Chapter 6 (Annex of the Application Guidelines)

＜Storage Batteries Area＞

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<tr><th>R&D Theme</th><th>Number of Projects to be adopted</th><th>Budget
(5-year total of direct cost)</th></tr>
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＜Hydrogen Area＞

R&D Theme	Number of Projects to be adopted	Budget (5-year total of direct cost)
Team-based research R&D Theme 1: “Realization of a Water Electrolysis System with Improved Efficiency and Durability and Reduced Costs”	1-2 projects	– For implementation of common research equipment: up to 600 million JPY approx. per project – R&D costs: up to 3 billion JPY approx. per project
Team-based research R&D Theme 2: “Realization of a Fuel Cell System with Improved Efficiency and Durability and Reduced Costs”	1-2 projects	– For implementation of common research equipment: up to 600 million JPY approx. per project – R&D costs: up to 3 billion JPY approx. per project
Team-based research R&D Theme 3: “Development of a Hydrogen Storage System with High	1-2 projects	– For implementation of common research equipment: up to 1 billion JPY approx. per project

Density, High Durability, and Low Costs”		– R&D costs: up to 2 billion JPY approx. per project
Innovative elemental technology research for R&D Themes 1-3	A few projects	Up to 10 million JPY for the first fiscal year

＜Biomanufacturing Area＞

R&D Theme	Number of Projects to be adopted	Budget (5-year total of direct cost)
Team-based core research R&D Theme 1: “Establish next-generation biomanufacturing platforms with a focus on microorganisms”	1 project	– For implementation of common research equipment: up to 700 million JPY approx. – R&D Costs: up to 2 billion JPY approx.
Team-based core research R&D Theme 2: “Establish next-generation biomanufacturing platforms with a focus on plants”	1 project	– For implementation of common research equipment: up to 700 million JPY approx. – R&D Costs: up to 2 billion JPY approx.
Team-based platform technology research R&D Theme 3: “Research to explore, analyze interactions between organisms” R&D Theme 4: “Research into evaluation systems using artificial systems” R&D Theme 5: “Research into more sophisticated analytical technologies and mathematical tools for information analysis”	1 project per R&D theme	R&D Costs: –for R&D Theme 3; up to 600 million JPY approx. –for R&D Theme 4; up to 400 million JPY approx. –for R&D Theme 5; up to 600 million JPY approx.
Innovative elemental technology research for R&D Themes 1-5	A few projects	Up to 10 million JPY for the first fiscal year

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1 Storage Batteries Area

Program Officer: KUWABATA Susumu (Dean and Professor , Graduate School of Engineering, Osaka University)

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* In some cases, the team for common research equipment in the R&D Theme 5 may also be required for the maintenance and operation of some of the common research equipment in the Hydrogen area. In such a case, the budget regarding the Hydrogen area will be allocated from the budget for the maintenance of common research equipment in the Hydrogen area, and will be additional to the maximum amount of 2.3 billion yen set forth here.

1-1 Overview of the Storage Batteries Area

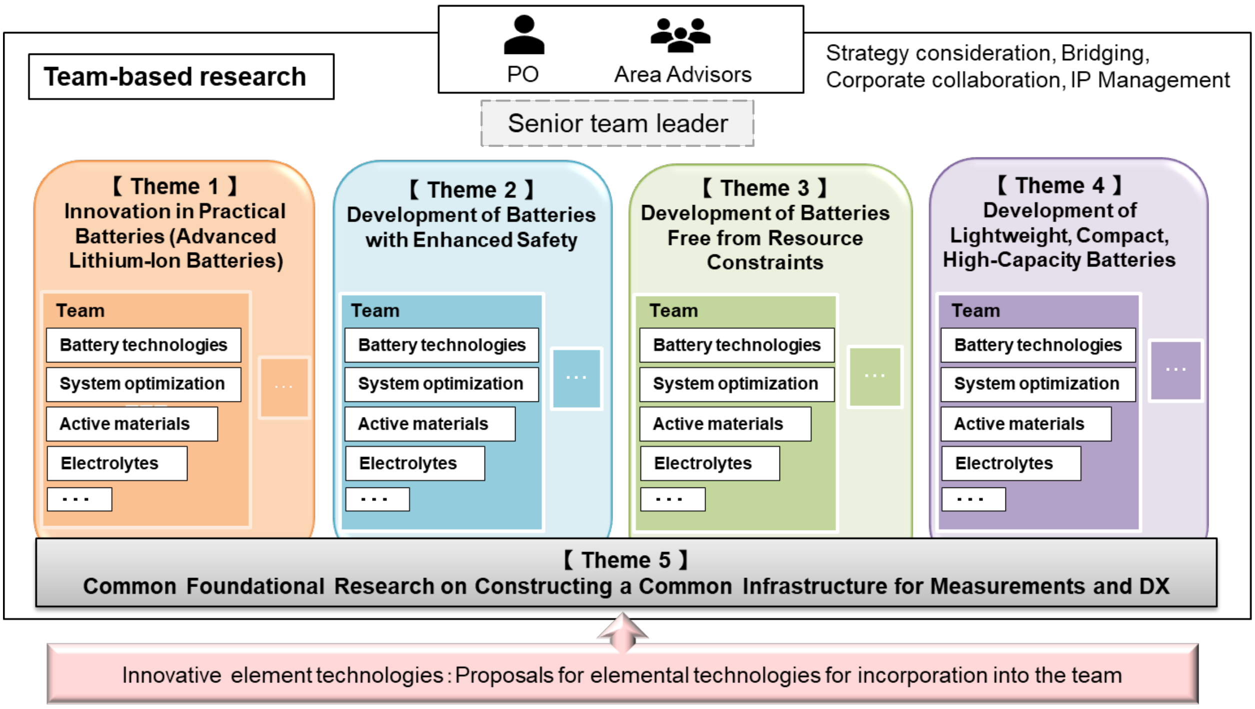
In this area, universities, national institutes, and companies will collaborate to develop innovative next-generation storage battery technology, one of the most important technologies for achieving carbon neutrality in 2050 and promote team-based research and development that seamlessly addresses from the establishment of academic principles to the resolution of technological issues in the industrial sector. To accelerate research and development, we will not only develop materials for individual battery components, but also consistently evaluate the performance of developed batteries as a total system, build a database to search for new battery systems, and establish fundamental technologies for next-generation storage batteries. The program also aims to foster human resources with broad perspectives and development capabilities.

1-2 R&D Themes

In this area, we will work on the development of innovative storage battery technologies under the themes presented below. Although specific battery systems are provided as examples for each of the themes, the call for proposals is open to any battery system based on the applicants' innovative ideas. An applicant is allowed to submit only one proposal that best fits their proposal based on a thorough understanding of the purpose of each R&D theme. (However, as a result of coordination by the PO, there is a possibility that the proposal will be selected and adopted under a different R&D theme from the proposed theme.)

Although examples of goals and milestones are provided for each of the R&D themes, each proposal should set ambitious goals that are appropriate to the objectives of the theme by the applicant him/herself. In addition, a necessary and sufficient R&D structure and an appropriate R&D schedule must be established for the deployment of R&D results to industry.

For each project, you are required to work on research and development while considering the impact on the circular economy and the GHG emissions for the entire life cycle including the manufacturing process when the technology is implemented in society.



