substances is also an important evaluation item.

It is not yet clear how, for example, the seasonal influenza virus, a hazard substance in the atmosphere will spread. One of the reasons is a difficulty in detecting influenza virus from people other than those already infected (or infected animals). The onset of influenza is known to be triggered by contact with the virus. Knowing where and how much influenza virus is found in the living environment enables its removal, which will bring great value to the society. If we can show POC for a specific measurement method or the construction of a measurement infrastructure, a company is likely to take over the research. For a new strain of influenza virus, it takes time to culture and propagate influenza virus for detection. Thus, taking preventive measures before the spread of infection requires the development of a method for detecting viruses from the atmosphere quickly and sensitively. On the other hand, it is a well-known fact that pollen is scattered to some extent. Your research should focus on providing measures to prevent human exposure, rather than detecting the accurate number of scattered pollen grains.

Not only proposals, other than the above, on “hazardous substances contained or suspended in the atmosphere” but also any new technology that can present a high-impact POC in line with the theme purpose of removing anxiety from the living environments are welcome.

This prioritized theme aims to bring a new added value, for example, [1] a town where no pollen fly, [2] a town that requires no masks and [3] a town without a fear for viruses, to the cities where people come and go, through the implementation of R&D as described above.

Figure 2: Image of aiming at the realization of a safe, secure and comfortable town free from hazardous substances in living environments

② Policies for R&D management

We prepare a research management system that can give researchers advice and guidance through confirmation of research plans and making site visits by members of the R&D management committee aiming to realize a society where everyone can feel being protected together.

For transition from feasibility studies to full-scale researches, we may restructure the system, such as reassignment or cancellation of individual groups that participate in research projects and of research themes.

③ R&D period and costs

For the R&D themes initiated in FY2019, a feasibility study should be planned with a period of up to two and a half years and a total cost of up to JPY 30 million (direct costs) for the whole feasibility study period.

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.

After the adoption, we will flexibly allocate the budget according to the research content.

New

2. Self-management of health based on the action mechanism of daily behaviors such as food, exercise and sleep

(1) About the theme

Under this prioritized theme, we will conduct R&D to elucidate the mechanisms of actions in the living body, such as food, exercise and sleep, which are the base of health maintenance, and provide scientific evidence that triggers truly effective behavior, aiming to widely disseminate self-management for health maintenance. This allows us to build a foundation for continuously creating services that can introduce health activities optimal for individuals to realize a healthy longevity society.

"Food," "exercise" and "sleep" are said to be the three basic elements that are vital to maintaining our daily health. To prolong a period in which we can stay healthy throughout our lives (healthy life), a proper management of these daily activities, such as a well-balanced diet, adequate exercise, and thorough rest and sleep, is considered vital. Japan is said to be facing a super-aging society. An increase in the proportion of people who complain of physical problems or of unhealthy people increases medical expenses, which could put pressure on the country's finances and adversely affect the continuity of social security, such as medical insurance. A prolonged healthy life extends a period of social participation. In a society that faces super-aging as in Japan, extending a healthy life span is an inevitable challenge in order to realize a society in which each individual can play an active role for a long time.

In order to maintain our health, a proper management of daily activities, such as food, exercise and sleep in our daily lives, is the key. It is also ideal to run a PDCA cycle of [1] PLAN, [2] DO, [3] CHECK, and [4] ACTION for daily activities. If a person who runs the PDCA cycle is found to be in a pre-disease stage at the step of [3] (CHECK), he/she can be restored to health through individual action at [4] (ACTION). This is how the self-management is expected to extend the healthy life span.

Unfortunately, it has not been fully elucidated how actions, such as “food,” "exercise" and "sleep" affect the maintenance of homeostasis in vivo. At present, most health information circulating in the society has been based on statistical correlation. However, as the elucidation of mechanism advances, it turns out that the statistical correlation to date is not necessarily correct. For example, lactic acid accumulated in muscles during exercise was considered to be the causative agent of fatigue based on the correlation data obtained in epidemiological studies. However, the progress in elucidation of the causal relationship between lactic acid and fatigue revealed that lactic acid has rather a suppressive effect on fatigue. As is shown above, information on health indicators based on the elucidation of mechanism is insufficient, despite a wealth of health information in society. To link the abundant health information to specific actions that improve individual health or to improvement of behavior, accumulation of health information based on the elucidation of mechanism on homeostasis maintenance is vital. Once a new indicator on health is developed, it is an important challenge how the indicator is recommended and disseminated so that people can perform self-management continuously based on that indicator.

In order to ensure the safety and security of our lives in the future, it is imperative for each of us to thoroughly implement the PDCA cycle on daily activities, such as “food,” "exercise" and "sleep" in our daily life and manage our own health. The accumulation of scientific evidence on the causal relationship between daily action and health, the creation of services capable of presenting the best health activities for individuals, and the construction of a system made available to everyone of us are expected to realize a society where we can live a long and healthy life.

(2) Policies of Program Officer for proposal selection and R&D management

Key point for 2019
• **About four proposals are to be adopted.**

① Policies for proposal selection

This prioritized theme aims to elucidate a mechanism through which daily activities, such as “food,” “exercise” and “sleep” of healthy or the early stage of Mibyou people (not receiving medical care) affect the maintenance of homeostasis in vivo. In particular, we welcome proposals that aim to elucidate the mechanism in consideration of the mutual relationship among food, exercise and sleep. Elucidation of the mechanism through which “food,” “exercise” and “sleep” affect the maintenance of homeostasis in vivo leads to identification of objective indicators (markers) that allow healthy people to further improve their health and the early stage of Mibyou people to be restored to health through self-management from the factors related to the maintenance of homeostasis. We welcome proposals for R&D of techniques to measure these identified markers easily and accurately in a minimally invasive manner. Furthermore, we also seek for a proposal with a clear vision for broadly recommending and promoting the self-management of daily activities to each generation, including working people and elderly people, by combining research on nudge effects and gamification with the measurement technology. The following are examples of expected R&D projects, but they are given for only information. Please feel free to propose R&D themes.

Example 1 of R&D project:

Recent studies have shown that continuing to take certain food ingredients has the same effect on muscles as exercise, and studies are conducted on the effects of diet and exercise on the body clock, partially revealing the mechanism through which daily activities, such as “food,” "exercise" etc., contribute to health. In these circumstances, aiming to measures the effects of daily activities with an indicator, we conduct various analyses on action site, mechanism, dynamics, metabolism etc. for factors whose secretions change in the body in response to daily activities. We will identify the factors considered effective to maintain health and develop methods for quantitatively measuring those factors anytime and anywhere using a simple apparatus. In addition, we will develop food products that have the same function as the factors found, and promote self-management by individuals through the sales and diffusion of these food products.

Example 2 of R&D project:

"Fatigue," along with "pain" and "fever," is said to be an important alarm indicating that the body tries to maintain homeostasis. Even healthy people may lose health as fatigue accumulates. Focusing on physiological fatigue and stress caused to healthy people by irregular "eating" or "sleeping" or lack of "exercise," we will elucidate the mechanism through which their daily activities affect the maintenance of homeostasis in vivo, leading to fatigue and stress felt by individuals. We will find objective indicators of fatigue and stress from the factors involved and develop methods for measuring these indicators quickly and easily at any time. This allows us to build a new system for managing the mental health of workers based on the objective indicators.

In this R&D area, we do not only intend to conduct cohort studies to track healthy people, but we also welcome R&D proposals based on long-term observation data accumulated in other cohort studies, etc.

In order to facilitate self-management of health in our daily lives, it is vital that people can measure their health status easily at home, at school, at work, at day-care centers, at drug stores, etc. So, we request researchers to present a highly feasible vision so that private companies, etc. can develop sales and services based on the POC shown in this research and widely recommend and diffuse self-management of health in our society.

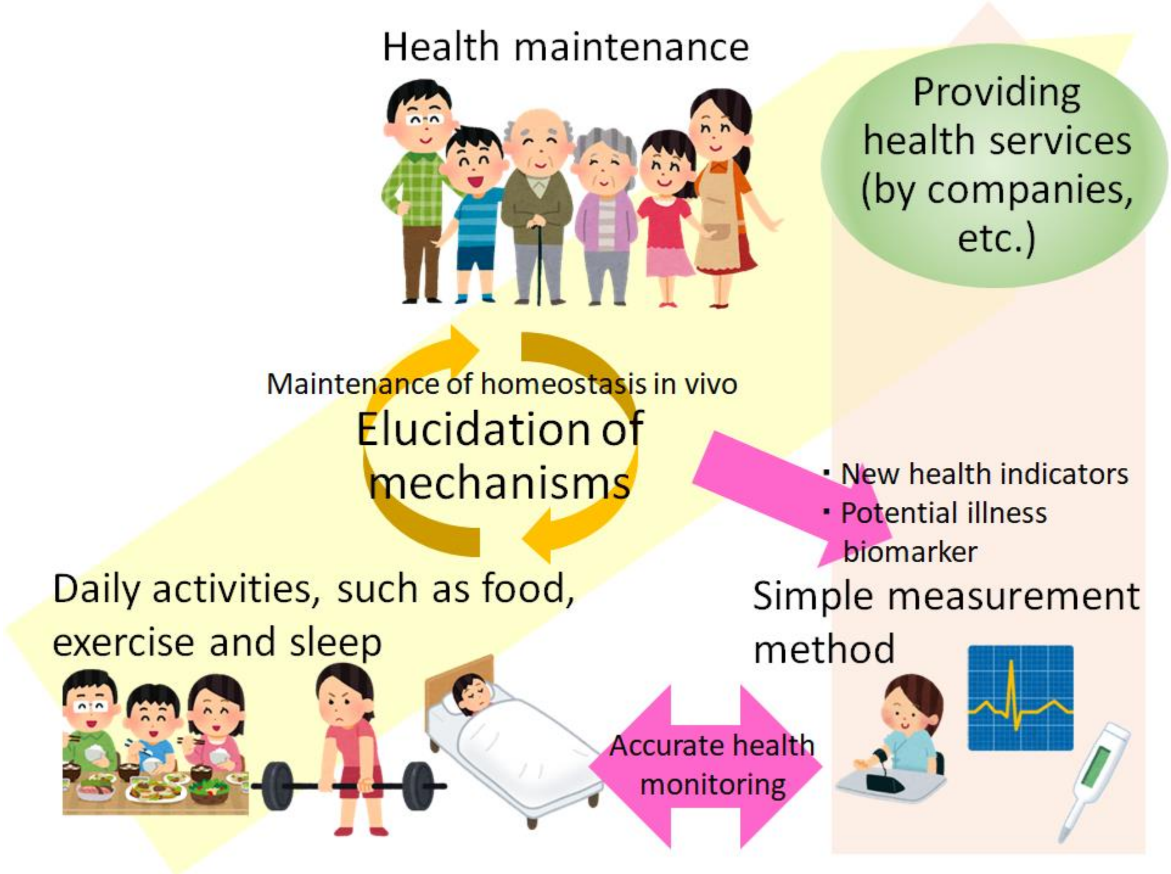


Figure 3: Self-management for health based on the action mechanism of daily behaviors such as food, exercise and sleep

② Policies for R&D management

We prepare a research management system that can give researchers advice and guidance through the confirmation of research plans and site visits by members of the R&D management committee aiming to realize a society where everyone can feel that they are protected together.

For transition from feasibility studies to full-scale researches, we may restructure the system, such as reassignment or cancellation of individual groups that participate in research projects and of research themes.

③ R&D period and costs

For the R&D themes initiated in FY2019, a feasibility study should be planned with a period of up to two and a half years and a total cost of up to JPY 30 million (direct costs) for the whole feasibility study period.

A full-scale research should be planned with a period of up to five years and with a total cost of up to JPY 750 million (direct costs) for the whole full-scale research period.

After adoption, we will flexibly allocate the budget according to the research content.

6.1.4 “Realization of a low carbon society, a global issue” area

Research and Development Supervisor (Program Officer: PO):
Kazuhito HASHIMOTO
(President, National Institute for Materials Science)

I. Goal of “Realization of a low carbon society, a global issue” 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 “National Energy and Environment Strategy for Technological Innovation towards 2050” (NESTI 2050) compiled by the Council for Science, Technology and Innovation in April 2016 presented, keeping the year 2050 in view, some prospective technologies with the potential to reduce emissions that should have a large impact, as well as the organization to advance long-term research and development; furthermore, the “Plan for Global Warming Countermeasures,” a cabinet decision in May 2016, stated strategic endeavors 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, 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 Steering Meeting, examined the prioritized theme for fiscal year 2019.

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 fiscal year 2018, "realization of a low-carbon society through 'game-changing technologies.'" Furthermore, we classified the fields of the technologies in relation to low-carbon emission into four Sub-Themes; 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 issues facing the technologies in implementing achievements in the society) presented last fiscal year, we reset our bottleneck issues to call for more research-and-development proposals for solving those issues.

It should be noted that "the management method by harmonized various technological seeds" will be introduced from fiscal year 2019 in Sub-Theme "④ Creation of recycling-oriented polymer materials to realize a low-carbon society." This is a new approach for creating new social values by combining technological seeds in different fields and systems for early accomplishment and social implementation of the results. For details, refer to "● Policies for R&D management."

II. Prioritized theme

Realization of a low carbon society through game changing technologies

Sub-Theme	Classification	Bottleneck Issue
① **Sunlight- and hydrogen-based energy generation and devise-based energy storage technologies**	B1	Pb-free and high durable perovskite solar cell
	B2	Photovoltaic cell based on a new concept realizing twice or more conversion efficiency than conventional solar cells
	B3	Solar cell manufacturing technology featuring “a device thinner than ever before”
	B4	Innovative top cell technology for highly efficient tandem solar cells
	B5	Organic solar cells with small voltage loss
	B6	Artificial photosynthesis (photochemical synthesis with water as the electron source)
	B7	CO_2-free hydrogen production technologies aiming at cost reduction to 1/10
	B8	Development of highly-ionized conductive solid electrolytes according to new material systems
② **Energy-saving technologies based on high-efficiency application of materials and physical/chemical processes**	B9	High efficiency of CO_2 reduction equipment and facilities using layered structure technologies
	B10	Innovative bonding and separation technologies that possess both bonding strength and separation or decomposition functions
	B11	Innovative reliable lifetime prediction and prolonging technologies for durable structural materials contributing to CO_2 reduction
	B12	Innovative cooling technologies for superconducting instruments
	B13	High performance and protection technologies of high temperature superconducting coil
	B14	Energy saving and high efficiency related technologies for electric power/power conversion systems
	B15	Fundamental technologies of green electronics for energy saving data communication and innovative information processing
	B16	Development of innovative thermal energy utilization technologies
	B17	Chemical process enhancement technologies using high-efficiency, high-performance separation technologies
	B18	Innovation of bulk chemicals production technologies based on a new reaction fields to save energy required for causing chemically difficult reactions

③ **Carbon neutral technologies based on chemical processes, biotechnologies and biomaterials**	B19	Technologies for large-scale and efficient conversion of CO_2 into methanol, olefins, and other chemicals
	B20	Development of highly efficient greenhouse gas separation membrane and sorbent
	B21	Development of highly efficient biomass gasification processes for chemicals production
	B22	Development of photosynthetic microorganisms robust against changes in environmental conditions for large-scale production
	B23	Technologies for improving biomass productivity with minimum resource input
	B24	Synthetic biological technology and innovative bioprocess technologies for designing cells with high productivity for useful substances
	B25	New synthetic technologies for high-efficiency production of high-performance/high-functionality materials from biomass raw materials
	B26	Technologies for controlling layer structures to create next generation nano-cellulose materials
	B27	Technologies for chemical modification/composition to create next generation lignin materials
④ **Creation of recycling-oriented polymer materials to realize a low-carbon society**	B28	[Management method by harmonized various technological seeds] Creation of recycling-oriented polymer materials to realize a low-carbon society
⑤ **Other**	B29	New approaches for a low-carbon society

* “Sub-Theme” here refers to those in sub-classification of the bottleneck issues.