Structure of the Storage Batteries Area

1-2.1 Theme 1: Innovation in Practical Batteries (Advanced Lithium-Ion Batteries)

Description of R&D

Liquid lithium-ion batteries are anticipated to be one of the primary storage batteries in the industrial world for the foreseeable future. To strengthen Japan's industrial and international competitiveness in this area, this theme aims to create innovative elemental technologies that will lead to higher energy density, improved safety, reduced resource constraints, methods of recycling battery materials, and manufacturing processes with low environmental impact, enabling Japan to strengthen its manufacturing infrastructure, accelerate the development of practical applications, and create and capture markets. While NEDO's R&D is focused on reducing costs and improving energy density in order to increase the cruising range of vehicles[1], the aim of this theme is to dramatically improve the performance of lithium-ion batteries and to identify and solve fundamental issues using creative approaches based on scientific understanding. This research primarily targets the development of high-capacity, low-potential anode materials such as metallic lithium, the development of high-capacity, high-potential cathode materials, and the development of battery materials such as electrolytic solution, separators, and binders to enable operations with these materials. The project is also expected to address issues that have become obstacles to social implementation from a life cycle assessment perspective, such as the development of technologies that contribute to the recycling of battery materials and the development of components and materials that allow for manufacturing processes with reduced environmental impact and simplified mass production processes. In order to develop a battery system whose research achievements can be quickly transferred to industry, this R&D will be conducted in collaboration with organizations possessing technologies for evaluating practical batteries and companies that can be expected to develop the research results. The projects under this theme will strive to find quick resolutions to problems by repeating a sequence in which academia conducts R&D, verifies and checks the battery characteristics, and companies identify issues in the industrial sector.

Goals and Milestones for Technical Issues

The first aim of this research is to identify bottleneck issues to technological development in industry and social implementation and to clarify and work to resolve research issues that must be addressed by academia (e.g., deepening our fundamental understanding of batteries by elucidating the structural, chemical, and physical property changes that occur internally while a battery is charging and discharging; clarifying mechanisms of battery degradation and establishing guidelines for solving problems based on this understanding; and providing effective problem-solving techniques). Due to the intense competition currently underway worldwide on the development of lithium-ion batteries, the goal of this R&D is to create results that could resolve these issues in approximately three years. With the goal of further improving battery performance based on these results, this theme will endeavor to establish the basic design of an innovative lithium-ion battery equipped with a metallic lithium anode (or anode-free) and new high-performance materials over approximately five years. Over a maximum R&D period of ten years, we hope to develop technologies that will contribute to reduced environmental impact during the life cycle of the storage battery (e.g., recycling rare metals in batteries and developing battery materials and manufacturing processes with low CO_2 emissions) for drastically improving resource recycling and energy consumption during manufacturing.

Points to Consider When Submitting Your Proposal

It is preferable that companies expected to develop the research results participate in this R&D from the start.

1-2.2 Theme 2: Development of Batteries with Enhanced Safety

Description of R&D

We are working on developing batteries with established safety features, which will be essential for expanding battery applications. For example, all-solid-state batteries employing solid electrolytes are safer because they do not contain flammable liquids and do not leak. All-solid-state

[1] R&D and social implementation for the Green Innovation Fund Project "Next-Generation Storage Battery and Motor Development"

batteries are expected to become mainstream in the automotive battery storage market beginning in the early 2030s. In the SOLiD-EV project, the researchers have been developing sulfide-based all-solid-state lithium-ion batteries that use sulfide-based solid electrolytes while retaining the same electrode materials used in current lithium-ion batteries. If the cooling system of the battery pack can be simplified for all-solid-state batteries, volumetric energy density for the packs is expected to improve and the high lithium-ion transference number, which is a feature of solid electrolytes, is expected to make rapid battery charging and discharging possible. However, in the case of all-solid-state batteries, the research under this theme is expected to focus on resolving fundamental issues and clarifying mechanisms specific to all-solid-state batteries, such as the development of metallic lithium anodes and sulfur-based cathodes, which are high-capacity electrode materials, we must strengthen the R&D foundation for alternatives to lithium-ion batteries, the design of solid-solid interfaces, and the development of electrolytes having resistance to oxidation and reduction. This theme targets all types of electrolytes (sulfide, oxide, and polymer), but applications for sulfide-based batteries will be limited to more challenging types, such as batteries using electrode materials expected to significantly improve the battery characteristics, including lithium metal anodes and sulfur cathodes, and batteries employing non-lithium ions as charge carriers. We aim to accelerate battery development in collaboration with NEDO, companies, and other organizations by repeatedly working on issues identified in battery prototyping and evaluations.

Goals and Milestones for Technical Issues

A solid electrolyte having higher ionic conductivity is required for operating bulk-type batteries, such as an oxide-based all-solid-state battery. Moreover, a high sintering temperature is needed to form the dense electrode-electrolyte interfaces. This leads to numerous technical challenges, including increased interfacial resistance caused by reactions between the electrode material and electrolyte, which prevents good battery properties from being realized. In other words, it is not sufficient to explore solid electrolytes alone. Research on all-solid-state batteries must also take into account the combination of the electrolyte with electrode materials, including the process of forming the solid-solid interfaces. This study is expected to focus on the development of solid electrolytes with high ionic conductivity as candidate materials for bulk-type batteries and to evaluate the safety of all-solid-state batteries over approximately five years. After simultaneously developing and selecting cathode and anode materials that match these solid electrolytes and establishing a basic battery manufacturing process, this study is expected to work on improving battery performance by introducing active materials in high-capacity electrodes and high-potential cathodes, which pose high technical hurdles, and to realize a battery structure unique to solid electrolytes (stacking, etc.) within a maximum R&D period of ten years.

1-2.3 Theme 3: Development of Batteries Free from Resource Constraints

Description of R&D

Lithium as a raw material not only comes with geopolitical risks owing to the limited number of producing countries, but also the danger of sudden price hikes when supplies get tight. Therefore, it is hoped that batteries using sodium, magnesium, or other materials that have no resource constraints will be developed to replace lithium batteries. We intend to realize such development in order to increase the available options for achieving energy security and carbon neutrality. Batteries that use no rare metals tend to be inexpensive and conducive to scaling up, which makes them most suitable as large stationary storage batteries for which cost reduction is imperative. However, there remain many fundamental issues that have yet to be addressed, such as consideration for the active materials in electrodes and the deficiency of gravimetric energy density, which would require a major breakthrough in R&D based on new concepts. This R&D theme is not just concerned with the development of batteries at the material level, but also on identifying and resolving issues in the assembled battery system by evaluating battery characteristics during full-cell operations. We aim to accelerate battery development in collaboration with NEDO and other companies or organizations by repeatedly working on issues identified in battery prototyping and evaluations.

Goals and Milestones for Technical Issues

Magnesium batteries, as one example, are still at the development stage at which operations in sheet-type full cells have been confirmed, and a major breakthrough in active materials and electrolytes will be needed to realize a high-performance magnesium battery. This will require us to clarify the migration behavior of divalent magnesium ions in solids and to design materials based on those fundamental principles. Over approximately five years from the start of research, the adopted project is expected to search and select battery materials (cathodes and anodes, electrolytes, separators, etc.), complete a full-cell prototype, and evaluate the battery to determine the potential of magnesium batteries. If potential is confirmed, the project is expected to continue over a maximum R&D period of ten years, during which time it will explore battery materials and their optimal combinations for improving the performance of the magnesium battery by realizing higher voltage, higher capacity, and better cycle and temperature characteristics.

1-2.4 Theme 4: Development of Lightweight, Compact, High-Capacity Batteries

Description of R&D

There is increased demand for lightweight batteries as the power sources in home energy storage systems, for example. Existing storage batteries employ compounds containing heavy metals. Developing compact and lightweight battery systems will require the use of elements other than heavy metals. The construction of a lightweight storage battery system may be possible through the use of metal lithium as the anode active material and the use of sulfur or oxygen molecules as the cathode active material, for example. One problem with such batteries is that sufficient cycle characteristics cannot be obtained at the current densities anticipated from the conditions of battery use and under conditions that do not allow for surplus electrolytic solution. Therefore, we hope to investigate the mechanisms of cycle degradation to find a new development approach for solving this issue. In collaboration with NEDO and other companies and organizations, we aim to accelerate the development of innovative batteries that are lightweight, compact, and high in capacity by repeatedly working on issues identified in battery manufacturing and evaluations.