* Describe the names of the prioritized themes, Sub-Theme numbers (①-⑤), Classification of Proposals (B1 – B29), and the names of the bottleneck issues in the “application to prioritized themes” on the cover sheet of the R&D Proposal (Form 1).

【Example of the description】

Prioritized theme	Realization of a low carbon society through game changing technologies ① B1: Pb-free and high durable perovskite solar cell

* It is assumed that the proposal relates to multiple bottleneck issues, as the individual bottleneck issues are not necessarily independent and may be related to one another. In such case, please select the bottleneck issue that its technology is most strongly related to or “⑤ B29: New approaches for a low-carbon society” and propose it.

(1) About 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 CO2 emissions are drastically reduced.

Fig. 1 shows an overview of this area.

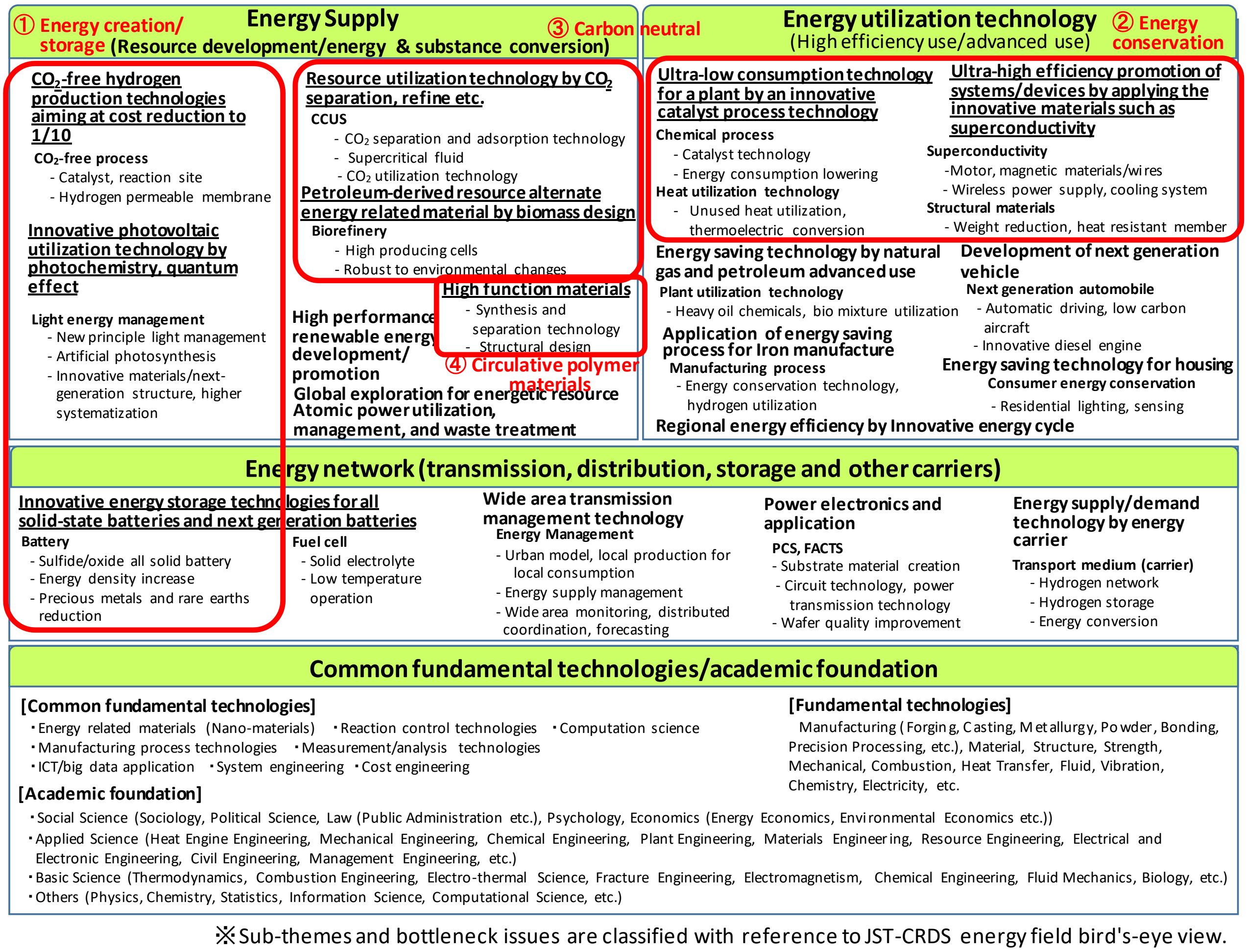


Fig. 1. An overview of the “Realization of a Low Carbon Society, a Global Issue” area

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 that “the mid- and long-term research and developments in the fields of energy and environment for realizing innovation in the reduction of CO_2 emission should be strongly advanced by wisdom gathered from the industries, academes, and governmental bodies, applying the achievements in the world.” This is one of the concepts involved in

NESTI2050. This R&D strategy agrees with the concept of the creation of a game-changing technology that is addressed in this area, promoting the research and developments that are closely connected to the public interest.

Furthermore, we, considering the research and development 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 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 “Keidanren's Action Plan for the Low-Carbon Society in 2030” (formulated in April 2015, revised in April 2017) 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 even covering the years after 2030.” 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 area, and the technology is transferred to corporations.

(2) Program Officer’s policies for proposal selection and R&D management

● Policies for proposal selection

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 research and development).

- 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

Moreover, for the sake of the implementation in the society, we, if necessary, will cooperate with other governmental bodies in other programs to transfer our achievements.
Through our endeavors stated above, we aim to create a game-changing technology that will, while satisfying the expected demands for services in the year 2050, drastically reduce CO_2 emissions and, thus, we lead it to implementation in the society, contributing to the realization of the low-carbon society.

● **Evaluated items and norms**

Our selection will be based on the following evaluated items for the comprehensive examinations of proposals.

[Adequacy of Targets]

・The proposal uses quantitative expressions to present that the technological issue, which the proponent wants to cope with, will contribute to the realization of a low-carbon society by around the year 2050.

[Adequacy of Means]

・The measures for the solution of an issue, which the proponent wants to cope with to achieve a goal, exhibit superiority and uniqueness.
・The plan for the research and development is adequate (including the organization for the research and development and the scale of its implementation).

[Feasibility]

・The measures for the solution of an issue, which the proponent wants to cope with to achieve a goal, will be feasible at the time of the completion of the full-scale research.
・The scenario covering the events from after the completion of the full-scale research to the practical application is adequate.

● **Description on research and development**

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 area, aim to create a game-changing technology that contributes to the realization of a low-carbon society based on measures for mitigation.

To this day, various trials have been performed in the course of the development of technologies that contribute to the reduction of CO2, a large number of which have not been applied in the real world. The causes of this, i.e., “bottleneck issues,” will be compiled and presented by the parties relevant to this area.

In this area, we think that 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 made by the researchers in this field. Therefore, based on the analysis of the contents in the prioritized themes called for from the general public, as well as on the bottleneck issues presented in the last fiscal year, we reset our bottleneck issues to specifically describe the contents. The four Sub-Themes (① to ④) that classify this field are shown below.

① Sunlight- and hydrogen-based energy generation and devise-based energy storage technologies

B1 Pb-free and high durable perovskite solar cell

Lead-containing solar cells require specific management for their production and disposal, which increases their costs. Apart from mega-solar systems, the application for home-appliance use is also increasing; to prevent the environmental load from growing, lead-free applications are essential. Many studies have been already conducted to cope with the lead-free application to perovskite solar cells; however, currently, they have not yet achieved sufficient characteristics. In addition, it is necessary to replace solar cells in a short period if they do not have sufficient durability; therefore, what we want here is solar cells that have high durability for long-term use. It is guaranteed that the solar cells currently in use can be used for 20 to 25 years. Perovskite solar cells have improved durability, owing to the optimization of materials and processes; however, this is not yet sufficient.

With these circumstances considered, we call for challenging proposals aiming to realize a perovskite solar cell that is lead-free and composed with the low-environmental load materials, has both of high durability and high efficiency of 20 % or more.

B2 Photovoltaic cell based on a new concept realizing twice or more conversion efficiency than conventional solar cells

The conversion efficiency of the cells used in Si solar cells has reached approximately 25 %; the logical maximum efficiency of the single-junction-type solar cells is said to be around 30 %. Ordinary solar cells cannot absorb light that has energy lower than the band gap; therefore, in the case of light with high energy, the residual energy is converted to heat and is then lost. However, in the case of quantum dot solar cells, it is possible to form an intermediary band in the band gap; thus, it has been pointed out that it becomes possible to convert a large portion of the energy from light into electricity. In the case of an intermediary-band solar cell, it is said that an efficiency of 60 % or more, logically, can be attained with a concentrator type. Having said that, the conversion efficiencies that have actually been attained are still low. Apart from the fundamental and principle-based examinations, including the adequacy and feasibility of the theoretical model, we need quantum dots or other intermediary-band materials, the method of formation, the structural optimization of solar cells, and more. With these conditions considered in this area, we call for challenging proposals for the designing principle of the use of new concepts such as quantum effects to embody conversion efficiencies twice or more as high as that of single-junction-type solar cells, for the structure of solar cells and the construction of the formation method based on such principle, and for the embodiment of these. Our scope includes a variety of solar cells types that use quantum dots (the method of realizing a high density and a long carrier lifetime), nanowire (wall), near-field light (dressed photon), photon up-conversion, multi-exciton formation, hot carriers, and so forth. There is no restriction on materials or mechanisms; our evaluation points shall be that the proposals probe the superiority to conventional solar cells, and furthermore, step up to propose the specific methods of production.

B3 Solar cell manufacturing technology featuring “a device thinner than ever before”

Almost all crystalline Si wafers, which are commercially produced at present, are produced by wire saw technology and optimized with a wafer thickness of 180 μm, almost the lowest limit.

If it is made thinner than this by the wire saw technology, not only yield loss will occur, but there will be an inappropriate situation in terms of manufacturing cost that the amount of Si shavings (kerf-loss) generated with cutting will increase. In wire saw technology, contamination of Si shavings with lubricating oil is a problem, and appropriate collecting technology has not been developed. This is a major challenge in terms of the effective use of expensive materials.

In this field, in addition to the technology to produce the ultra-thin (1/4 or less of the existing thickness) crystalline Si wafers with a general-purpose 6-inch square size, we call for the solar cell manufacturing technology which can achieve the cell efficiency of 23 % or more from the crystalline Si wafers of such thickness.

At the time of commercialization, even such ultra-thin crystalline silicon solar cells require a string formation process in which multiple cells are connected in series. Also consider this connection technology (including the way to re-consign against appropriate solar cell or module manufacturer).

We also call for the thin film solar cell technology with an integrated structure that can achieve a cell efficiency of 23% with the same size as a general-purpose 6-inch square crystalline Si wafer. In this case, cell efficiency is defined by the total area including plus/minus electrodes located at both ends of the integrated structure. Also, in this case, consider the commercialization image.

The manufacturing technology to be obtained in this field is positioned as a main power source. Simultaneously realizing both the weight reduction and making flexible of solar cell technology (that is, the crystalline Si solar cell and thin film solar cell), which are becoming increasingly important as a commercial power source, eliminate the installation restriction. This will contribute to the further introduction and spread of solar power generation systems.

B4 Innovative top cell technology for highly efficient tandem solar cells

In order to realize drastic enhancement in the conversion efficiency of 30 %, which is the theoretical limit on single-junction-type solar cells, it is expected to laminate semiconductor materials of different band gaps to expand the absorbing wavelength band for tandem-type solar cells; however, this has not brought any sufficient enhancement in terms of efficiency. As the solar cells in the bottom layer, Si and CIGS solar cells (band gap 1.1 eV), are optimum as they have high conversion efficiency and exhibit excellent durability. As the solar cells on in the top layer, the semiconductor layer solar cells with the band gap of approximately 1.5–1.7 eV have been studied; however, any solar cells with low-cost, high efficiency and high durability are yet to be realized. For instance, perovskite solar cells (band gap - 1.5 eV), chemical compound semiconductors (CuGaS), and others have been studied as a top layer. Recently it was reported that efficiency of the tandem solar cells of silicon and perovskite is more than the world highest efficiency of simple silicon solar cells.

The top layer materials and the development of devices are essential to realize high-efficiency tandem-type solar cells. Furthermore, in order to develop tandem-type solar cells, we need to understand the optimum band gap control, joining interface and output amperage/voltage characteristics of the multi-junction and, also, need to design or optimize the structure, including photon management. Therefore, apart from the solution of the electric and optical characteristics for a drastic enhancement in the efficiency of the top layer, we are expecting challenging proposals that aim to realize the significant improvement in the performance of solar cells with low costs by applying a tandem type structure with the electric and optical characteristics of the module and system as a whole toward its practical application.

B5 Organic solar cells with small voltage loss

Organic solar cells have excellent characteristics such as the high film forming characteristic, light, flexible and low cost. Therefore, they are among the prospective candidates for solar cells in the future. With similar characteristics as the solar cells, the development of perovskite solar cells is advancing; however, the organic lead, which is included in them, requires specific management for its production and disposal. This is one of the significant obstacles for the home-appliance use, beyond the application to mega-solar systems. Lead-containing perovskite solar cells can have both high short-circuit current density (Jsc) and open-circuit voltage (Voc); therefore, conversion efficiencies exceeding 20 % have been attained. On the contrary, improving the conversion efficiency of organic solar cells is said to be difficult, particularly because of the process of losing Voc. We need to solve the mechanism of such voltage loss and to construct a scenario to connect to the enhancement in efficiency; moreover, we need to develop materials that suppress the route of voltage loss based on such construction. Recently, with the development of a new non-fullerene type bulky acceptor for thin-film solar cells, the conversion efficiency has rapidly improved, such as the efficiency exceeds 15% in a single cell, and reaches to 17.3% in a tandem cell, and it has reached a new phase.

With these circumstances considered, it is necessary to elucidate the mechanism of the voltage loss process, construct a scenario that leads to the improvement of efficiency, and develop materials that can suppress the voltage loss process. We call for challenging proposals to realize organic solar cells that can have both good Jsc and Voc. We can think a non-fullerene acceptor as a desirable candidate. The high design characteristic of organic compounds is the most appropriate for the light absorption matching of each cell required for tandem cell development. We call for challenging proposals that elucidate the molecular mechanism of electron and hole-transport, develop materials and battery structures based on that, aiming a breakthrough efficiency improvement and durability.

B6 Artificial photosynthesis (photochemical synthesis with water as the electron source)

Artificial photosynthesis is, to realize the low-carbon society, the ultimate goal. We call for “proposals in relation to the photochemical synthesis of useful substances with water as an electron source” as an artificial photosynthesis project that is surely useful to the society but is not a mere model research. The methods to activate stable small molecules such as water or carbon dioxide to convert to the useful substances such as hydrogen or methanol, and development of catalysts that promote such converting process are the very important bottleneck issues. In this case, it is a key to use water as an electron source, but not to use a sacrificial electron donor. In addition, these issues include the synthesis of organic chemical compounds socially 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.

B7 CO_2-free hydrogen production technologies aiming at cost reduction to 1/10

For the realization of a low carbon society, our country needs to drastically reduce its CO2 emissions (to reduce the emission of greenhouse gases by 80% by 2050). The government, in the "Plan for Global Warming Countermeasures" (cabinet decision, May 13, 2016) and on other occasions, has expressed its determination to try and change the existing energy supply structure and move to a new energy system.

Conventionally, our attention is focused on hydrogen as a type of clean energy carrier that neither involves carbon nor emits CO_2 while we use it. In its production phase, we can use the carbon dioxide capture and storage (CCS) technology and renewable energy so as to complete the use of an energy carrier that is CO_2-free.

As of date, there are industrial uses of hydrogen generated as a by-product at factories or hydrogen produced by the reformation of natural gas, LPG and etc. Owing to the practical application of hydrogen power generation (turbine) and the spread of fuel cells, the demand for hydrogen will increase by a thousand times by 2030 compared to the current level. The hydrogen procurement only for power generation use is estimated to consume 300,000 tons a year (1,000 times higher than the current) that demands of some technology to produce a considerable amount of hydrogen with low costs ("Basic Hydrogen Strategy," Resolution of the Ministerial Council on Renewable Energy, Hydrogen and Related Issues December 26, 2017).

However, the by-product hydrogen or most of the reformation production methods emit 10 tons or more of CO_2 for 1 ton of hydrogen generation. Therefore, in this field, we call for CO_2-free hydrogen-producing methods.

Also, from the past time, technologies with using the renewable energy electricity, such as the water electrolysis and etc. utilizing electrode reaction, the water photolysis utilizing the light-related process, pyrolysis utilizing thermochemistry process, the bio-hydrogen production from organic resources and organism, and etc., have been studied. In this field, we call for such proposals which are not only the solution of individual elemental technologies but also integrate the technology development based on the whole hydrogen production process, especially a group of technologies necessary for actual operation of such process, with reference to the challenges at the development as shown below. In addition, as the other technologies, proposals using the alternative technologies which are not used in the past time, are also included as the target. We expect the challenging proposals which will ultimately aim to lower the cost of production to 1/10th of the present cost.

(i) Technological Issues in Water Electrolysis

Hydrogen production from water electrolysis has been highly expected in CO_2 free process, for utilizing renewable energy like solar energy, solar thermal energy and wind power. But there is a broad array of issues to discuss including efficiency, load fluctuation, costs, lifespan and so on. Moreover, because of conflicting elements in these issues, strategic research and development is needed.

For example, for the large-scale water electrolysis method fully uses the renewable energy, the low-cost alkali water electrolysis is also practically applied, but the technologies corresponding to the fluctuating renewable energy response to the efficiency improvement or expansion to the large scale are the challenges. On the other hand, to use excess energy from renewable energy with no demands are suitable for proton exchange membrane (PEM) electrolysis which highly adapted to frequently start-stop, but for its utilization, development of substitutional low-cost materials is highly expected for expensive electrode catalyst, polymer electrolysis membrane strong acid resisted electrolysis cell material.

In recent years, it has been promoted to develop the solid oxide electrolysis cell (SOEC) expected for demand response function of power, coordination, emergency response adding to produce hydrogen but its biggest challenge is manufacturing cost reduction. In order to resist working in high temperature (800°C), cost down of device materials and thermal insulation technology are needed. For solid electrolyte of ceramics, improvement for large area, enforcement of mechanical strength and expansion and contraction by fluctuation of temperature are also challenges. Selection of electrode materials, improvement of the structure, and measures for various factors that affect cell characteristics and durability are also required.

(ii) Technological Issues in Water Photocatalytic Degradation

The development of a high-efficiency photo-catalyst that enables the production of hydrogen from water photolysis is one of the most anticipated technologies because CO_2-free hydrogen can be produced by future practical use of it. For this, we want the energy-conversion efficiency from sunlight to hydrogen to be at a level comparable to the energy-conversion efficiency in the case in which a solar cell is used for water photolysis. For this purpose, it is essential that the developed photo-catalyst should function efficiently even under visible light. In addition, the stability that bears long-time use and, furthermore, safely separating generated hydrogen and oxygen are also among important issues.

(iii) Technological Issues in Thermochemistry Processes

For producing hydrogen from the thermochemical decomposition of water, a variety of endeavors have been made till date, including copper-chlorine cycles, IS processes, UT-3 processes, among others. However, some problems do exist; that is, we have only some limited types of thermal sources if the reaction temperature is as high as 1,000°C or higher, whereas if the reaction temperature is low, we have complex reactions that generate hazardous by-products and the like. This is why we want the development of an innovative technology in thermochemistry processes that suppresses reaction temperatures, simplifies reactions, and suppresses the generation of harmful by-products and the like.

(iv) Technological Issues in Biomass Utilization

For the production of bio-hydrogen, they have been using dark fermentation, bio-photo reactions, and others. It is said that it is difficult to generate hydrogen from a variety of organic resources; the issues are not only the slow speed of hydrogen generation and the low efficiency of hydrogen conversion, but also the instability. Therefore, for the quick and stable generation of bio-hydrogen from organic resources, it is wanted that methods such as synthetic biology, metabolic engineering, and process engineering should be used to design and control microorganisms and oxygen, thereby developing a technology that may drastically enhance the efficiency of hydrogen conversion. In addition, reductions in the generation of extra gases, including CO_2, in the course of the generation of hydrogen are also desired; what is wanted here is the development of a technology that converts CO_2 into some useful chemical compound and, at the same time, enables the production of hydrogen.

(v) Other technologies

The hydrogen production technology and measures for solving the challenges, by approaches different from the above technologies are also targeted in the research proposal. For example, the hydrogen production from substances (ammonia, formic acid, etc.) that are expected to be used as energy carriers and hydrogen storage media, and hydrogen production by thermal decomposition of natural gas containing methane etc. are also targeted. In addition, we can expect the creation of new high value-added hydrogen by controlling the physical properties in some way.

Furthermore, the proposals for the construction of a comprehensive CO_2-free hydrogen recycling system that includes the use of renewable energy other than solar light, and the use of chemical products and energy are also targeted.

B8 Development of highly-ionized conductive solid electrolytes according to new material systems

As a key device for the construction of a low carbon society, the all-solid-state batteries which are potentiality beyond the lithium-ion batteries are expected. Currently, all-solid-state batteries using various solid electrolytes such as sulfides, oxides, and polymers are being studied, and search for solid electrolytes in these systems is being conducted. On the other hand, the search for highly ion-conductive solid electrolytes other than conventional material systems is also considered extremely important. Therefore, we call for the development of highly ion-conductive solid electrolytes based on new material systems that are completely different from the conventional ones, such as hydrides and chlorides. The electrolyte should have all of the following characteristics: ① high ionic conductivity ($10^{-3}Scm^{-1}$ or more), ② resistance to oxidation and reduction, ③ high plasticity, and ④ stability in the atmosphere. Ultimately, it is assumed that the solid electrolyte of a new material system which combines these characteristics is developed and design, manufacturing, and verification of the all-solid battery will be conducted. At the same time, we also expect the creation of science such as basic scientific logic construction that will serve as a design guideline for high ion conductivity solid electrolytes.

② Energy-saving technologies based on high-efficiency application of materials and physical/chemical process

B9 High efficiency of CO_2 reduction equipment and facilities using layered structure technologies

For instance, high-temperature, high-strength materials that are used for high-efficiency energy equipment such as those for power generation, which have great influence on the reduction in CO_2, are under stringent design restrictions because they are difficult to process; this is a large obstacle to its application to high-efficiency energy equipment, which is linked to the effective reduction in CO_2. It is understood that the layered structure, which has made rapid progress in recent years, is one of the prospective technologies that will be expanding in the field of the production of heat-resistant materials enabling even the complex shapes.

We have called for the technology development to manufacture clean powder and the challenging efforts which are hardly affected by contamination in the powder manufacturing and layered structure forming process, and furthermore, contribute to the effective and robust alloy development against oxide or nitride coming from the powder surface. Its achievements are steadily coming out, at present, and the overall level is also rising. However, there still remains many obstacles to be surmounted in designing the equipment/facilities with high CO_2 reduction effect utilizing such technologies. Therefore, we call for the proposals to develop high efficient CO_2 reduction equipment/facilities by utilizing the layered structure technology, in addition to the powder manufacturing and alloy development suitable for the existing layered structure technology.

B10 Innovative bonding and separation technologies that possess both bonding strength and separation or decomposition functions

When you classify the amount of CO_2 emission by the source sector, the industrial (factories etc.) and transportation (vehicles, watercraft, etc.) sectors account for half of the total CO_2 emission in this country; more specifically, CO_2 is conspicuously emitted during the production of structures and products. Therefore, what is wanted here is some means (process) for comprehensively reducing CO_2, involving the production, conjunction, use, and disposal of materials. In terms of the production phase, this will require the production of such products that are excellent in CO_2 efficiency based on a multi-material application effectively combining different types of materials. In addition to this, long-term use and reuse, which may require repairs, etc., are wanted as well as the application of low-CO_2 systems in recycling processes.

The technology for connecting and separation is the severe obstacles. If innovative connecting/separating technologies for compatible connecting strength and separating/dismantling performance are established, we can reduce the energy necessary for the dismantling. Therefore, we can embody a recycling society and low-carbon society involving a large number of products. In particular, we call for technology that enables the effective use of existing resources as the materials for social infrastructure, as well as rapid demolition and building, and the longevity of infrastructure systems. Additionally, we call for proposals that contribute to an innovative application for the joining and separation of multi-materials with consideration to the recycling performance of light-weight materials, which consume a large amount of energy during production.

B11 Innovative reliable lifetime prediction and prolonging technologies for durable structural materials contributing to CO_2 reduction

A variety of structural materials that have high durability are used for equipment in relation to the conversion and/or use of energy; for instance, there are many cases in which the limitation on the operable temperature of a power generation facility or any other property of a material interferes with the life-cycle low-carbon designs of equipment. Currently, apart from the ALCA, developments of excellent materials for equipment that contributes to the reduction in CO_2 are ongoing all around the world. In order for them to connect to the designing of a low-CO_2 application to equipment or facilities, the forecasts of the performance and longevity are essential to guarantee the whole of their use periods. However, the use periods of such equipment and facilities are as long as tens of years; therefore, longevity assessments depending on tests that cover the whole of such periods impede the implementation in the society corresponding to the tempo of CO_2 reduction, which requires urgent handling.

Therefore, we call for the technology of innovative longevity assessment with high reliability that can accurately predict the long-term deterioration behavior of durable materials contributing to the reduction in CO_2 generated from the long-term use. And furthermore, it is effective for reducing carbon emission on the life cycle to extend the lifetime by renovation and etc. In addition, to predict the lifetime, therefore we also call for the proposals from a standpoint of the longevity assessment and life extension.

B12 Innovative cooling technologies for superconducting instruments

Superconductivity systems are about to enter the phase of social implementation; to prove its priority in the competition against existing non-superconductivity systems and to be prosperous in social implementation, the whole system, including not only the superconductivity equipment per se but also the cooling system, should progress toward performance enhancement. More specifically, the development of the various types of equipment including freezers as the components of the cooling system, as well as, the important elemental technologies considering lower losses, operation costs reducing, less maintenance work frequency and etc. are required. In the development of a superconductivity system, the research and development of cooling systems is important, as described above; at the same time this needs to satisfy the preconditions of the system, including its practicability. We may need to select some cooling methods depending on the conditions of the system. However, it is also highly expected that an innovative technology will lead to a breakthrough on the issues with cooling systems based on a cooling technology that can be recognized as a common platform without strongly depending on any applicable equipment. For this purpose, to advance the research and development of cooling systems for superconductivity equipment with the use of MgB2 wire materials, REBCO wire materials, or Bi-related wire materials, we also call for proposals that aim to enhance the performance of the followings; low-temperature equipment such as freezers, compressors, refiners, flow meters, and liquid level meters; the heat-transfer flow characteristics of the coolants such as He, H_2, N_2, and others; the thermal-insulation pipe systems; the cooling technology inside of the superconductivity equipment and etc.

B13 High performance and protection technologies of high temperature superconducting coil

In the case of superconductivity equipment and systems with the application of magnetic fields, superconductivity coils are among the important components; increasing the performance of high-temperature superconductivity coils is one of the important issues in enhancing the superiority of the superconductivity equipment to compete with other technologies. More specifically, it is wanted that the mechanism of high-temperature superconductivity coils, which ought to have high thermal stability by nature, should be revealed so that they do not cause any coil burnout or similar issue that could result from partial performance deterioration or uneven cooling. On this basis, the designing highly practicable coil systems, development of production technology, and development of technology for protecting coils should be affected. In addition, it is also necessary that the AC loss or similar that is generated with a coil should be sufficiently low, even if the coil is used under conditions where the magnetic field and/or the amperage may vary, such that there is sufficient competitiveness with respect to the loss and efficiency of equipment and/or systems. It is highly expected that an innovative technology will be developed for the enhancement in the performance and protection of such high-temperature superconductivity coils.

Under these circumstances, for the sake of the enhancement in the performance of high-temperature superconductivity coils using REBCO wire materials or similar, of the technology to protect such coils, and of the research and development of low-loss applications, we are calling for proposals for the development of new ideas, experimental verification, numerical analysis technology, and more. However, as for such high-temperature superconductivity coils and the conditions of their usage, it is required that they should be used for superconductivity equipment and/or systems that will be capable of making great contributions to low-carbon applications and that their future economic performance should be also considered in the proposals.

B14 Energy saving and high efficiency related technologies for electric power/power conversion systems

Today, the gross power consumption of our country is 900 TWh, of which almost 60 % is used for the driving power of motors; we can drastically suppress the amount of greenhouse gas emission by some technology to reduce the power consumption in relation to such motors. The driver-power conversion efficiency of motors in present-day use exceeds 90 %; however, there is much more room for improvement in this efficiency regarding the power loss due to inverters and the technologies around them. Potential areas of improvement include, for ① the element structures and materials of integrated intelligent power modules, low-iron-loss magnetic materials and high-saturation-magnetic-flux-density magnetic materials; for ② the circuit operation of high-voltage resistant power switching elements (SiC, GaN, etc.), new gate driving methods and high-speed soft switching technology; and for ③ the control methods, a drastic reduction in transport energy is possible by miniaturizing and lightening the whole inverter system including motors and cooling devices. Additionally, of course, reductions in power losses from inverters can be achieved by introducing an automatic tracking technology to maximize the energy efficiency of motors or by some other means.