Goals and Milestones for Technical Issues

There are high expectations toward developing practical applications for metal-air batteries, for example, as they have a theoretical energy density that far surpasses that of other battery systems. However, full-cell evaluations have confirmed that cycle characteristics are a major issue. Science-based guidelines for developing such batteries have yet to be established as we have not sufficiently identified the degradation phenomena accompanying the charge-discharge cycle. Moreover, battery evaluations have been conducted solely in a pure oxygen atmosphere, and we await further studies on the potential for using air. To begin with, we expect to work on elucidating the mechanisms of battery degradation, particularly in the cathode, and to improve cycle characteristics over a span of about five years. We also hope to improve the cycle characteristics of lithium metal anodes (suppressing dendrite growth, etc.), which should become more evident as cathode performance improves. Thereafter, over a maximum R&D period of ten years, we expect the adopted project to work on improving the performance of various battery materials, constructing cells with optimized performance including cycle characteristics, and completing the prototype of a metal-air battery system envisioned to use air.

1-2.5 Theme 5: Common Foundational Research on Constructing a Common Infrastructure for Measurements and DX

Description of R&D

By establishing a common infrastructure team that brings together specific capabilities from the entire research area, we hope to achieve efficient management for the utilization of large, advanced measuring instruments and the construction of an integrated database. Exploring battery materials and analyzing the mechanisms of battery functions and degradation will require a detailed understanding of the surface structure and electronic state of materials and structural changes that accompany battery operations. To this end, it will be effective to conduct advanced measurements and analyses using large synchrotron radiation and neutron experimental facilities that possess high temporal and spatial resolution. At the same time, we anticipate developing automated and autonomous experiment to accelerate and automate R&D, as well as utilizing new research techniques and digital transformation (DX), including the utilization of automated experimental facilities to obtain large quantities of experimental data from a vast search space and the prediction of search candidates that have a high probability of success from a database storing this accumulated data. Additionally, the development of next-generation storage batteries will require a process for detecting issues at the configuration and material level of batteries and electrodes while manufacturing and evaluating battery prototypes.

The construction of these core technologies, commonly required for all R&D themes, will be undertaken by the entire research area while utilizing existing facilities. Further, since comprehensive evaluation methods such as analysis using various large equipment, as well as DX platforms such as automatic data collection using automated and autonomous experiments are expected to be utilized in other research areas (the area of hydrogen in particular), the project adopted for this theme will also be responsible for analyses and comprehensive evaluations using various large equipment and automatic data collection for related materials in other fields. We will also consider collaborating on data utilization with the MEXT Materials DX Platform.

Goals and Milestones for Technical Issues

The goal of this R&D theme is to establish, in approximately three years, a foundation for advanced measurement and evaluation technologies needed for analyzing storage battery phenomena, developing battery materials, and designing battery structures. Further, since the manufacturing, evaluation, and analysis of battery prototypes is essential for understanding the challenges facing next-generation batteries currently under development, we will assist in battery prototyping undertaken by each R&D team with technologies that require specialized expertise, such as the handling of active compounds and electrode coating. While making effective use of existing facilities, we will develop functions capable of contributing directly to problem-solving with consideration for the latest technological trends. R&D under this theme will be conducted in close cooperation with the teams under R&D Themes 1–4 and other areas while clarifying what research challenges require support. We will develop new research techniques and R&D tools that will utilize data science methods and streamline experiments and whose implementation will provide each R&D theme with design guidelines and process factors that are key to the creation of new functions and materials. Over approximately five years, the project under this theme will develop a system capable of structuring various types of data and automatically storing experimental data for each R&D theme in a reusable form. In consideration for the formulation of policies on data provision that include the guarantee of profit for providers of data, we will establish a DX infrastructure for automating experiments, for example, and promote data availability aimed at enabling efficient data acquisition and improving the reuse rate of data. After sufficient consideration for open and close strategies regarding data, we expect to construct infrastructure capable of supporting the promotion of efficient R&D, establish a data platform that will allow industry and academia to collaborate on developed research methods and R&D tools, and disseminate technology outside of this project.

<u>Points to Consider When Submitting Your Proposal</u>

The team selected for this theme must serve as a common infrastructure and platform capable of providing a smooth service system with sufficient technical support staff. The team is also expected to implement large facilities and equipment specified in the list of common research equipment on p. 10 of Chapter 1 of the Application Guidelines. Additionally, since materials and analysis samples such as metallic lithium, which are unstable in air, are expected to be handled, necessary ancillary functions such as handling in a dry environment, sample transport without exposure to air, and low-damage etching must also be provided. This team must collaborate with teams in the other Themes 1–4 and other areas while periodically adjusting its capabilities according to need.

1-3 Envisioned R&D Structure

<u>Team-Based Research</u>

- Large R&D teams with accumulated knowledge in the development of element technologies will conduct R&D while incorporating their interdisciplinary expertise.
- The team should be led by a researcher (Team Leader) capable of supervising comprehensive battery technologies, including overseeing and reviewing the entire battery system, and should include researchers in charge of “active materials,” “electrolytes,” and “the development of other components and comprehensive battery technologies and system optimization.” The program officer and others will also appoint an overall Team Leader from among the selected Team Leaders to provide overall support to all teams.
- The Team Leader must assemble multiple element technology groups to conduct R&D on element technologies such as active materials, electrolytes, and separators and must put together a team to promote integrated R&D.
- The Team Leader should assign a leader (group leader) for each element technology group for overseeing their respective group.
- While primarily conducting materials development for components (the development of element technologies and elucidation of mechanisms), the team should be structured for handling comprehensive R&D that includes the selection of materials, the optimization of components for a storage battery system, and the carrying out of manufacturing processes. Since the periods of R&D are likely to vary for some element technologies, please explain the timeline by which the team will develop the targeted technologies in such cases.
- Element technologies thought to be necessary for R&D, such as measurement and analysis technologies, materials exploration, and computational science, should be included in the team structure. Researchers from such varied disciplines as theory, computation, condensed matter physics, and organic chemistry are expected to participate actively in the project.
- A system for promoting interdisciplinary R&D will be established throughout the entire research area for undertakings required by a wide variety of battery systems, such as finding solutions to common problems (e.g., dendrite formation), developing materials, developing simplified manufacturing processes, and developing common basic technologies.

- While teams are expected to comprise primarily members of academia, it is hoped that companies or other organizations who would be capable of developing the research results will participate in the initial phase following adoption or during the R&D period since early social implementation is a goal of this project.

Team-Based Research (common basic research)

- This project will entail basic research common to all team-based research, including the development, evaluation, and analysis of new approaches such as DX, the prototyping of integrated systems, and automated data collection. Additionally, common research equipment for the above research (refer to Chapters 1–5 in the Application Guideline for details) will be developed and operated and made available for team-based research.

Innovative Elemental Technology Research

- While this call for proposals targets team-based research in principle, individuals or groups may submit proposals for Themes 1–4 related to innovative batteries based on new principles or materials or to R&D focused on a single element technology necessary for the practical application of storage batteries, such as electrolytes, active materials, measurement and analysis technologies, materials exploration, and computational science under the assumption that applicants will be incorporated into a team should their proposal be adopted and will conduct R&D as a member of that team. The program officer and others will be responsible for coordinating the team makeup when such proposals are adopted.

1-4 Proposal Considerations and R&D Management

Data utilization (DX) and collaboration with large synchrotron radiation facilities, etc.

- The experimental/measurement data will be used to accelerate research and development by accumulating, linking, and utilizing data and improving the reuse rate, while making maximum use of the existing "National Institute for Materials Science (NIMS) Data Platform" and the know-hows from the previous efforts on DX. For this purpose, experimental and measurement data generated daily in each of the R&D themes will be consolidated in a centralized database and utilized for structuring and providing data, based on policies such as ensuring the advantages of data providers. Applicants are required to handle various types of data in accordance with this principle.
- We will actively utilize the large synchrotron radiation facility[2] and the supercomputer "Fugaku" as a whole, and conduct research and development efficiently under an all-Japan framework.
- We will proactively build a cooperative framework for analytical technologies and issues that are common to the hydrogen area including catalysts, solid polymers, clarification of degradation mechanisms.

Installation of equipment, etc.

- Equipment that is in high demand for use across the entire R&D area, such as large-scale equipment for cell prototyping, evaluation, and analysis, will be efficiently and effectively operated by making maximum use of existing equipment at participating institutions and by introducing and operating such equipment in a somewhat coherent manner (see p. 7, "1.5 Common Research Equipment" in the Application Guideline). A list of equipment and devices that considered to be in scope for implementation in this area is provided on p. 10 of Chapter 1 of the Application Guidelines. Applicants are requested to make their own plans for the purchase of equipment and devices

[2] SPring-8, J-PARC, NanoTerasu, Inter-University Research Institutes, etc.

based on the assumption that the equipment and devices listed in the list will be implemented within the R&D area.

Intellectual property management

- We aim to acquire and utilize intellectual property that contributes to strengthening international industrial competitiveness and promoting commercialization. In order to manage intellectual property in a unified manner, a committee for managing intellectual property will be established within JST, led by the PO. After examining the deployment scenario of the project's R&D results, a policy for managing intellectual property in this area will be established and properly operated.
- The committee will determine whether or not rights should be applied for patent prosecution and how the research results should be handled afterwards as necessary, while keeping in mind the open and close strategies of the research results. The R&D organizations will be requested by the committee to handle the intellectual properties based on the committee's decision. For example, in order to obtain a patent with strong exclusivity, the committee may request that additional experiments be conducted as necessary, or that publications or patent applications be withheld for a certain period of time.

2 Hydrogen Area

PO：UCHIDA Hiroyuki (Project Professor, Clean Energy Research Center, University of Yamanashi)

R&D Theme	Number of Projects to be adopted	Budget (5-year total of direct cost)
Team-based research R&D Theme 1: “Realization of a Water Electrolysis System with Improved Efficiency and Durability and Reduced Costs”	1-2 projects	– For implementation of common research equipment: up to 600 million JPY approx. per project (*) – R&D costs: up to 3 billion JPY approx. per project
Team-based research R&D Theme 2: “Realization of a Fuel Cell System with Improved Efficiency and Durability and Reduced Costs”	1-2 projects	– For implementation of common research equipment: up to 600 million JPY approx. per project (*) – R&D costs: up to 3 billion JPY approx. per project
Team-based research R&D Theme 3: “Development of a Hydrogen Storage System with High Density, High Durability, and Low Costs”	1-2 projects	– For implementation of common research equipment: up to 1 billion JPY approx. per project – R&D costs: up to 2 billion JPY approx. per project
Innovative elemental technology research for R&D Themes 1-3	A few projects	Up to 10 million JPY for the first fiscal year

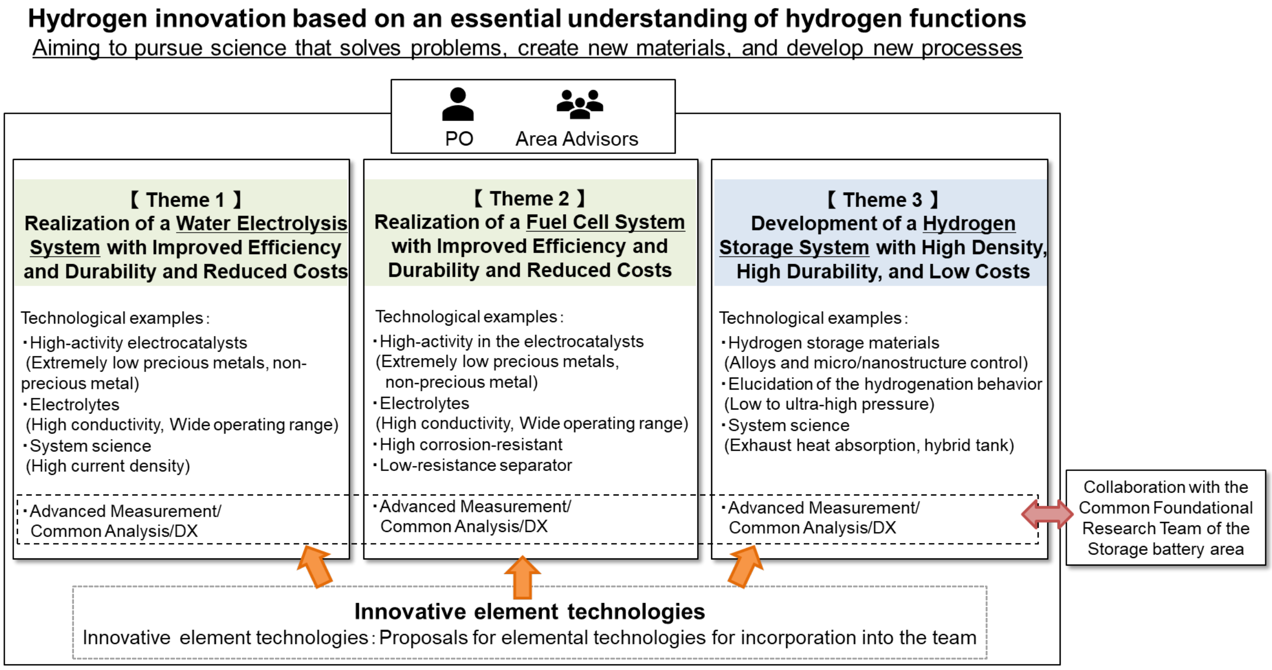
*Some of the common research equipment for Themes 1 and 2 will be implemented together with those in the Storage Batteries area. Large equipment required for the Hydrogen area that can be effectively used in the Storage Batteries area will be managed in the Storage Batteries area. Since the amount stated above includes the implementation of common research equipment in the Storage Batteries area, the actual cost of maintenance of common research equipment in the R&D Themes 1 and 2 will be less than the amount stated above.

2-1 Overview of the Hydrogen Area

In this area, we will contribute to the realization of a hydrogen society by developing advanced technologies for the production, storage, and utilization of hydrogen, which is essential for achieving carbon neutrality in 2050, through water electrolysis using electricity derived from renewable energy sources. The projects in this area will target the development of technologies to break through current bottleneck issues in an innovative manner, the creation of new concepts, and research and development for the practical application of these technologies, utilizing seeds from academia. The projects will promote integrated research and development by conducting not only basic research on elemental technologies but also evaluation of materials and prospects for scale-up. We will promote seamless and integrated research and development. The program also aims to foster human resources with broad perspectives and development capabilities.

2-2 R&D Themes

The Hydrogen area aims to develop innovative hydrogen-related technologies under the R&D themes shown in 2-2.1 through 2-2.3 below. Although each of the R&D themes has specific goals and milestones for the achievement of specific technological tasks, proposals based on innovative ideas are expected, including but not limited to goals mentioned in this application guidelines. Applicants (Team Leaders) may only submit proposals for one of the most appropriate themes, based on a thorough understanding of the objectives of each theme. Proposals for each of the themes must be submitted as a team-based research project that encompasses not only the R&D content of each theme, but also the R&D content indicated in Section 2-2.4 “Common items (Themes 1-3)”, which is specific to each field of research. The Themes 1 through 3 in the Hydrogen area include the implementation of common research equipment; however, if the equipment can be utilized in the Storage Batteries area, it should be integrated and implemented by the common basic research team in the storage battery area. Please refer to "1.5 Common Research Equipment" on p. 7 of Chapter 1 of the Application Guidelines for details on the implementation of common research equipment.