The issues we need to tackle in this technology area include ① a power module that can operate around 200°C, ② a low-iron-loss magnetic material that generates only a low amount of heat emission during electric-power conversion, ③ a high-speed switching element that is durable against voltages exceeding 1 kV, ④ an arbitrary waveform gate drive integrated circuit, and a variety of hardware in addition to some essential ingenuity for new software programs with a method to drive and control motors. We are calling for proposals that address these issues. When we assume a future large-scale implementation in the society, it is also important that the proposals include measures to reduce the development cost of the motors, magnetic materials, and so on that do not require rare magnetic elements and a high level of convenience based on invertor-integrated motors and so forth.

B15 Fundamental technologies of green electronics for energy saving data communication and innovative information processing

There has been a rapid expansion of the usage of the Internet, in which sensors are attached to things and humans, such as for daily health management; to home appliances, buildings, and transportation equipment; and for certain agricultural uses or similar for communications in Internet of things (IoT) applications or machine-to-machine (M2M) communications, through which the big data is collected and its utilization is rapidly increasing. In addition, in terms of mobile communication equipment, the needs for 4K/8K and other video content, as well as for high-resolution static images for security, educational content, medical content, and others have been rapidly increasing. The amount of data communication keeps on rapidly increasing. For instance, for the next-generation 5G communication systems, a capacity increase of one-thousand times or more and speeds exceeding 10 Gbps are expected; to satisfy the expanding demand for telecommunications in the long run, it is required to reduce the communication power consumption per bit to a tenth or lower.

The issues we should solve in this area of technology (communication bottlenecks) are everywhere in the communication paths from the edge side to the cloud side; we have to solve the bottlenecks in a variety of hardware aspects including the ultralow-power -consumption edge information processing chips, and low-power-consumption high-speed router devices.

For implementation in the society twenty to thirty years from now, we call for the proposals of ① the new technologies of telecommunication-related hardware that are expected to embody an epoch-making reduction in the communication power consumption per bit, and ② the extremely low power information processing device by the innovative architecture including the quantum computing.

B16 Development of innovative thermal energy utilization technologies

High power conversion efficiency based on the Carnot cycle can be obtained in turbines and engines that operate at high temperatures, but in the middle and low temperature region that accounts for the majority of energy consumption, the technology for using thermal energy meeting the costs for manufacturing/maintenance of the system is still not matured. So, much heat is discarded to the environment. For this reason, there is a strong demand for development of thermal power conversion technology and heat management technology such as heat transfer, heat storage, and heat dissipation that contribute to the reduction of greenhouse gas emissions in the middle and low temperature region. We call for proposals of the innovative thermal energy utilization technologies which can meet this demand. For example, innovative and highly efficient heat exchangers, heat transfer media with high heat transfer efficiency and excellent durability, highly thermally insulated/highly functional heat insulating materials, highly efficient thermoelectric conversion materials/systems, low friction interface formation/mechanism, and the heat utilization system, such as binary power generation, thermos acoustic engine, heat pump, heat pipe, etc. are assumed. In addition, we also expect ideas for innovative thermal energy utilization technologies in a broad sense that go beyond conventional technologies. Principles of thermal energy utilization, concreteness such as structure, and feasibility of social implementation such as system maintenance and manufacturing cost are important points of evaluation.

B17 Chemical process enhancement technologies using high-efficiency, high-performance separation technologies

The productivity of production processes in the chemical industry and their energy-saving performance are restricted by the energy and cost that are required to separate, collect, and recycle the non-reactional raw materials, products, and solvents; mainly because of the issue of the cost required, non-reactional raw materials and solvents are not recycled in many cases, and, therefore, are a large source of CO_2 emission. Therefore, developing a separation technology with high-efficiency, and high-performance is the bottleneck issue to strengthen the chemical processes.

In addition to the separation membranes with innovative separation performance and high-performance separation processes and the hybridized various separation technologies (such as membrane separation, phase separation, adsorption, extraction, crystallization, etc.), the reaction separation technologies such as the membrane reactor, reactive absorption, reactive crystallization and reactive distillation, are included in the targeted technologies.

In particular, membrane separation process is expected as the separation technology, with high-efficiency and energy-saving, replacing the reactive distillation. As the material for the separating membranes, we have a variety of options to select, including organic polymer materials, inorganic materials, organic–inorganic compound materials, and etc., however, it is necessary to establish the innovative technology beyond the conventional technologies with respect to permeability, selectivity, and durability for the practical application. This time, in addition to the research and development of these new separation membranes, our scope includes the development of support layer for separation membranes as well as a new membrane module structure and module materials that enable energy saving and cost reduction. At the proposal, it is given as a requirement to show superiority (prospect) over conventional process in the energy saving rate when the target technology is realized.

B18 Innovation of bulk chemicals production technologies based on a new reaction fields to save energy required for causing chemically difficult reactions

C1 chemistry is a system of reactions in the production of the chemical products that come from the conversion of each type of carbon source into CO or H_2, or come directly from methane material, which involve many problems. For instance, the current methanol synthesis process is a process consisting of methane steam reforming (endothermic reaction) and methanol synthesis reaction (exothermic reaction) under a high temperature of 750°C or higher, and has become an energy-intensive process that emits a large amount of CO_2. Also, research on direct methanol synthesis by oxidation of methane has been conducted, but it is not easy to oxidize low-reactive methane and stop it with highly reactive methanol, and it has become one of the highly difficult reactions.

Although development of catalysts for reducing the energy consumption of such energy-intensive processes and improving selectivity for highly difficult reactions is active, breakthroughs for dramatic improvement of catalyst performance are desired.

Generally speaking, it is assumed that a catalyst should be used in a thermal equilibrium reaction field; however, in this area, we focus on the development of a catalyst that is highly active in a thermal non-equilibrium reaction field or in its reaction field, which means we are calling for proposals for new reactions and reaction processes that are not observed in conventional reaction fields. As the means for supplying energy to a new reaction field, we may think of electromagnetic waves, supersonic waves, magnetic fields, electric fields, and some complex thereof. As for the reactions, our scope includes the currently ongoing reactions in which a large amount of energy is consumed for the production of general-purpose chemical products that are profusely produced, and the compatibility of a high-yield and low-energy application to the reaction that is difficult to make. The proponents are required to compare the energy provided to the production system (estimate) with the technology for the production in their proposal.

③ Carbon neutral technologies based on chemical processes, biotechnologies and biomaterials

B19 Technologies for large-scale and efficient conversion of CO_2 into methanol, olefins, and other chemicals

Currently, chemicals are produced from fossil resources is the source of energy. But, being, finally, discharged into the air it becomes the source of CO_2. The ultimate ideal in the production of chemicals in our low-carbon society is to embody the carbon circle, in which chemical products are synthesized from the chemical raw materials resulting in CO_2 reduction with CO_2-free hydrogen. As one of the courses in the development of the CCS technology, the technologies to separate and collect CO_2 have been strenuously studied around the world.

Some of them are in the phase of verification tests. However, except for the case of the production of polycarbonate or similar materials, the development of technology to recycle collected CO_2 rarely advances. To acquire resources at a large-scale from CO_2, it is necessary to develop some technology for the mass production of hydrogen as a reducer by using recyclable energy without emitting CO_2. However, as the development of such technology is one of the long-term issues, we are allowing proponents in this area to assume a combination with some existing technology such as the use of methane, which emits relatively a low amount of CO_2, and are thus calling for proposals for the establishment of a technology for efficiently acquiring resources from CO_2 at a large-scale, which is one of the important elemental technologies.

Specifically, our issues include the synthesis of methanol from CO_2, reaction to synthesize FT from CO_2, synthesis gas production by property improvement of CO_2, general-purpose polymer materials directly synthesized from CO_2, efficient application of the partial oxidation reaction of methane, and etc.

B20 Development of highly efficient greenhouse gas separation membrane and sorbent

The amount of CO_2 emissions that are caused by the use of greenhouse gas, especially fossil resources, is enormous; to reduce such emissions, the development of a technology for saving energy and the moving to CO_2-free, recyclable energy have been in progress. However, we, under the current circumstances, cannot help depending on fossil energy for some time; according to a test calculation (IEA-ETP Report 2017), approximately 14 % of the accumulated reduction amount of CO_2 until 2060 will be managed by CCS (Carbon dioxide Capture and Storage). According to a test calculation, the current cost of CCS is six thousand yen per t-CO_2 or higher by currently the most popular chemical adsorption method (amine); we require significant cost cutting for its practical application.

Of the costs for CCS as a whole, the cost for separating and collecting CO_2 covers 50 to 60 % of the total; the development of an innovative technology for such separation and collection is one of the bottlenecks that are preventing CCS from being accepted in general. Today, we have a variety of methods including chemical absorption, physical absorption, membrane separation, cryogenic separation, and absorption separation; in any of these methods, the development of innovative technology is required.

As for the technology to separate or collect CO_2, we can think of various approaches, because the operating conditions and requirements vary depending on the type of fuel used for this purpose. We expect that as proponents submit their proposals, they should clarify the conditions of operation and the size, consider how close their separated energy would come to the theoretical amount of energy, and also keep a low-cost application of the operation and facility in view to develop an innovative absorbent liquid, absorbent material, and/or separating membrane. At the same time, we also include in our scope the proposals for the development of new modules that can make efficient use of these materials. Apart from CO_2, our scope also includes the technology to separate and collect other gases that have a large global warming potential.

B21 Development of highly efficient biomass gasification processes for chemicals production

In order to alleviate global warming, we want increasingly from the present time on, to make use of some source of carbon in the fossil resources and to recycle it. Biomass resources or the collected CO_2 are especially important as the sources of carbon; however, establishing a process to convert either of them into chemical products and/or usable fuel is one of our important issues.

According to a test calculation, converting biomass into gas is more prospective than using the collected CO_2 from a cost point of view. However, as of now, even the market price of methanol, which is one of the core chemical products, is estimated to be approximately three times higher than that of those acquired in the process of biomass conversion; cost cutting is the major key to the wide and general acceptance of this process.

To realize this, we need to attain an energy-utilization efficiency of 70 % or higher (cold gas efficiency) in the process of gas conversion with the well-known biomass types, and, in addition to this, we need to be able to provide a stable supply of some high-purity synthetic gas that does not have a negative influence on the downstream production processes of chemical products and fuel. By achieving these two types of technology, one can obtain a process that provides stable production of chemical products at a low cost.

We, on this occasion, also call for proposals for the research in relation to the enhancement of downstream processes, including the applications to low-cost synthetics and high value-added chemical products, such as chemical products and fuel that use synthetic gas acquired from biomass conversion.

When you apply such technology to practical use, you can aim to make use of the potential of the abundant biomass resources in our country and, thus, to use domestically produced low-carbon energy; you can contribute to the realization of a low-carbon society and, by promoting the use of biomass, contribute to the activation of forestry as well.

B22 Development of photosynthetic microorganisms robust against changes in environmental conditions for large-scale production

There has been considerable interest in the production of chemical products and fuel from microalgae, cyanobacteria, or other photosynthetic microorganisms because we can produce substances from CO_2 during photosynthesis. Till date, there have been researches for the efficient production of a target substance based on the examination on cultivation conditions and the technology to control genes. Some of these achievements involve the production of value-added chemical products or the like, which seem to be prospective for their practical application; various types of large-scale verification tests have been attempted for the practical applications. What has been revealed that there are several high hurdles in large-scale cultures we should overcome and that they are different from those in laboratories. The topmost issue is that the productivity, in the cases of large-scale cultures, is extremely low compared to the analyses at laboratories. For instance, the appropriate light intensities are different depending on the types of microalgae. In a laboratory you can use an ideal light and temperature environment for the microalgae of your subject. However, the light and temperature environments outdoors vary considerably depending on the weather, which cannot be artificially controlled. This variance of the intensity makes it impossible to maintain a high-density culture outdoors, leading to the degradation of the productivity of a subject, contamination, and the issue of a cost recovery. In addition, not only in the case of a large-scale closed-system cultures outdoors but also in the case of such cultures indoors, there are issues completely different from those in the analysis systems in a laboratory; these include the difference in the cell environments in the surface layer and the deep layer of a culture tank, stirring issues, and the issue of the necessity of illumination to light up deep area.

We are calling for proposals for the development of photosynthetic microorganisms robust against environmental changes to overcome the bottleneck of large-scale productions. For instance, as described above, if you can develop microalgae that can keep productivity constant regardless of the light intensity or the depth of a culture tank and/or the microalgae that can realize a high density of cell concentration in a room with soft illumination, then you are causing a large ripple effect. Moreover, if an effective fracturing technology is linked to the extraction of chemical compounds from the collected fungus bodies, the feasibility of a practical application becomes even higher.

B23 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.

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, you can think of a variety of measures including 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. Moreover, we are also expecting the 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, or the like.

Furthermore, we are also calling for proposals for the 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. 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. What we are expecting here include the following: (1) research on identifying the optimal composition of microbial florae for excellent culturing fields; (2) the 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 (3) research on using genome information to modify plants.

Furthermore, we also welcome proposals on innovative methods of producing low-energy biomass resources from the viewpoints of information analysis and/or engineering with respect to the plants and soil in culturing fields.

B24 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 have been tried to synthesize chemical products from a variety of sugar sources and low molecular weight gas such as CO_2 and methane.

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. 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.

We also include the innovative development of (cell-free) bioprocesses using these synthetic biological findings. 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 innovative development of new (cell-free) high-efficient bioprocesses to replace conventional chemical processes
- The new process development to easily connect / link both biological and chemical processes

B25 New synthetic technologies for high-efficiency production of high-performance/ high-functionality materials from biomass raw materials

An important issue is the development of a new technology for the high-efficiency production, in an energy-saving process, of chemical products and/or polymeric materials that are useful for our daily lives and/or for industrial use from saccharide and/or lignin collected via component separation of biomass resources (woody plant- or herbaceous plant-related materials). In recent several years, a variety of processes have been proposed to pertinently separate mainly the three constituents—cellulose, hemicellulose, and lignin—from woody or herbaceous plant materials; the development of the separation technologies, each with special characteristics, has been progressing rapidly. Consequently, now it is possible to produce cellulose, saccharide, lignin, etc., of a relatively high purity.

To develop a bio-refinery system for this country, it is necessary to contribute to the low carbon society and to simultaneously make it profitable. Therefore, the first bottleneck is to develop a new chemical/biological synthesis method of converting cellulose, saccharide, and lignin, which are produced from bio-mass resources, efficiently into the high-performance and/or highly functional chemical products and/or polymeric materials that are wanted by the society. In addition, it is also necessary to develop the technology to convert terpene, polyphenol, etc., which are not attracting attention because they include only small amounts of biomass resources, into some functional products with high added value. The second bottleneck is the development of the technology that can produce general-purpose chemical products, such as organic acids and alcohol, from biomass resources at a low cost. When these bottlenecks are solved, petroleum-based platforms can be converted into biomass-based platforms for the first time ever, and thus, after a low carbon society, a genuine carbon-circulating society will be realized.