Structure of the Hydrogen Area

2-2.1 Team-Based Research, Theme 1: Realization of a Water Electrolysis System with Improved Efficiency and Durability and Reduced Costs

Description of R&D

Renewable-energy-based water electrolyzers are already being implemented in society in the form of alkaline and proton exchange membrane (PEM) electrolyzers. Alkaline electrolyzers do not require the use of precious metals in their electrocatalysts but cannot operate properly at high current densities and suffer from poor responsiveness to output fluctuations in renewable energy. PEM electrolyzers using a strongly acidic electrolyte membrane have fast dynamic response to output fluctuations but require the use of precious metals that are corrosion resistant and highly active under acidic conditions to be used in both electrocatalysts. Due in part to the limited supply of precious metals (e.g., iridium), efforts must be focused on drastically reducing the use of and recycling such precious metals. Technical issues remain in both types of electrolyzers for which we expect to clarify scientific principles, such as how to improve durability through an understanding of the degradation mechanisms. In order to further popularize the use of hydrogen, we must be able to supply large quantities of hydrogen efficiently and stably, and further improvements in efficiency, durability, and cost will be essential. In addition to solving the most pressing technical issues in existing water electrolysis systems that are currently being implemented in society, the goal of this project is to conduct R&D aimed at the social implementation of water electrolysis systems based on new principles and materials.

Goals and Milestones for Technical Issues

Technical challenges to further expanding the social implementation of water electrolysis systems such as PEM and alkaline electrolyzers include elucidating the degradation mechanisms and other principles of the systems, drastically reducing the use of precious metals in electrocatalysts (including through the recycling of precious metals), and improving the durability of electrolyte membranes. We must aim at generating research output in the short term (approximately three years) and subsequently develop those results for industry. In addition to systems that are already being implemented into society, we must work toward the social implementation of systems not yet ready for practical use but whose performance innovation is theoretically needed from the perspectives of higher efficiency, higher durability, and lower costs. The projects to be adopted under this theme is expected to devote about three years on water electrolysis using a neutral electrolytic solution and between five and seven years on an anion exchange membrane (AEM) water electrolysis system. The study will also consider the prospects for scaling up systems and will be conducted in parallel with a study on materials development. If scaling up is deemed effective, an R&D period of between about five and seven years is expected to be necessary to realize a neutral electrolyte system and a maximum of ten years to realize an AEM system. Additionally, while still in the seed exploration stage, challenging issues that could give rise to technological innovations in PEM water electrolysis, such as the realization of precious-metal-free electrolysis and rapid life predictions, must be addressed over a long R&D period based on the acquired research findings, with the goal of achieving ultimate performance. We will also attempt to clarify the scientific theories that could help increase current density through an analysis of gas-liquid two-phase fluids in cells and an analysis of mass transfer at the reaction interface and to establish a system by combining these scientific theories in nontraditional ways. We expect technical collaboration on non-precious-metal electrocatalysts and other technologies for use in AEM and neutral electrolyte water electrolysis, and anticipate that stack technologies used in PEM water electrolysis can also be developed for these systems. Thus, an integrated approach to R&D through collaboration within the team is desirable.

Points to Consider When Submitting Your Proposal

Since there are many common technologies under the themes of water electrolysis and fuel cells, opportunities aimed at social implementation will be established as needed to promote collaboration among teams, such as the prompt sharing of issues from materials development to practical applications.

2-2.2 Team-Based Research, Theme 2: Realization of a Fuel Cell System with Improved Efficiency and Durability and Reduced Costs

Description of R&D

Fuel cells that use hydrogen as an energy source are already being implemented in society for stationary fuel cell and fuel cell vehicle (FCV) applications, and their use is expected to expand further, particularly for applications in large trucks and other heavy-duty vehicles (HDV). However, we face various technical challenges in developing fuel cell systems for diverse applications, including material costs, fuel consumption, power density, and load weight, and it will be critical to develop fuel cell systems that satisfy all aspects of improved efficiency, improved durability, and reduced costs. For example, with PEM fuel cells, which currently have practical uses, we need to accelerate activation of the membrane electrode assembly (MEA) to shorten the production period, improve durability of the fuel cells by clarifying the degradation mechanisms of the separator materials and electrolyte membrane, significantly reduce the use of precious metals while increasing activity in the electrocatalysts, and improve performance in the medium current density range and under low humidification conditions, which will help to resolve issues such as fuel consumption and costs. In addition to these challenges, this R&D theme seeks to contribute to the development of fuel cell applications and their implementation in society through the development of AEM fuel cells and fuel cell systems based on new principles and materials.

Goals and Milestones for Technical Issues

For polymer electrolyte fuel cells, which are already being utilized in passenger cars, the projects under this theme are expected to produce results in a short period of approximately three years in such areas as rapid activation of MEA for shortening the production period, elucidation of degradation mechanisms in separator materials, for example, and improved performance in the medium current density range aimed at resolving issues of fuel consumption and cost. With the goal of using fuel cells in HDVs, the projects will strive to produce results over about five to seven years on issues pertaining to further improving performance and durability and reducing costs, such as the scientific clarification of degradation mechanisms, improved electrocatalyst activity, significant reduction in precious metal usage, improved electrolyte membrane durability, and improved performance under low humidification conditions (clarification of the mechanisms of oxygen reduction catalysts over a wide temperature range). Following this period, we expect the projects to develop these results for social implementation. On the subject of AEM fuel cells, which have not yet been implemented in society but are destined to undergo a structural transformation, or fuel cell systems based on new principles and materials, the projects are expected to develop and evaluate materials used in the MEA over approximately five to seven years while also considering the potential for scaling up the systems. The long-term efforts to establish these fuel cell systems are expected to require a period of no more than ten years.

Points to Consider When Submitting Your Proposal

Since there are many common technologies under the themes of water electrolysis and fuel cells, opportunities aimed at social implementation will be established as needed to promote collaboration among teams, such as the prompt sharing of issues from materials development to practical applications.

2-2.3 Team-Based Research, Theme 3: Development of a Hydrogen Storage System with High Density, High Durability, and Low Costs

Description of R&D

Developing materials to realize safe, high-density storage systems is a major barrier to the utilization of hydrogen energy. The aim of this theme is to develop new materials for achieving a hydrogen storage density on par with that of liquid ammonia under normal temperature and pressure. We are seeking researchers to conduct R&D on potentially game-changing hydrogen storage materials and methods of using and creating systems from these materials by dramatically improving hydrogen storage density through alloys and micro/nanostructure control, elucidating the currently unknown hydrogenation behavior between ultra-high and normal pressures, and developing next-generation hydrogen storage systems based on these findings.

Goals and Milestones for Technical Issues

Hydrogen-absorbing alloys have been studied primarily under normal pressure to date, but achieving the hydrogen storage density required for use in HDVs is thought to be an extremely high hurdle. Recently, superhydrides have attracted much attention owing to their ability to store hydrogen at extremely high densities under ultra-high pressures. We are looking for proposals on the development of innovative hydrogen storage materials that goes behind the boundaries of conventional research to elucidate hydrogenation behavior from normal to ultra-high pressures. We must further increase the density of these materials through structural control at the micro and nano levels. Through these efforts, we will conduct R&D for realizing a storage density at normal temperature and pressure at a similar level to that of liquid ammonia and will work to scale up the hydrogen storage system. To this end, we must in the short term establish and network a collection of evaluation and analysis equipment, which has yet to be developed. Once in place, this equipment will be used for the purpose of elucidating mechanisms under expanded search conditions with the aim of developing a high-pressure hydrogen storage system in about five to seven years. Based on these results, we hope to create new materials with innovative performance and incorporate these materials into systems over a maximum R&D period of ten years.