On this occasion, we are calling for challenging proposals on the development of a new synthesis technology to realize the efficient production of high-performance or high-function chemical products or polymeric materials by using energy-saving processes and materials including those in the first bottleneck, that is, cellulose, saccharide, lignin, terpene, and polyphenol.

We are expecting the proposals such as the following. Cellulose, saccharide, lignin, terpene, polyphenol, or the like is not converted into inexpensive general-purpose chemical products or energy sources such as organic acid or alcohol but, instead, into, for instance, the following:

- Some high-performance or high-function chemical products or polymeric materials by making use of the skeletal structure such as the biologically originated six-membered ring contained in, e.g., cellulose, sugar chain, lignin, terpene, and polyphenol converted by a chemical or biological synthesis technology

- The chemical products that are expected to be in short supply in the future because of the difficulty in the production based on natural gas or shale gas, which is expected to be produced more profusely in the future; an example is C4 or more chemical compounds and aromatic compounds produced at a low cost efficiently by using cellulose, saccharide, lignin, terpene, polyphenol, or the like based on the developed synthesis technology
- Technological development on lignin degradation reaction and its process to solve this problem. Since lignin is a cross-linked polymer, it is known that it decomposes in a short time only under severe reaction conditions such as high temperature and pressure, and that it is extremely difficult to obtain efficiently the low molecular weight compounds such as aromatic compounds from it.

B26 Technologies for controlling layer structures to create next generation nano-cellulose materials

The development of technology to efficiently separate, from biomass resources, nano-cellulose of approximate thickness 20 nm (cellulose nanofiber (CNF), cellulose nanocrystal (CNC), etc.) has advanced; domestically and abroad, some test productions for the industrial use of nano-cellulose have begun. The tensile strength (3 GPa) and the modulus of elasticity (140 GPa) of nano-cellulose are generally the same as those of aramid fiber and other ultrahigh-strength fibers, and its thermal deformation is small, too; therefore, nano-cellulose has much potential as a high-performance material. In addition, nano-cellulose has a large surface area, and its surface has such a large number of hydroxyl groups that you can introduce various types of functional groups after chemical modification, or make metal ions and metal nanoparticles adhere on the surface of nano-cellulose at high density; nano-cellulose has a great potential as a highly functional material, too.

However, to use hydrophilic nano-cellulose solely or in a composite with some other material to produce a high-performance or high-function material, you need to develop technology for the accurate structure control of each layer of the primary, secondary, and tertiary-layered structures of the materials on the platform of nano-cellulose. We are calling for challenging proposals in relation to the technology development to use CNF for the design and creation of next-generation materials.

We are expecting the proposals such as the following.

- The technology to control crystalline regions and non-crystalline regions
- The technology to remove moisture with the evenly dispersed super-structure in water maintained
- The technology to control hydrophilic/hydrophobic characteristics for the complete dispersion over hydrophobic polymers or rubber
- The technology in consideration of a new function resulting from layered structures and/or of a drastic improvement in the performance (hygroscopicity, heat resistance, etc.)
- The technology to add some robust and flexible characteristics and/or shock-resistance performance for applications in fabricating automobile bodies and/or some other components

B27 Technologies for chemical modification/composition to create next generation lignin materials

Conventionally, the metamorphosis of lignin advances with the preprocess of paper making, which is collected in the form of a blackish liquid (black liquor) mixed with a chemical used for the preprocess, and thus used as fuel for some industrial use. However, to reuse lignin as a material for chemical products or polymers, research and development has been enthusiastically pursued to decompose lignin into low-molecular-weight substances and to convert the acquired low-molecular-weight chemical compounds into chemical products or to polymerize them into polymers. However, there are several serious issues including the slow reactions, low yields, multiplicity of phases in the processing, and high energy consumption; at present, there is no perspective on practical application. Nevertheless, as the research and development to separate lignin has been advancing in recent years; it is gradually becoming possible to acquire pure lignin, generally free of metamorphosis from biomass resources. Lignin has many hydroxyl groups; therefore, it is an attractive material that has the possibility of recycling as a high-performance and high-function material that has never been before when it is chemically modified it and various functional groups are introduced, or it is composited with some other material. We are calling the challenging proposals in relation to the technology development to convert lignin as a polymer into a next-generation material without decomposing it as in conventional approaches.

We are expecting proposals such as the following.

- The technology to control its quality by understanding the structure of lignin and by solving the relation between its structure and characteristics, because lignin is a chemical compound that has different basic structures and characteristics depending on the type of its raw material
- The technology to recycle lignin as a high-performance and high-function material by chemically modifying it and by introducing various functional groups to make it complex with a polymeric material or an inorganic material, because it has many hydroxyl groups

④ Creation of recycling-oriented polymer materials to realize a low-carbon society

B28 [Management method by harmonized various technological seeds] Creation of recycling-oriented polymer materials to realize a low-carbon society

There is no doubt that polymeric materials (plastics, elastomers, etc.) have provided convenience and benefits to our lives for many years since their invention and that they are useful materials in the future. On the other hand, it becomes a big problem that polymer material waste is less effectively used compared to metals etc. (effective use rate of plastic packing container waste wholly in the world is 14%[a),] in Japan is 84%[b)]). Even in Japan, where the effective utilization rate of plastic container and packaging waste reaches 84%, the breakdown shows that material recycling is only 23%, chemical recycling is only 4%, thermal recycling is 57%, simple incineration is 9%, and landfill is 7%. Finally, 66% of the whole is incinerated and become a source of carbon dioxide gas.

The total amount of plastic produced by humanity between 1950 and 2015 reached 8.3 billion tons, but the production of plastic is increasing by 5% per year from now on. If it continues as it is, it is estimated that a total of more than 33 billion tons of plastic will be produced by 2050[c)]. Therefore, if it proceeds as it is, a large amount of plastic waste will be discarded, and the problems of facility shortage and waste treatment (heat recovery and incineration) will cause CO_2 emission that affect global warming. This issue will be raised in extremely high possibility. Recently, there is concern about the outflow of plastic waste from land to the ocean, and it is predicted that plastic exceeding the weight of fish will flow into the marine environment by 2050.

In order to fundamentally solve the above concerns and problems, this time, we expect the proposal of the high-risk and high-impact fundamental research and fundamental technologies aiming "Creation of recycling-oriented polymer materials to realize a low-carbon society."

Here, "circulative polymer materials" means the polymer materials (plastics, elastomers, etc.) which can contribute to the realization of the low carbon society as the result of cyclic use in ecosystem in a sustainable manner. In order to do it, the effort to enable such materials made from limited resources to be easily reproduced is required. Specifically, biomass plastics[*1], biodegradable plastics[*2], easily recyclable plastics[*3], long-lasting plastics[*4] or similar elastomers can be mentioned.

*1: Biomass plastics (carbon neutral)

*2: Biodegradable plastics (used as fertilizer for plant growing)

*3: Easily recyclable plastics (reducing incineration waste by recycling)

*4: Long-lasting plastics (reducing incineration frequency by long life)

In addition, the following issues can be illustrated as the bottleneck.

1. Biomass plastics (including elastomer)
   - Plastics that use biomass as a raw material and are preferable than the petroleum-based plastics in terms of high heat resistance, high strength, impact resistance, and long-term stability
   - Development of high functional materials composited with nano-cellulose
   - Development of high value-added materials based on natural rubber
2. Biodegradable plastics (including elastomer)
   - Biodegradable plastics that have a function to respond to physical, chemical and biochemical special stimulus, and it is triggered to break down
   - Biodegradable plastics in which physical, chemical and biochemical degradation functions in a continuous or parallel manner
   - Biodegradable plastics in which physical, chemical and biochemical degradation rates can be controlled
3. Easily recyclable plastics (including elastomer)
   - A decomposition mechanism for chemical recycling is incorporated into the plastics, and activating it after recovery allows the plastics to be easily recovered, for example, as it is a low molecular weight polymer
   - By activating the decomposition mechanism after recovery, it is possible to easily recover the components / parts from the material, part or system combined with plastics

・ Plastics that can be recycled as it is, because it is stable and easy to refine
・ A composite material that can restore its original excellent physical properties (such as mechanical strength) by re-forming even if it is crushed and recovered after use

4. Long-lasting plastics (including elastomer)
・ Plastics with self-healing function
・ Plastics of which molecular weight doesn't decrease
・ Plastics that improves their performance with use

5. Technology relating to monomer production for the synthesis (polymer polymerization) of the above plastics 1 to 4 (including elastomers)

6. Fundamental technology required to advance the above 1 to 4
・ Analysis of plastics decomposition mechanism
・ Nano-structure analysis and physical property correlation of plastics
・ Data accumulation for designing degradable plastics and simulation technology of ideal structure using it
・ Relationship between plastics structure and biodegradable bacteria and its optimization

In order to achieve the tasks 1 to 6 above, it is important to utilize science seeds in all fields such as bio, chemical (catalyst, polymerization), analysis, database construction, and simulation.

a): "Single-use plastics: A roadmap for sustainability" (UN environmental plan, 2018)
b): "The status of production, disposal, recycling and treatment of plastic products 2018" (Plastic Waste Management Institute)
c): Roland Geyer, Jenna R. Jambeck and Kara Lavender Law, Production, use, and fate of all plastics ever made, Science Advances 2017; 3: e1700782 (19 July 2017)

● Assumption on where achievements are applied

In this area, the challenging research and development 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 research and development 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. To create innovative research and development 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.

● Organization for the projects

In the case of feasibility studies, we have a strong awareness of the exits while adopting challenging research themes. 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 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 the phase of full-scale research, we, being well aware of "the possibility of the contribution to a low-carbon society," take management to accelerate the research and development for the implementation in the society.

● Policies for R&D management

JST, since year 2010, has been continuing "Advanced Low Carbon Technology Research and Development Program" (ALCA). In the ALCA, we have adopted "the Small Start & Stage Gate method" as a program that is specialized for the research and development 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 research and developments aiming at the implementation of the achievements and transferring it for practical applications in the society in around year 2030.

In this area, we follow the principles of the ALCA management and advance the research and development 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 research and development programs with the same goal, i.e., the realization of a low carbon society, aiming at synergy effect (Fig. 2).

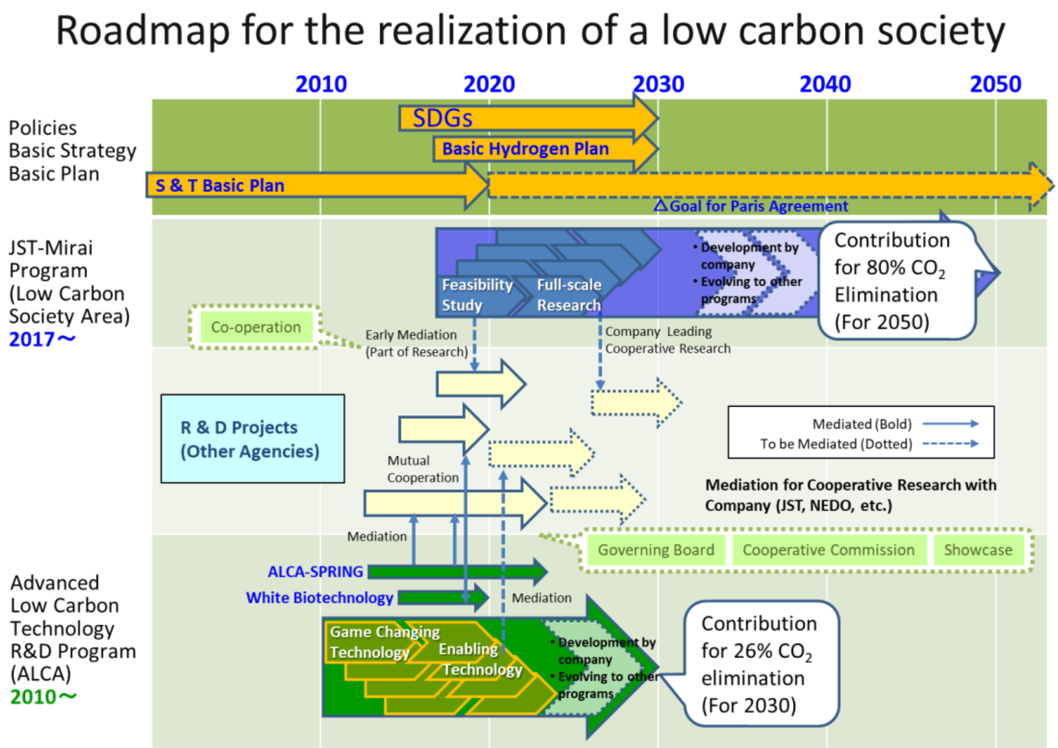


Fig. 2. A roadmap for the realization of a low carbon society

Furthermore, in this 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-scale research. Moreover, if the Research and Development Supervisor determines the necessity for the maximization of the social and/or economic impact, we may integrate two or more research and development issues and reorganizing research teams, etc.

* About the management method by harmonized various technological seeds

From 2019, we will introduce “management method by harmonized various technological seeds” in the Sub-Theme “④Creation of recycling-oriented polymer materials to realize a low-carbon society." This is a new attempt to create new social value by combining technology seeds from different fields and other systems in order to achieve early results in the creation and social implementation.

It is a mechanism that calls for nurturing multiple small-scale technology seeds created in different fields and other systems, and evaluating and fusing them into a large research and development system for a specific Sub-Theme (including the fusion between other Sub-Themes). After the fusion, team formation will be carried out to promote research and development aimed at achieving goals entirely across the fields (Fig. 3).

- R&D budget is different from other Sub-Themes. Please refer to the "● R&D period and budgets" below.
- Describe the name, issue name, R & D representative and period of other systems for which this technology seed has been created in "6. Other" of the R&D plan of Feasibility Study (Form 3).

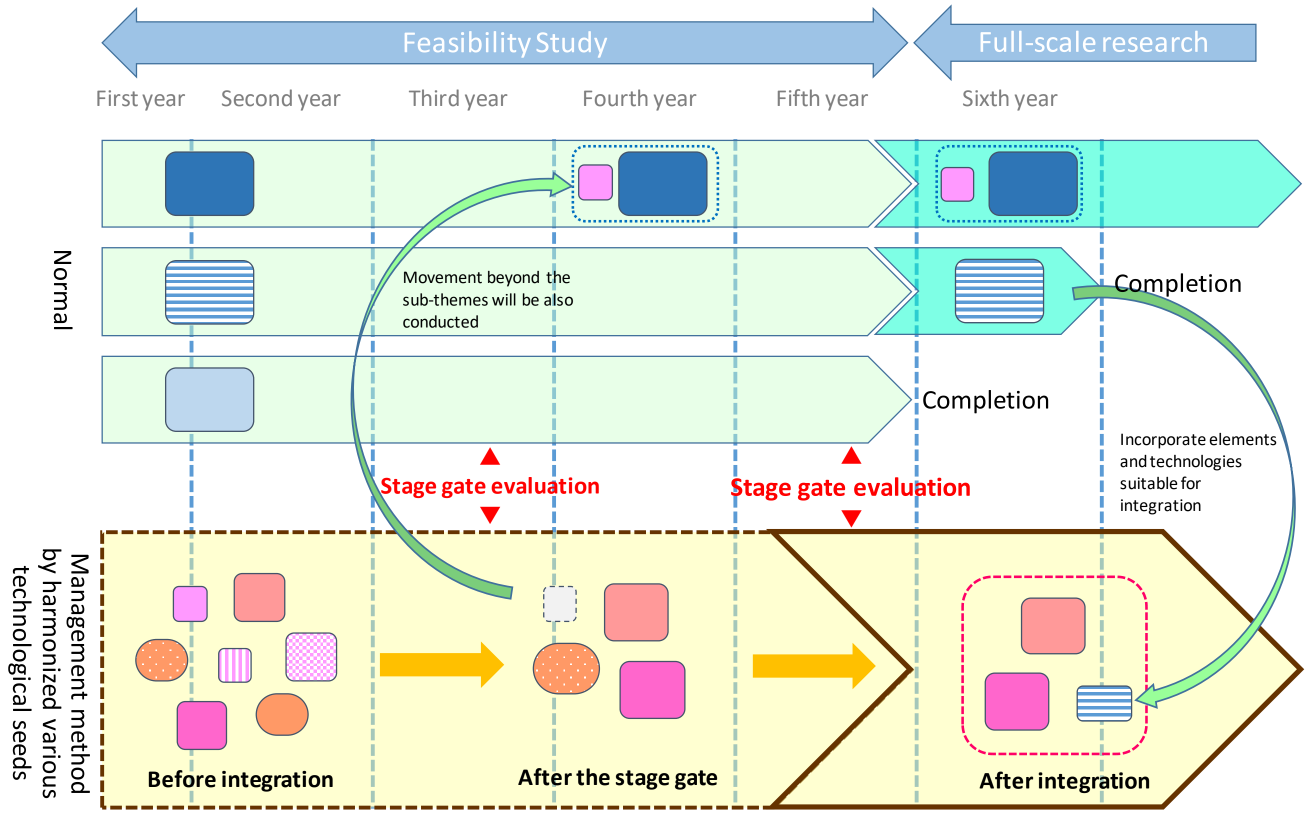


Fig. 3. Image for management method by harmonized various technological seeds (example)

At adoption, R&D issues will be individually promoted. At least one of the stage gate evaluations will be carried out before the transition to full-scale research (there is a possibility of small-scale fusion also at this stage). The large-scale fusion is carried out at the transition to the full-scale research, and we aim achieving POC with a large research and development system.

● Stage gate evaluation

In this area, the transition to "full-scale research" in 2024 is generally specified, and it is necessary to carry out at least one of the stage gate evaluations before the transition. The timing of the first stage gate evaluation and the goals to be cleared (a milestone) will be decided after the adoption, by taking interviews with the responsible R&D operation committee members. Depending on the progress as a result of stage gate evaluation, the early transition to the full-scale research will be also considered.

● R&D period and budgets

① Feasibility Study

Feasibility study period is up to 4 and a half years until the end of fiscal year 2023; the upper limit of the R&D cost in your plan must be JPY 130 million (direct costs) in total, covering the whole period of the feasibility study.

② Full-scale Research

In this area, the period and the budget for the full-scale research are determined based on the stage gate evaluation of the feasibility study; the period of the full-scale research at the proposal phase is 5 years at the maximum; the upper limit of the R&D cost in your plan must be JPY 500 million (direct costs) in total, covering the whole period of the full-scale research.

* About the management method by harmonized various technological seeds

① Feasibility Study

Plan the feasibility study with the maximum period of 4 and a half years, and the R&D cost of up to JPY 5 million (direct costs) per year. Depending on the results of stage gate evaluation, the budget may be increased due to the narrowing of R&D issues and fusion with other issues.

② Full-scale Research

Plan the full-scale research with a maximum period of 5 years, and the R&D cost of up to JPY 100 million (direct costs) covering the whole period of the full-scale research (this JPY 100 million is the maximum amount for the result of the fusion of multiple issues).

6.1.5 "Common Platform Technology, Facilities, and Equipment" Area

Research and Development Supervisor (Program Officer: PO):
Nobuyuki OSAKABE
(General Manger, Strategy Division, Smart Life Business Management Division/Chief Executive of Healthcare Business Unit, Hitachi, Ltd.)

I. Goal of the “Common Platform Technology, Facilities, and Equipment” Area

This area was established to cover common platform technologies supporting a wide range of research and development (R&D) activities and advanced research instruments in the fiscal year (FY) 2018.

Research and development has served as the fountainhead of innovative knowledge and products that impact future society. In order to strengthen the research capacity of our country currently in a disadvantaged position in terms of number of researchers and R&D budgets compared to the United States and China, we have to promote more efficient and effective R&D activities by realizing innovative common platform technology, facilities, and equipment for R&D. However, the number of published papers, an indicator for R&D vigor, has not increased much in recent years. It is feared that the R&D capability of Japan may be declining with the rise of other countries and changes in Japan’s demographic structure. To reverse this declining trend, it is necessary to steadily promote research to meet needs of R&D activity as well as research toward an exit to social needs.

In consideration of background as this, the “Realization of Common Platform System and Equipment that creates Innovative Knowledge and Products” has been adopted as a prioritized theme in this area and the following three points are focused:

(1) Development of high-risk and high-impact advanced measurement and analysis technologies/instruments

(2) Development and systemization of applications, such as data analysis and processing technologies

(3) Technology development that contributes to improving productivity of research fields

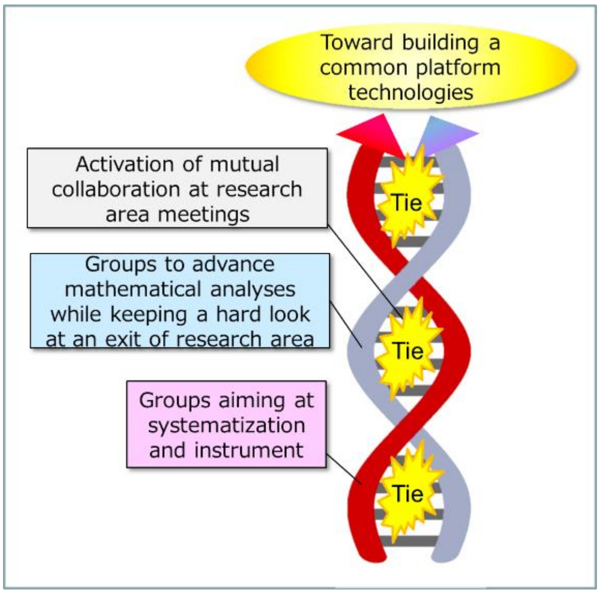


Fig.1 Scheme of Area management

We will aim to realize a common platform to support R&D by emphasizing mathematical science and mathematical engineering, which have made rapid advances recently in various applications. Collaboration between measurement and analysis technologies/instruments and such mathematical methods is highly encouraged (Fig. 1).

II. Prioritized theme

Continuation

Realization of Common Platform Technology, Facilities, and Equipment that creates Innovative Knowledge and Products

(1) About the theme

<Background>

A disruptive technology is one which displaces an established technology and shakes up the industry or even creates a completely new industry. R&D is no exception. Existing R&D techniques are being replaced by new technologies, such as atomic level structure analysis for membrane proteins and single molecules by cryo-electron microscope, which earned Jacques Dubochet, Joachim Frank and Richard Henderson the 2017 Nobel Prize for Chemistry, massive parallel genome sequencing, and the gene editing technology like CRISPR-Cas9.

For example, the human genome project cost USD 3 Billion from 1990 through 2003, whereas next generation sequencers can analyze genomes of five persons per day with the cost of USD 1,000 apiece. The marked decrease in analytical costs expanded its applications from a technique in R&D laboratories to a medical testing technology indispensable for realization of tailor-made medicines. This technology spawned Illumina, which owns the technology and grew to a market capitalization at JPY 4.4 trillion as of May 2018.

Innovations have proceeded also in materials development. An example is the “material genome initiative,” which has been promoted in the United States since 2011. It aims to take advantage of data-driven science to halve the 20-year period from material development to practical application fielding. It is a grand plan, to which more than USD 500M is said to have been invested thus far. China has followed suit by producing many results. The National Institute of Materials Science, a National R&D Agency, has played a central role in R&D in Japan.

Japan, which has fewer researchers and a smaller research budget than the United States or China, should perform efficient and effective R&D based on its basic science capabilities to improve research. This requires an innovative common platform.

<Goal>

This program aims for Proof of Concept (POC) within a period of full-scale research. A POC for this area means that a state in which a prototype should be used to reach a level for verifying usefulness in R&D laboratories.

Common platform technologies created in this program is expected to contribute to one of the following goals:

Goal 1: To Take Advantage of Common Platform Technologies to Improve the Research Capability of Japan
Goal 2: To Convert Common Platform Technologies to Commercialization that Strengthen the Industrial Competitiveness of Japan

Goal 1 demands that research using a developed system/instrument should exert a big industrial or academic impact on society. Even if a system/instrument itself does not create a big business, research using the system/instrument is expected to create big results.

Goal 2 aims for the system/instrument itself to become a big business. A system/instrument initially used in research fields is expected to improve in performance, including cost and throughput, and will be directly used in the society beyond the framework of research fields, thus impacting the economy.

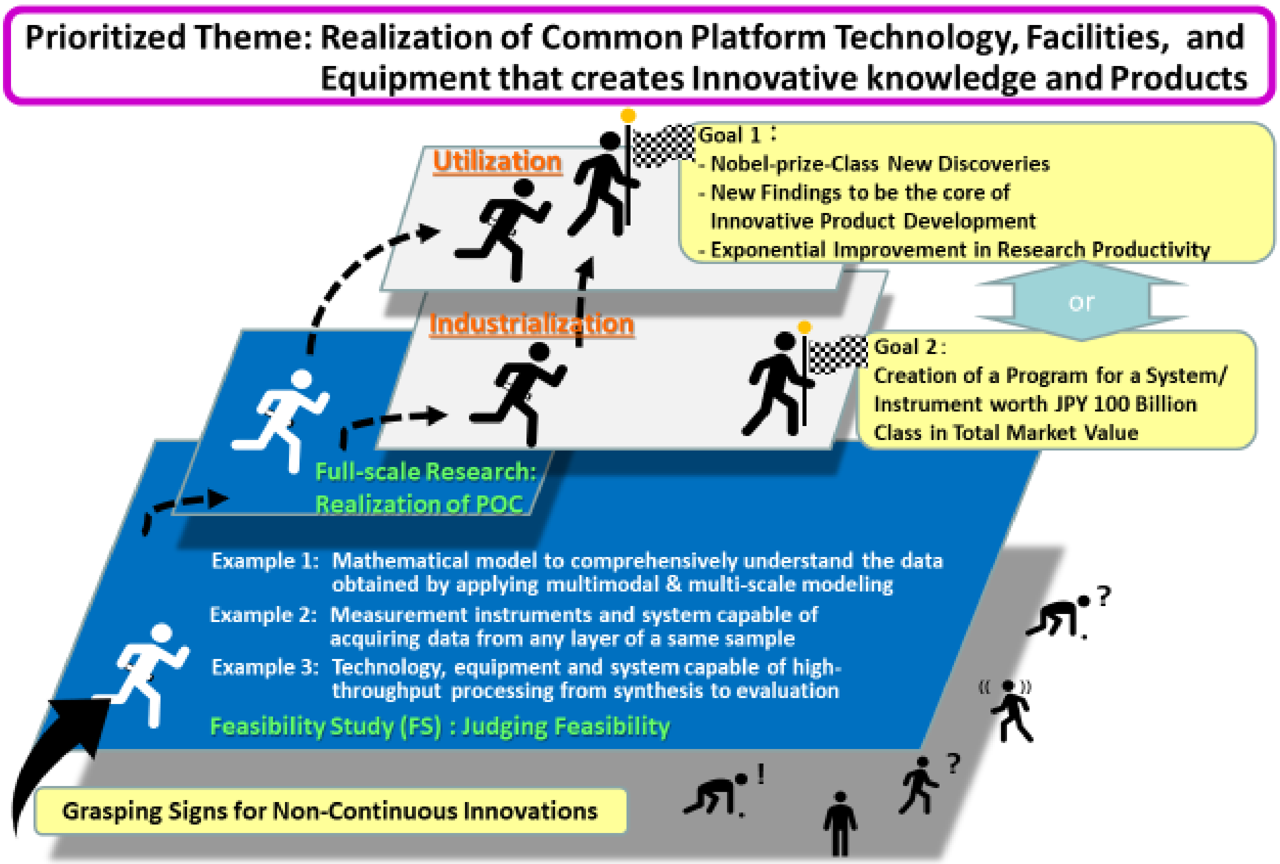


Fig. 2: Conceptual illustration of the goal of the Prioritized Theme and R&D phase

(2) Program Officer's policies for proposal selection and R&D management

● **Policies for proposal selection**

Key points for 2019 ・**In 2019, we call for two "Preferred issues for Proposal" while continuing ten Sub-Themes that were set up last year.** ・**About six to nine proposals are to be adopted.**

To achieve these challenging objectives of Prioritized Theme set forth in this area, we have to share these objectives and make progress on mutually-linked multiple issues simultaneously. To do this, following two issues are set up for public calling this year as "Preferred issues for Proposal" that require proposals on the basis of opinions and ideas, which were provided through website of this program, about proposed preferred issues for the "Common Platform Technology, Facilities, and Equipment" area and the outcome of the advisory workshop attended by experts, while continuously working with extensive and fundamental ten Sub-Themes identified under the Prioritized Theme last year.

- Development of measurement and analysis technologies/instruments capable of advancing comprehensive understanding of an atom, molecule and cell up to living body/materials (Y01)
- Development of innovative technology that helps reduce workload in research fields and contributes to making super high-quality experiments (sampling, cultivation, synthesis etc.) (Y02)

Specifically, for the case (1), proposals of instruments, analytical methods and mathematical science that comprehensively understand the data obtained by measuring different samples, multimodal analysis and multiscale analysis will be requested.

For the case (2), proposals of high-throughput evaluation technology that evaluates pretreatment, synthesis, purification and measurement & analysis will be requested

(Please see the “Description on Research and Development” to be hereinafter described).