2-2.4 Common Items (for Themes 1–3): Establishment and Utilization of Infrastructure for Advanced Measurements, Analyses, and DX

Description of R&D

A thorough understanding of surface structures and electron states is necessary for materials exploration and the analysis of functions and degradation mechanisms in this field, in which it is thought that advanced analysis and computational science utilizing large synchrotron radiation and neutron experimental facilities with high temporal and spatial resolution could be effective. We anticipate using the facilities at SPring-8 and NanoTerasu since direct analysis of catalyst and carrier behavior at the three-phase interface and operando analysis during the reaction process is particularly effective in water electrolysis and fuel cells. Neutron beams are effective for elements with low atomic numbers such as hydrogen and may be useful in operando analyses of fuel cells at the cell level and analyses of hydrogen storage materials. Additionally, since it will be indispensable to speed up searches over a broad range of materials, this project aims to construct an R&D infrastructure using such techniques as materials informatics (MI) and to study DX tools and develop automated and autonomous experimental techniques for streamlining data acquisition and storage. Further, infrastructure created by merging DX and analysis may be useful in establishing effective and efficient methods of experimentation, such as methods of combining multiple measurement and analysis techniques. These issues will be essential to carrying out R&D in the above themes. In addition to conducting R&D within the team responsible for each theme, we seek to promote R&D through cross-disciplinary collaboration while utilizing the infrastructures of other fields (particularly the area of storage batteries).

Goals and Milestones for Technical Issues

The most important consideration for promoting the use of DX to accelerate R&D is the efficient and effective accumulation of data. First one must establish a place to accumulate data and then develop a method of efficiently collecting and effectively utilizing the various data generated daily at R&D sites. While it is effective to establish common infrastructure as the data collection site, each team must develop their own methods of data collection and utilization in the short term. Collaboration with the MEXT Materials DX Platform may also be effective. We must strive to accelerate materials exploration using this accumulated data, as well as MI and other techniques, and must continuously work on establishing automated and autonomous experiments that will improve efficiency and allow for a massive expansion of the exploration area. By implementing a phased approach over about five years to first automate experiments for enabling increased throughput and to then establish autonomous experiments, we hope to establish a DX infrastructure for the field of hydrogen. Analyses using advanced measurements and common analysis techniques are also very important. For water electrolysis and fuel cells, we must elucidate reaction mechanisms through operando analyses on the behavior of oxygen atoms, bubbles, and catalyst carriers at the catalyst interface during the reaction process and on migration phenomena of water, protons, and oxygen. For hydrogen storage, we must conduct structural analyses of metallic materials, polymer materials, and micro/nanostructured materials and clarify the dynamic behavior of hydrogen atoms within materials in a hydrogen atmosphere. We also expect to verify the effectiveness of techniques that combine multiple measurement and analysis techniques in the short term and, if proven effective, to study the establishment of infrastructure over approximately five years. The long-term goal is to establish an infrastructure for DX, measurements, and analyses as a platform that includes the accumulated data, while introducing new research techniques.

<u>Points to Consider When Submitting Your Proposal</u>

In addition to each team addressing the above items in a manner specific to each field, including the R&D personnel in each team that will implement Themes 1–3, R&D will be promoted through cross-disciplinary collaboration. Consequently, team-based proposals for these items in the field of hydrogen will not be accepted, however each team will be required to form an R&D system including personnel responsible for the Common Items. For items which are common to the Storage Batteries Area such as analysis technologies and large facilities for evaluating materials in catalysts and electrolyte membranes, and foundational system for DX utilizing automatic and autonomous experiments for automatic data collection, it is necessary to ensure mutual collaboration with the Storage Batteries area. Therefore, research in the above-mentioned items will be promoted through the platform to be constructed by the common basic research team solicited under “Theme 5: Common Foundational Research” in the Storage Batteries Area.

2-3 Envisioned R&D Structure

<u>Team-Based Research</u>

- Multiple R&D teams described below will be formed in this area for implementing Themes 1–3.
- A team is the basic unit for conducting R&D. Each team should be led by a Team Leader and be configured not only of researchers developing element technologies and materials and researchers in charge of advanced analyses of reaction and degradation mechanisms, but also researchers in charge of DX and computational science to accelerate these development efforts, researchers who evaluate the performance of single cells assembled from the developed materials, and researchers who can oversee and review the system in its entirety, including the prospects for scaling up the developed materials. The Team Leader must establish a research and development system comprising multiple element technology groups that conduct R&D while promoting the integration of materials and technologies and the optimization of systems with an eye toward social implementation. Therefore, when submitting a proposal for Themes 1–3, please also include an R&D description for “Common Items (for Themes 1–3): Establishment and Utilization of Infrastructure for Advanced Measurements, Analyses, and DX.”
- Teams should be composed not only of researchers who have traditionally conducted hydrogen-

related research. Researchers from diverse fields (e.g., measurement and analysis technologies, computational science, information science, condensed matter physics, and organic chemistry) who have not been involved in hydrogen research are also encouraged to actively participate with a willingness to take on new challenges.

- The Team Leader is encouraged to assign a leader for each element technology group (group leader) for overseeing their respective group.
- When undertaking short projects, it is particularly important to begin by drawing up a clear roadmap to practical applications since the period from the start of R&D to social implementation is short. We encourage those who will be receiving the research outcomes from each team to participate in the planning and to collaborate with the team.
- A common protocol is expected to be used for evaluating performance during R&D on water electrolysis and fuel cells. Thus, it is desirable that organizations having knowledge of social implementation, such as the Collaborative Innovation Partnership (CIP), participate and collaborate in these evaluations.

<u>Innovative Elemental Technology Research</u>

- While the units of this open call for research are “R&D teams” in principle, proposals may also be made on element technologies of water electrolysis, fuel cells, and hydrogen storage that can contribute to the above themes. For example, we envision receiving proposals for element technologies such as electrolytes expected to have remarkable proton activity, or catalysts expected to exhibit innovative properties. We also anticipate proposals from researchers in a variety of fields who have not participated in hydrogen research to date. The program officer and others will be responsible for coordinating the team makeup when such proposals are adopted.

2-4 Proposal Considerations and R&D Management

<u>Regarding the common research equipment.</u>

- Facilities in large-scale those that are effective for hydrogen research and have high nationwide needs but are used only infrequently at a single institution, and facilities with high management and operation costs, are considered effective for use as common research equipment. Equipment that can be effectively used in conjunction with the Storage Batteries area will be consolidated and provided to the common foundational research team in the Storage Batteries area. In addition, the common research equipment to be implemented by each team will be installed and operated under the leadership of the Team Leader to form a network of mutual support among the participating institutions, with a sufficient support system of technical staff within the team.

<u>Intellectual property management</u>

- We aim to acquire and utilize intellectual property that contributes to strengthening international industrial competitiveness and promoting commercialization. In order to manage intellectual property in a unified manner, a committee will be established within JST, led by the PO. After examining the deployment scenario of the project's R&D results, a policy for managing intellectual property in this area will be established and properly operated.
- The committee will determine whether or not rights should be applied for patent prosecution and how they should be handled afterwards as necessary, keeping in mind the open and close strategies of the research results. The R&D organization will be requested by the committee to handle the intellectual properties based on the committee's decision.

Open and Close Strategies

- JST, led by the PO, will formulate an open and close strategy for each field (water electrolysis, fuel cell, and hydrogen storage) that defines in advance the research methodology, the extent to which results will be disclosed, and the degree of corporate participation in the research. Team leaders are expected to promote research and development in accordance with these strategies. The strategies will be revised as necessary based on the progress of the research and other factors.

Data Strategy

- JST, led by the PO, will develop a data strategy for sharing and releasing research data in each field (water electrolysis, fuel cell, and hydrogen storage). The Team Leader is required to follow this strategy and appropriately define the scope of the data, as well as to consider how to accumulate data including negative data, standard data formats, data management tools, etc., as appropriate. The strategies shall be reviewed as necessary and appropriate based on research progress and other factors.