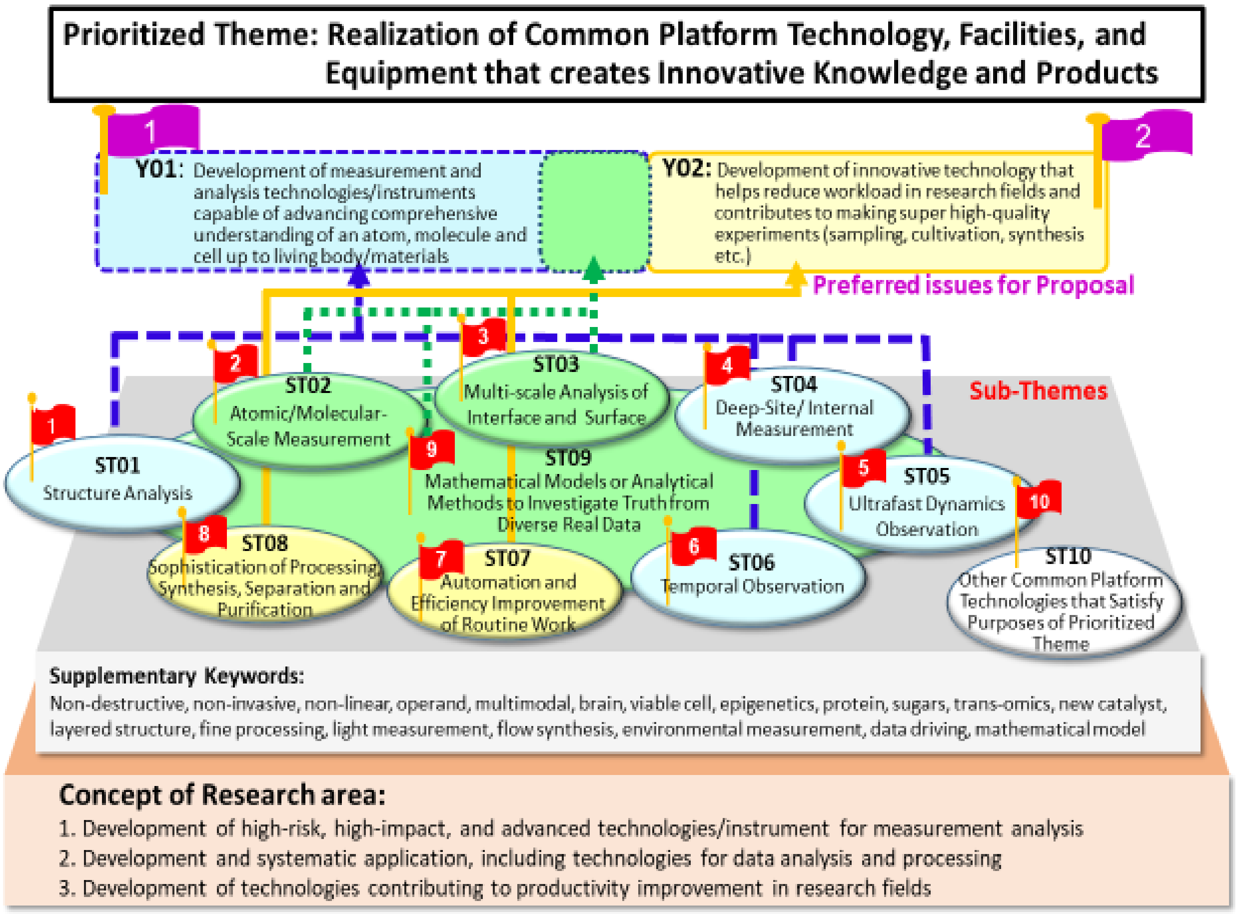


Fig. 3: Preferred issues for Proposal, and Sub-Themes in the “Common Platform” area

Under this theme, a representative of an adopted proposal is requested to promote R&D while receiving advices from the theme manager.

In the same way as last year, in addition to research proposals aiming for transfer to full-scale research, proposals of "Feasibility Study (Component Technology Type)," which contributes to the realization of the Prioritized Theme, are called for.

The R&D representative who performs R&D of a Component Technology Type is asked to take on the R&D and introduce the results into full-scale research under the prioritized theme and to establish a component technology for achieving the POC. However, in the same way as last year, priority is given to feasibility studies (general type) for this fiscal year as well, and proposals are called for mainly by Section ST09 "Developing mathematical models or analytical methods that can find out the truth from diverse real data," which is expected to be a common platform covering several Sub-Themes. Section ST10 is excluded.

Considering the contents, some proposals applied as ordinary feasibility studies may be adopted, provided they satisfy the condition to participate as a Component Technology Type.

- **Theme Manager**

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Kazuyuki AIHARA
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Theme Manager
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Theme Manager
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- **Description on Research and Development**

In 2019, relevant technologies to the following two Preferred issues for Proposal will be requested as described in the Policies for proposal selection. Also, excellent proposals that conform to the Sub-Themes to be described hereinafter will be applicable to adoption regardless of relevance to the following two issues.

①Preferred issues for Proposal

Classification	Title of "Preferred issues for Proposal"
Y01	Development of measurement and analysis technologies/instruments capable of advancing comprehensive understanding of an atom, molecule and cell up to living body/materials
Y02	Development of innovative technology that helps reduce workload in research fields and contributes to making super high-quality experiments (sampling, cultivation, synthesis etc.)

1) Development of measurement and analysis technologies/instruments capable of advancing comprehensive understanding of an atom, molecule and cell up to living body/materials (Classification: Y01)

Development of measurement technology capable of dramatically improving the quality of information obtained from optical and electron microscope image data etc. and development of the technology of four-dimensional integrated analysis capable of analyzing information, which were traditionally handled separately such as genome information, precisely including temporal data analysis are currently required to accelerate health, medical care, substance production and functional material related researches amid globally intensified competition.

Then, we aim to achieve dramatic improvement in temporal and spatial resolutions, which is impossible for traditional imaging technology, to serve the progress of new research. Specifically, improvement in temporal and spatial resolutions of each different modality, and development of instrument and systems that integrate imaging technology with omics data can contribute to progress in comprehensive understanding of life system and material development.

For example, we aim to develop followings;

1. Method capable of measuring with temporal resolution of millisecond (ms) or less and spatial resolution of one micrometer (μm) or less, although these resolutions are impossible to reach for traditional measurement methods
2. Technology that can accommodate both temporal and spatial resolutions from a wider point of view

Again, traditional measurement technology observes measuring objects of different samples and multiscale optimized modalities for each layer and integrating these approaches has been difficult.

On the other hand, if effective techniques that can combine obtained omics data and imaging technology in the area of life science or techniques that can integrate measurements performed for each layer from a macro or micro perspective and enable entire understanding in the area of material science are developed, these techniques can become a new “Common Platform Technology.”

For example, cancer, as already elucidated, is the disease caused by genetic mutations and remarkable diagnostic progress has been observed thanks to the development of genome sequencer. However, knowledge of genome sequence does not necessarily elucidate the mechanism of diseases, e.g. neurodegenerative disease such as Alzheimer's diseases. Diagnostic progress based on new knowledge can be expected by comprehensively understanding data collected from each layer of these diseases.

Again, to realize these accomplishments, we welcome proposal of methods that can obtain simultaneously the information, which has been traditionally collected by measurement of each modality, by using a same sample, or proposals of the development of a new highly sensitive labeling technology and proposals of a new mathematical and information processing technology.

2）Development of innovative technology that helps reduce workload in research fields and contributes to making super high-quality experiments (sampling, cultivation, synthesis etc.) (Classification: Y02)

We aim to realize a smart laboratory in addition to the contribution to “Development of the Technology That Helps Improve the Productivity in Research Fields,” which is one of prioritized point of views in this area, by automating repetitive works such as pretreatment, cultivation and chemical synthesis from large amount of same varieties to small amount of many varieties. Materializing high-throughput processing of “1. Pretreatment, 2. Synthesis, 3. Purification and 4. Evaluation technology” as the common issue to be addressed in each research field and integrating those can contribute to innovative efficiency in research fields. For example, in the field of life science, processing from synthesis to measurement of cell-surface molecules and molecules in and out of a cell will be required in addition to existing omics analysis. At the same time, high-throughput and high-level reproducibility will be required to integrate with mathematical science.

In the material science field, multiple projects are going on to explore new materials in the area of material informatics. Technical development of synthesis and measurement equipment etc. will be required to materialize high throughput processing of pretreatment, synthesis, purification and analysis of targeted material as “Common Platform Technology” to support these projects. Also, proposals of high throughput processing materialized by automation, becoming ubiquitous and eliminating purification process will be included in this. Especially, building mathematical model from metadata, experimental high-throughput data, multimodal and multiscale data is a must in order to shift toward data-driven model. This mathematical model is required to generate not only particular experimental results but also material properties in more general manner and therefore it is necessary to devise the descriptor.

Also, we expect to see the proposal that looks forward to contributing to the international competitiveness of our country through realizing standardization of both measurement and analysis technologies/instruments and analytical equipment obtained in the R&D.

To materialize what is stated in 1) and 2), development of a new mathematical model that leads the radical innovation of mathematical model, analytical method and measurement method for describing and extracting essential information from the knowledge of relevant measurement and analysis field will be required due to abstractedness and universality of number (Please see “Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data (Classification: ST09)” for details).

Also, when preparing and submitting a proposal, we request it to address magnitude of the social impact generated when these issues are solved and the technical gap between current status and existing technology level that must be filled to solve these issues, and the policy to fill the gap as much as possible by comparing with analysis of internationally competitive technologies and factoring in the expectations of business enterprises who participate during the proposal stage.

② List of Sub-Themes (Continued from FY2018)

Classification	Sub-Theme
ST01	Structure Analysis
ST02	Atomic/Molecular-Scale Measurement
ST03	Multi-Scale Analysis of Interface and Surface
ST04	Deep-Site/Internal Measurement
ST05	Ultrafast Dynamics Observation
ST06	Temporal Observation
ST07	Automation and Efficiency Improvement of Routine Work
ST08	Sophistication of Processing, Synthesis, Separation and Purification
ST09*1	Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data
ST10*2	Other Common Platform Technology, Facilities, and Equipment that Satisfy Purposes of Prioritized Theme

*1 The upper limit of the R&D costs for ST09 is different from those of other Sub-Themes (see "R&D period and budgets," described later.)

*2 This Sub-Theme does not ask for a proposal of the Component Technology Type.

* When you apply via the e-rad, please select appropriate number from "Prioritized Themes" (Y01 or Y02) or "Sub-Themes" (ST01 to S10) (multiple selection possible).

* Please select appropriate number for a proposal of component technology type when you apply via the e-rad. Also, please keep in mind that different type of format is required for a proposal of the Component Technology Type.

* Selection is not performed independently by each Prioritized Theme or Sub-Theme but proceeds by comparing all proposals regardless of Prioritized Themes or Sub-Themes, simultaneously. Some Sub-Themes may have several adopted projects and some may have none of consequence.

1) Structure Analysis (ST01)

This Sub-Theme performs common platform technology development of structure analysis for substances of complex structures.

The field of material science has many needs for grasping a detailed structure of a newly prepared material to elucidate a relationship between the structure and properties for designing a new material. Structure analyses of multidimensional materials, non-homogeneous materials, and complex polymer materials are an issue, along with how to grasp structural defects and the positional information of dopants. Difficulty of analyzing light atoms has long been a problem. Techniques are still sought for solving the problem and developing simpler and more accurate analyses.

In the field of life science, structure analysis of various molecules in a living body is an important element of development, especially in the field of health care, therapy, and drug discovery. For example, attention is paid to such drug discovery targets as higher structures of chromatin, complex proteins, membrane proteins, 3D structures of peptides, and sugar chains.

A broader conceptual view of structure analysis would find intense needs for sequencing DNA. We request technology development to make marked improvement in existing techniques for subsequent generation technologies beyond the so-called “next generation sequencers,” which are the mainstream at present, is being requested.

2) Atomic/Molecular-Scale Measurement (ST02)

This Sub-Theme develops techniques for measuring various subjects in an Atomic/Molecular-Scale that exert various effects on whole systems.

To understand properties and specific characteristics of a material, the material science field demands measurement of electric/magnetic fields, photons, phonons, spins, electronic states, oscillations, and fluctuations.

The field of life science demands observation of a single molecule, not average values of a group of molecules. Current needs are for single molecular analyses of membrane protein structures, especially G-protein-coupled receptors and Channel; their relations with a ligand; single molecule separation by microfluid dynamics; evaluation of its functions; and, analytical technology for analysis of single molecules in a viable cell.

3) Multi-scale Analysis of Interface and Surface (ST03)

This Sub-Theme attends to interfaces and surfaces for performing R&D for measuring localized sites and for micro-, meso- and macro-scale analyses.

The material science field requires evaluations from micro- to macro-viewpoints in research of material design and tribology. Development of technologies is desired for detailed and wide-ranged analyses as part of R&D for substance evaluation and improved performance. The research is being expected to realize development of reliable and durable products and to contribute to resource and energy savings.

The life science field seeks to analyze not only part of the cell membrane but also the molecules that are distributed throughout the whole membrane. Membrane proteins on cell surfaces are an important subject of analysis for communications between a cell and extracellular space. For example, an R&D field that tries to implement substance production using cells in a society seeks detailed analyses for elucidating phenomena.

4) Deep-Site/Internal Measurement (ST04)

This Sub-Theme performs R&D for measuring structure of deep/internal sites of a substance and internal phenomena.

The field of material science seeks measurement of internal degeneration for checking and evaluating the quality of structural materials and batteries, detecting internal impurities, and observing internal chemical changes to analyze situations of function expression.

The field of life science seeks deep-site measurements for cell dynamics in the blood vessel, analysis of a single cell in organs, and brain analysis (nerve plasticity).

Low/non-invasive or non-destructive manipulation to avoid situation changes during observation is important for all fields. Development of measurement technologies should take these into consideration.

5) Ultrafast Dynamics Observation (ST05)

This Sub-Theme performs R&D that aims to make marked improvements in time-resolution of existing measurement methods as technology for observing ultrafast dynamics, including transitional situations of chemical reactions.

Electrons, for example, move too fast to be directly observed by ordinary measurement techniques. However, research fields of various areas may need to build a hypothesis to explain ultrafast dynamics for the elucidation of physical properties in product development. The ultrafast dynamics requires observation for its verification. New techniques should be established by controlling femtosecond and attosecond lasers or by raising the level of pump–probe methods through improving detection performance.

6) Temporal Observation (ST06)

This Sub-Theme develops technologies required for research subjects in individual fields and for high-impact temporal observations.

The material science fields desperately need technologies to observe internal heat conduction in an all solid battery and to observe and understand what triggers material degeneration in addition to needs for observation and measurement of chemical reaction progress on a catalyst. New findings are sought for time-consuming elucidation of creep phenomena and new measurement methods of efficiently testing accelerated degeneration. Development of the above technologies are being expected to improve durability and reliability of products.

The life science field demands new technologies for quantitative analysis of gene expression, chronological modifications, such as DNA methylation, various omics analyses of protein and metabolites, and temporal observations of drug dynamics.

7) Automation and Efficiency Improvement of Routine Work (ST07)

This Sub-Theme automates and makes efficient work already sorted by type in research fields to realize exponential improvement and acceleration of research productivity and to aim to reach results in a shorter time.

Various needs and subjects are presumed.

In the field of material science, for example, technology exists for preparing a novel material possessing a desired atom sequence by stacking individual layers one-by-one. This is a task requiring specialized skills. Therefore, demand exists for automation, robotic efficiency, and passing technology down through generations. Automated preparation of a chemical compound library in combinatorial chemistry is also needed.

The field of life science requires automation, improved efficiency, and high speeds of various biochemistry and molecular biology experiments. A specific example is the standardization of the pretreatment for omics analyses and automated measurement are given as specific examples.

Not only automation, but also higher levels and simplification of various treatment prior to measurement are sought.