3 Biomanufacturing Area

PO : KONDO Akihiko (Vice president, Kobe University / Professor, Graduate School of Science, Technology and Innovation, Kobe University)

R&D Theme	Number of Projects to be adopted	Budget (5-year total of direct cost)
Team-based core research R&D Theme 1: "Establish next-generation biomanufacturing platforms with a focus on microorganisms"	1 project	– For implementation of common research equipment: up to 700 million JPY approx. (*) – R&D Costs: up to 2 billion JPY approx.
Team-based core research R&D Theme 2: "Establish next-generation biomanufacturing platforms with a focus on plants"	1 project	– For implementation of common research equipment: up to 700 million JPY approx. (*) – R&D Costs: up to 2 billion JPY approx.
Team-based platform technology research R&D Theme 3: "Research to explore, analyze interactions between organisms" R&D Theme 4: "Research into evaluation systems using artificial systems" R&D Theme 5: "Research into more sophisticated analytical technologies and mathematical tools for information analysis"	1 project per R&D theme	R&D Costs: –for R&D Theme 3; up to 600 million JPY approx. –for R&D Theme 4; up to 400 million JPY approx. –for R&D Theme 5; up to 600 million JPY approx.
Innovative elemental technology research for R&D Themes 1-5	A few projects	Up to 10 million JPY for the first fiscal year

*The common research equipment is not intended for equipment that is dispersed and installed at each research site and used for joint research with other research sites (these are paid for from the R&D funds), The equipment must be maintained and managed in an integrated manner under the supervision of a manager, and must be used for convenience, including sample preparation and equipment operation by a full-time operator.

3-1 Overview of the Biomanufacturing Area

In this area, in order to apply biomanufacturing technologies to a wide range of manufacturing industries such as chemical, textile, food and beverage, which emit 80.9 million tons of CO_2 per year, we aim to increase productivity, diversity, and enhancement of functions and CO_2 fixation capability of chemicals such as various aliphatic and aromatic compounds (materials or raw materials for rubber products, plastics, synthetic fibers, etc.), SAF (Sustainable Aviation Fuel) and other next-generation fuels. We will promote research that will lead to the next-generation biomanufacturing system infrastructure using microorganisms/plants. The R&D area also aims to foster human resources with broad perspectives and development capabilities.

3-2 R&D Themes

In this area, we expect the following R&D themes aimed at promoting research into biomanufacturing.

(1) Microorganisms

i) Preparation of innovative microorganism platforms, including the development of hub cells (basic cells) that exhibit the minimum functions needed to allow development for the production of chemical products

ii) Discovery of useful genes and novel enzymes for the production of chemical products, such as organic compounds chemically identical to those produced from petroleum or petroleum substitutes; development and introduction of novel metabolic pathways; development of microorganisms for the highly efficient production of products; and development of simple methods for the insertion of novel enzymes and development of screening methods

iii) Discovery and development of useful microorganisms to allow the production of chemical products directly from CO_2, for example; discovery and application of microorganisms that can proliferate in inexpensive culture media to the same degree as in nutrient-rich culture media; and discovery and application of robust microorganisms that remain proliferative, productive, and active at high or low temperatures, in harsh environments such as in the presence or organic solvents, and regardless of environmental changes

(2) Plants

i) Elucidation of the mechanisms of complex metabolic pathways for biosynthesis in plants; improvement of photosynthesis efficiency; and development of novel metabolic pathways to increase productivity of useful substances or to produce chemical products such as organic compounds chemically identical to those produced from petroleum or petroleum substitutes

ii) Development of novel technologies to insert useful genes into plants, such as technologies for the direct insertion into individual plants of the gene(s) for plant cell dedifferentiation or redifferentiation; and development of technologies that allow rapid modifications to plants

(3) Platform technologies

i) Preparation of data platforms relating to genes or metabolic pathways in microorganisms or plants; discovery of new biological resources including in extreme environments and utilization of biological information

ii) Development of innovative technologies relevant to Design-Build-Test-Learn (DBTL) cycles (e.g., algorithm development to predict functionality, use of mathematical science in biological information analyses, DNA synthesis and genome editing technologies, AI technologies, robotics and automation, omics analysis technologies, imaging technologies, structural analysis technologies)

iii) Technologies for the analysis of biological interactions that can contribute to reducing CO_2 emissions; elucidation of microorganism-plant interactions; identification of substances that contribute to interactions; discovery and elucidation of metabolic pathways involving these interactions/substances; and isolation and identification of microorganisms and substances that help promote plant growth

iv) Measurements using biomolecules in cell-free systems; development of technologies for use in the production of substances; and origination of novel highly active enzymes etc.

v) Development of component technologies for engineering purposes, such as simulations to scale up microorganism or plant cultures

The following is a list of specific themes for publicly solicited proposals, based on the R&D themes listed above. The following “Goals and Milestones for Technical Issues” are examples only, and applicants are expected to set their own reasonable and ambitious goals and milestones for each proposal that are appropriate for the purpose of the R&D theme.

3-2.1 Theme 1: Establishment of next-generation biomanufacturing platforms with a focus on microorganisms

Description of R&D

Research will be conducted to develop platforms for next-generation biomanufacturing, from the design and build stages right through to production, with a focus on the use of microorganisms to produce useful substances.

Specifically, each element of the DBTL cycle will be updated to next-generation processes for the creation of useful microorganisms including through the selection of cells and individual organisms optimized for bioproduction: (1) Design—computer-aided design of metabolic pathways or cell control systems for the production of useful substances; (2) Build—parallel, rapid output of specifically designed microorganisms through the use of robotics; (3) Test—high throughput evaluation using specially constructed automated equipment for microorganisms/cells; and (4) Learn—development of machine learning and identification of rules, as well as data control. Furthermore, in order to expand the types and functions of the substances produced and increase productivity to improve CO_2 fixing capabilities, we need to discover useful microorganisms, develop basic cells, and develop unused resources or elucidate metabolic pathways. The R&D area will also promote research into production processes to be able to apply the useful microorganisms created through the DBTL cycle to the production of chemical products. At the same time, the area will promote comprehensive and integrated research into other elements, such as looking beyond microorganisms and investigating the introduction of new metabolic pathways found in plants or analysis in cell-free systems. Through all these research efforts, the R&D area aims to establish next-generation platforms for biomanufacturing with a focus on microorganisms, and looks to connect the resulting research outcomes to NEDO Green Innovation Fund Projects etc. In addition, from the very start of the research, there will be close collaboration with teams working on R&D Theme 2 to build data platforms for use within this field and promote the collection of data for biomanufacturing platforms.

Goals and Milestones for Technical Issues

Over a period of around three years, the adopted project will generate results from the discovery of useful microorganisms or genes etc. with high CO_2 fixing capabilities that will contribute to reduced CO_2 emissions, as well as the development of novel metabolic pathways. Using these findings, over a period of around five years, the project will generate results from research to expand the types of products and functions from these microorganisms/genes, increase productivity, and improve CO_2 fixing capabilities, and also verify biomanufacturing using innovative microorganisms. Through these outcomes, the results from the project will include an increase in the diversity, functionality, and types, as well as improved production efficiency, of chemical products such as next-generation fuels like sustainable aviation fuel (SAF) or a range of aliphatic or aromatic compounds (the raw materials or components used in rubber products, plastics, or chemical fibers). After ten years, the project will establish next-generation microorganism biomanufacturing platforms. When pursuing this research, the project is expected to also take into consideration existing production processes and lifecycle assessment (LCA) for production processes using biomanufacturing.

3-2.2 Theme 2: Establishment of next-generation biomanufacturing platforms with a focus on plants

Description of R&D

Research to develop platforms for next-generation biomanufacturing will be conducted, from the Design and Build stages, with a focus on the use of plants to produce useful substances, right through to production.