8) Sophistication of Processing, Synthesis, Separation and Purification (ST08)

This Sub-Theme conducts R&D for raising levels of universal technologies in research fields, including processing, synthesis, separation, and purification technologies.

For example, processing/synthesis technologies in the field of material science seeks to raise levels of crystal growth technologies, fine processing technologies, and layered structure technologies. For example, one problem that has been pointed out is that fine parameters of a prepared sample are altered by the equipment used for crystal growth for novel drug discoveries. A fundamental solution is in demand. There are discussions about utilization of artificial intelligence for chemical synthesis processes and of building modular flow synthesis systems for efficient substance production. By realizing such apparatus, functional peptides, which are needed for various industries, including drugs, food, and cosmetics, are expected to decrease in manufacturing cost.

An example of separation and purification technology in the field of life science is protein purification from a living body sample. There are strong needs for complex proteins and proteins in an elementary process among them, not only as research elements but also as drug discovery targets. Separation and purification of intracellular particles and exosomes released from cells have many problems of yield and purity, for which universal technologies are being sought.

Previously, purification was a precondition for measurement in the fields of both material science and life science. But, now a measurement technology without pretreatment of purification is desired.

ST08 partly overlaps ST07, automating technologies for processing, synthesizing, separating, and purifying existing materials already sorted by type. ST08 contains basic element technologies that have not yet been realized for processing, synthesizing, separating, and purifying. That is how we distinguish ST08 from ST07.

9) Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data (ST09)

From viewpoints of the abstract and universality of mathematics, creating mathematical models and solutions for describing/extracting “intrinsic information” about findings in the measurement/analysis fields related to a common platform technology area and new mathematical techniques that can lead fundamental reorganization of the measurement technologies are being required. With the help of these measures, in addition to aforementioned two "Preferred issues for Proposal" the research for mathematical techniques is promoted, which will contribute to the major progress in realization of “Common Platform Technology,” and the establishment of common platform technologies this area aims for.

For example, multidimensional and noisy time series data obtained from research fields via non-invasive measurements are used to estimate nonlinear dynamics of a system producing the data to develop a mathematical model. If the research realizes technology for building a mathematical model of a data-driving type, which extracts hidden law, the technology is being expected to provide breakthroughs in various research fields.

Basic mathematical technologies are also important for building new techniques for analysis and processing of measured big data. For instance, measurement information of life dynamics observed in ST06 should be further subjected to integrated mathematical analysis for understanding life phenomena. Mathematical scientific and engineering analysis of multilayered-omics data that integrate groups of molecules (omics layers) of different properties (e.g., DNAs, RNAs, proteins, and metabolites) elucidate not only each layer but also an integrated multi layered network structure, including mutual interactions between the layers. More profound understanding is sought for life phenomena.

The field of material science recognizes how important the utilization of big data is in property assessment and materials informatics. Furthermore, new mathematical models born in such approaches are expected to play intrinsically important roles for understanding real phenomena.

* Propose a proper budget according to the proposal contents. No lower limit is set.

* This area will be managed to allow mathematical models and analytical techniques yielded from research on this Sub-Theme to contribute to solutions of important programs of other Sub-Themes. One group aiming to develop a system/instrument and another aiming to raise levels of mathematical models and analyses are expected to effectively collaborate on an increasing basis and in an optimal form to solve problems.

* This Sub-Theme proactively requests proposals for the component type technology as a common platform to bridge multiple Sub-Themes.

10) Other Common Platform Technology, Facilities, and Equipment that Satisfy Purposes of Prioritized Theme (ST10)

Proposals are requested not only for cases that relate to the nine Sub-Themes described above but also the R&D projects that meet the purpose of this prioritized theme and create common platform technologies that you consider is in need “now” in the field of research. Such a proposal should select this Sub-Theme. We are waiting for proposals that can be a scientific technology solution for “visualization” of things previously not visualized and “measurable” of things previously not measurable.

This Sub-Theme does not ask for Component Technology Type.

- **Presumed Applications of Results**

This area collaborates with other JST programs [Adaptable and Seamless Technology Transfer Program through Target-driven R&D (A-STEP), Support Program of Capital Contribution to Early-Stage Companies (SUCCESS) and Program for Creating STart-ups from Advanced Research and Technology (START) etc.] and programs of other ministries at an early stage. This is to allow other R&D programs closer to actual application, to build on results of projects needing a longer-term approach and for passing results to start-up firms and industries.

- **Collaboration with Related Programs**

To aim for the procurement of innovative knowledge and products and promoting challenging R&D that impacts research activities, this area closely collaborates with other JST programs and those of other ministries to positively promote utilization of results of programs at a research stage.

Also, many R&D tools have become available for practical use in the programs including JST program of Development of Advanced Measurement and Analysis Systems until now and it will be appreciated if you take them into account while you perform the study on new R&D tools (Please see 4.25 Accomplishments of the JST program of “Development of Advanced Measurement and Analysis Systems”).

Furthermore, collaboration with facilities and equipment for joint use is encouraged from the viewpoint of promoting R&D by considering users’ needs (Please see 4.14 “Promotion of the Joint Use of Research Facilities and Equipment”).

- **Policies for R&D management**

In approaching challenging R&D projects, this area positively promotes multidisciplinary collaboration without constraints of conventional academic boundaries, participation of young researchers, and collaboration with business firms and academia to emphasize diversity of research teams and incorporation of novel ideas. A management system that provides advice and guidance through checking research plans and site visits by members of the R&D management conference, including theme managers, is prepared and aims to reorganize research techniques and realize a common platform system/instrument that procures innovative knowledge and products.

For the transition from feasibility study to full-scale research project, the recombination of individual groups is envisioned each participating in the research project and themes, as well as their termination or reorganization.

- **R&D period and budgets**

Plan a period of 2.5 years as maximum for a feasibility study to be adopted for FY 2019 and maximum JPY 35 million as total direct cost for regular type R&D and maximum JPY 23 million as total direct cost for component technology type.

The feasibility study is subject to review for transfer to full-scale research at a time instructed by the Program Officer up to the end of FY2021. Plan a total R&D cost of JPY 750 million (direct cost) and a period of five years maximum for full-scale research. However, a total is set at a maximum of JPY 500 million for a proposal of ST09 “Building Mathematical Models or Analytical Methods to Investigate Truth from Diverse Real Data.”
After adoption, we will flexibly allocate the budget according to the research content.

6.2 Large-scale Type

The technology themes of large-scale type that are believed to be important for forming the bases of future technologies, has been determined by The Ministry of Education, Culture, Sports, Science and Technology based on the information analysis on science and technology innovations. For the 2019 fiscal year, proposals are sought for large-scale R&D projects relating to the technology themes described herein.

Research and Development Supervisor (Program Officer: PO):
Yoshihiro OISHI
(Senior Research Fellow, General Manager, Research and Development Unit, Mitsubishi Research Institute, Inc.)

6.2.1 Management policies for projects in large-scale type

(1) Policies for requesting and selecting proposals and R&D

To achieve the realization of the technology themes presented, projects should include an adequate R&D process to reach a stage (proof of concept, POC) where application feasibility can be judged by society and industry. Continued development of research achievements after the POC stage is expected to result in the enhancing of relevant base technologies that will exert impacts on a wide range of sectors.

Therefore, technology themes for large-scale type are stipulated and relatively clearly defined. The R&D representatives (program manager, PM) themselves are expected to define the POC that will lead to the implementation of these technologies in society. The PM is requested to choose a high-level, challenging goal; create, protect, and utilize intellectual property strategically; and depict the overall vision as noble so that its achievement would solve social problems and create a new industry. The PM is also expected to describe his/her vision for the project’s development after POC, an outcome in which the technology creates innovations in the society and industries in the future, and to plan an exit strategy, such as collaboration with business firms or participating in a related business venture.

It is crucial for projects to boast the highest level of R&D capability and knowledge. See “2.2.2(5) Selection viewpoints” for a description of the evaluation criteria for the adoption of proposals. During the R&D process, projects are expected to be managed to use those opportunities to merge with various technology fields or collaborated with researchers or research organizations, including opportunities to recruit new members or obtain new findings or technologies.

The large-scale projects are also expected to attract investment from private sectors during the R&D process preceding the POC. In order to attract private investments, we recommend an early entry of companies and in particular, we are seeking for introduction of funds of a certain size from the target institutions in the first stage gate evaluation (Be sure to refer to 2.2.1 (3), 8) “Stage gate evaluation”). We strongly hope that PM determines the timing of POC tests based on his/her original and excellent R&D concept, creates a milestone for achieving that in anticipation of deployment after POC, and manages R&D while actively and flexibly communicating with the companies etc.

In managing research and development (R&D), we consider local and overseas R&D trends and changes in the social environment to boldly review our R&D plan for flexible management.

(2) Policies for requesting and selecting proposals and R&D (by technology theme)

Innovative thermoelectric conversion technologies for stand-alone power supplies for sensors

In Society 5.0, a huge number of sensors are expected to be installed in every situation, which makes it imperative to secure power source for driving the sensors. Thermoelectric conversion technology that converts heat sources in the environment directly to electric power is attracting attention as one of enabling technologies. Unfortunately, the conventional technology has various problems to be solved, such as conversion efficiency, material issues (resource restrictions, toxicity, etc.), mass productivity, reliability, cost, etc. and has not been widely used. A technology that can solve these problems and enables independent power supplies for sensors needs to be developed. Aiming to establish a thermoelectric conversion technology that simultaneously achieves power generation performance, safety, durability, mass productivity, etc. required for independent power supplies for sensors, the R&D representative (PM) should conduct a consistent R&D that covers field work, application development, optimization according to application and demonstration. For example, we request for the development of an innovative thermoelectric conversion technology that is not an extension of conventional technologies through search for new materials, the utilization of new phenomena (spin Seebeck effect and Anomalous Nernst effect, etc.) discovered in recent years, improvement of energy capture efficiency (including imparting of flexibility), mass production technology and its scientific exploration. We expect researchers to involve companies from the early stages of R&D, aiming at early social implementation, and manage R&D while responding quickly and flexibly to R&D trends in Japan and abroad in this field, where global competition is fierce, and to the social environment.

As for the commissioned R&D cost from 1st to 4th year, the amount of fund is set at JPY 250 million/year (total of JPY 1.0 billion) for direct costs only. Indirect costs are treated differently for each fiscal year. The entire R&D period is up to nine and a half years. The expenses necessary for promoting the R&D theme should be budgeted with the total amount of about JPY 3.1 billion for 10 years. If multiple proposals and researchers are adopted under this technology theme, the budget for each selected proposal is determined within the above budget.

6.2.2 Technology theme

Innovative thermoelectric conversion technologies for stand-alone power supplies for sensors

(1) Theme name

Innovative thermoelectric conversion technologies for independent power supplies for sensors

(2) Outline

In Society 5.0, a new value is expected to be created by having sensors acquire all information and having AI analyze the acquired information. In future, a huge number of sensors are expected to be installed in every situation, which makes it imperative to secure power source for driving the sensors, and various technologies are being considered. One of such technologies is thermoelectric conversion technology that converts heat sources in the environment (for example, exhaust heat, body temperature, etc.) directly into electricity. This technology is attracting attention as one that enables independent power supplies for sensors used in places where wiring is difficult or on moving objects, such as animals and humans. Unfortunately, the conventional thermoelectric conversion technology is not widely accepted because of material issues, such as resource restrictions, toxicity etc., and problems in mass productivity, reliability and cost due to the complex structure of elements. If you successfully solve these problems and develop an innovative thermoelectric conversion technology that enables independent power supplies for sensors, the sensors can be installed in every situation, contributing to the realization of Society 5.0.

(3) Goal

Researchers should aim to establish the thermoelectric conversion technology that simultaneously achieves power generation performance, safety, durability, mass productivity, etc. required for independent power supplies for sensors, which helps realize Society 5.0, and conduct a consistent R&D that covers field work, application development, optimization according to application and demonstration, while having a concrete idea of where the technology is to be socially implemented, such as plant, farmland, etc. Researchers should conduct R&D up to a point where they can determine that the technology can be put into practical use (proof of concept, POC) after verification of the technological superiority over conventional technologies and market competitiveness. Before conducting R&D, researchers should clearly determine specific achievement points and milestones for social implementation. For example, researchers are expected to draw a path to enable mass production at low cost: Achieve the same amount of power generation as button batteries and make thermoelectric elements commercially available in five years, while solving various problems, such as materials and elements of the conventional thermoelectric conversion technology, and achieve the amount of power generation significantly larger than that in 10 years. In anticipation of practical use after the end of the project, researchers should keep it in mind to establish an R&D system for industry-academia collaboration that includes not only the manufactures of independent power supplies for sensors but also the players who can be the users.

(4) Future society image to be kept in mind while conducting research

The management of the R&D project is believed to lead to the realization of a future society, as described below:

- Wireless sensors can be mounted in places where wiring is difficult or on moving objects, such as animals and humans, which enables society to utilize Big Data in every situation, including the management of water and sewage infrastructures, livestock production, and safety confirmation of children and the elderly.
- 65% of Japan's primary energy is discarded as waste heat, but regenerating this waste heat as electricity allows society to significantly reduce greenhouse gas emissions and meet electricity demand for driving one trillion sensors.

(5) Specific research examples

Specific research examples may include the following:

- Search and development of efficient materials that are less toxic and free of rare elements which facilitate stable and efficient thermoelectric conversion.
- Stabilization of thermoelectric conversion and realization of flexibility of power generation modules that can be installed in various places.
- Elucidation of damage phenomena required to make flexibility and durability compatible and establishment of measures.
- Maximization of the energy capture efficiency of the thermoelectric conversion element in consideration of the size, power generation and shape required for each application, and optimization of device structure in consideration of mass productivity.

(6) R&D trends

For thermoelectric conversion technology, there is a large demand for IoT and trillion sensors, and R&D competition has become active on a global basis in recent years. The thermoelectric conversion based on the Seebeck effect has a long history; in the 1960s, it was used as a nuclear battery for space exploration. In Japan, SEIKO and Citizen put a thermoelectric watch into practical use in 1998 and 1999, respectively. In order to regenerate electrical energy from unused waste heat, which accounts for 65% of primary energy, research on thermoelectric conversion technology has been promoted all over the world, including Japan, since then. For example, new concepts for improving energy conversion efficiency, such as energy filtering and Nano inclusion, have been presented. Research that involves the use of highly toxic materials and materials containing rare elements is being conducted mainly in the United States to discover PbTe-based materials and new principles in pursuit of the highest performance.

Unfortunately, in truly achieving a wide implementation of thermoelectric technology that enables independent power supplies for sensors in society, there still remain problems to be solved, for example, material issues, such as resource restrictions and toxicity, and problems in mass productivity, reliability, and cost due to the complex structure of elements.

In Japan, the “Phonon Engineering Research Group” was launched in 2017 and the “Energy Harvesting Research Group” was launched in 2018 at the Japan Society of Applied Physics. A wide range of experimental and computational sciences have been widely developed for the thermoelectric conversion technology, including the development of new substances and nanostructured substances, and new phenomena, such as the spin Seebeck effect and the Anomalous Nernst effect.