Specifically, as with the research focused on microorganisms, the research will involve development through the entire DBTL cycle using biological information such as plant resources. The R&D theme aims to enable bioproduction in plants of substances that are difficult to produce using microorganisms and improve the CO_2 fixing capabilities of plants. The adopted project is expected to generate results on useful plants/useful plant cells and useful metabolic pathways by conducting research that elucidates unknown metabolic pathways that will contribute to biomanufacturing, with biological information such as plants and microorganisms included as part of the scope of research, as well as results on high-speed evaluation of information on plant resource quality, such as production or growth conditions. Furthermore, the project will develop next-generation genome editing/DNA synthesis technologies, gene transformation technologies, and rapid plant breeding methods and other techniques to build genomes, insert genes, and breed plants. In addition, because taking novel and useful metabolic pathways identified in plants and utilizing them for bioproduction in microorganisms has proven to be an effective approach in many cases, the R&D theme will promote comprehensive and integrated research into basic cell development or other elements such as microorganisms or cell-free systems, with the goal of expanding the types and functions of substances produced in microorganisms and improving productivity. Through all these research efforts, the theme aims to establish next-generation platforms for biomanufacturing with a focus on plants, and looks to connect the resulting research outcomes to NEDO Green Innovation Fund Projects etc. In addition, from the very start of the research, there will be close collaboration with teams working on R&D Theme 1 to build data platforms for use within this area and promote the collection of data for biomanufacturing platforms.

Goals and Milestones for Technical Issues

Over a period of between three and five years, the project will elucidate unknown metabolic pathways, develop novel gene delivery technologies, and cultivate rapid breeding methods, and these outcomes will provide a roadmap to reduced CO_2 emissions. Over a period of around five years, it will create innovative results in the development of next-generation technologies for genome editing and DNA synthesis. It will also become possible to utilize new and useful metabolic pathways discovered in plants for bioproduction in microorganisms. In addition, after around five years, the project will have created plant biomanufacturing platforms that run right through to the production of target chemical products, and will also verify new biomanufacturing methods using plant resources. Through these results, the project will enable the production of chemical products such as next-generation fuels like sustainable aviation fuel (SAF) or a range of aliphatic or aromatic compounds (the raw materials or components used in rubber products, plastics, or chemical fibers) through bioproduction by plants (e.g., substances that are difficult to produce in microorganisms) or bioproduction by microorganisms (e.g., the introduction into microorganisms of metabolic pathways etc. originating in plants). After around ten years, the project will establish platforms that are general-purpose and can be relocated to other sites. When pursuing this research, the project will also be required to draw on existing production processes and lifecycle assessment (LCA) for production processes using biomanufacturing.

3-2.3 Themes 3–5: Platform technology research

To overcome bottleneck issues, etc., we will sophisticate or combine multiple R&D themes, and conduct fundamental research common to R&D Theme 1 "Establishment of next-generation biomanufacturing platforms with a focus on microorganisms" and R&D Theme 2 "Establishment of next-generation biomanufacturing platforms with a focus on plants". The research period will be 5 years in principle. In addition, a R&D team that is evaluated in the stage-gate evaluation as unlikely to contribute to material production through biomanufacturing will be discontinued.

Since these researches also require the participation of researchers from different fields and the incorporation of researches with high originality, we invite applications as shown in the Themes 3-5.

Theme 3: Research to explore, analyze interactions between organisms

Description of R&D

Biological interactions (communication) between microorganisms, between plants, or between microorganisms and plants can lead to both microorganisms and plants acquiring new functions and producing substances or breeding in new ways not possible by individual microorganisms or plants alone. We therefore think that utilizing the many different types of biological interactions in the bioproduction processes with microorganisms/plants created through the DBTL cycle in R&D Themes 1 and 2 may be an effective approach to further increase productivity.

Under this R&D Theme 3, analysis of biological interactions will lead to elucidation of biological functions and mechanisms of action, including the analysis of exosomes or chemical substances (described below as biological interaction regulators) responsible for the interactions and exploration of genes and the relevant intracellular metabolic pathways. For example, by adding biological interaction regulators to culture solutions, it may be possible to culture microorganisms that are difficult to culture alone or achieve highly productive culture in microorganisms or plants. Another example could be platform technology development that will contribute to improved productivity or CO_2 fixing capabilities through the use of consortia of microorganisms or of microorganisms and plants. Furthermore, by exploring and elucidating biological interactions and the related metabolic pathways, the functionality discovered can be applied in microorganism/plant biomanufacturing platforms.

Goals and Milestones for Technical Issues

Over a period of around three years, the adopted project is expected to generate useful results relating to analysis of interactions between organisms that will contribute to the production of substances or efforts to develop methods for such analysis, as well as interactions between organisms that have the potential to improve substance productivity (including discovery and analysis of metabolic pathways relevant to such interactions or gene analysis, and identification of biological interaction regulators and elucidation of mechanisms of action). Over a period of around five years, the project will expand the types and functions of the biological interaction cases under analysis and will identify biological interaction regulators with the potential to improve production consistency or increase production volumes and elucidate mechanisms of action. Through this research, the project will generate results that will contribute to reducing CO_2 emissions, including improved bioprocess productivity and energy efficiency or improved CO_2 fixing capability in plants. Using these findings, by the tenth year from the project start, the goal is to have generated results in the installation of microorganisms/plant biomanufacturing platforms that utilize the functions of biological interactions. The R&D theme also aims to generate results in the underlying principles and validation of approaches to larger-scale production, by using gene modifications to amplify biological interactions or inexpensive biological interaction regulators and developing methods for the culture of useful microorganism consortia.

Theme 4: Research into evaluation systems using artificial systems

Description of R&D

This R&D theme will involve basic technology development with a focus on work that will contribute to research into production processes or increasing the sophistication and speed of the Build step of the DBTL cycle used in R&D Themes 1 and 2. A cell-free approach is rapid because it is based on reactions in a test tube and enables prototyping of enzymes or metabolic gene clusters, for example, as a preparatory stage when using microorganisms or plant cells to construct strains that produce useful substances. This can increase the sophistication and speed of the Build step. In addition, these evaluation systems are also expected to be useful in improving the functions of microorganism/plant biomanufacturing platforms, for example for the production of difficult substances for organisms (e.g. substances that are highly toxic to cells) or to reduce the cost of substance production. Specifically, the theme will involve the development of ultra-rapid evaluation systems and the construction of cell-free systems that will allow rapid measurement of biomolecules using cell-free methods, origination of novel artificial enzymes, and construction of useful metabolic gene clusters.

Goals and Milestones for Technical Issues

The project adopted under this theme will engage in the construction of evaluation systems using cell-free approaches for each step of the DBTL cycle for production of substances using microorganisms/plants. Over a period of between three and five years, the it will create technologies capable of evaluating (prototyping) the stages used in biomanufacturing that directly link to improved CO_2 fixing capabilities or high-efficiency production capabilities such as development of highly active enzymes, optimization of metabolic gene clusters, or highly sensitive/highly selective biosensors. After five years, the results from these evaluation systems will be verified in cell-based systems and work will be done to improve the accuracy of the cell-free evaluation systems to generate outcomes for metabolic pathway design or genome modification that help reduce CO_2 emissions. Using these findings, by the tenth year from the project start, the goal is to incorporate these technologies in microorganism/plant biomanufacturing platforms to create results that accelerate the Build and Test steps of the DBTL cycle.

Theme 5: Research into more sophisticated analytical technologies and mathematical tools for information analysis

Description of R&D

This R&D theme will involve platform technology development relevant to the Test, Design, and Learn steps of the DBTL cycle in R&D Themes 1 and 2: development of bioanalytical technologies with a focus on increasing the sophistication of the Test step and development of mathematical analytical techniques for bioinformation, sharing of data across teams, and construction of data platforms with a focus on contributing to greater sophistication in the Design and Learn steps.

For more sophisticated analytical technologies, the project adopted under this theme will work on developing more sensitive and higher throughput analytical and measurement technologies, such as omics analysis including genome and expression analysis, structural analysis, or mass spectrometry analysis to contribute to biomanufacturing. Research will also be conducted to develop sample handling or simple and highly reproducible methods.

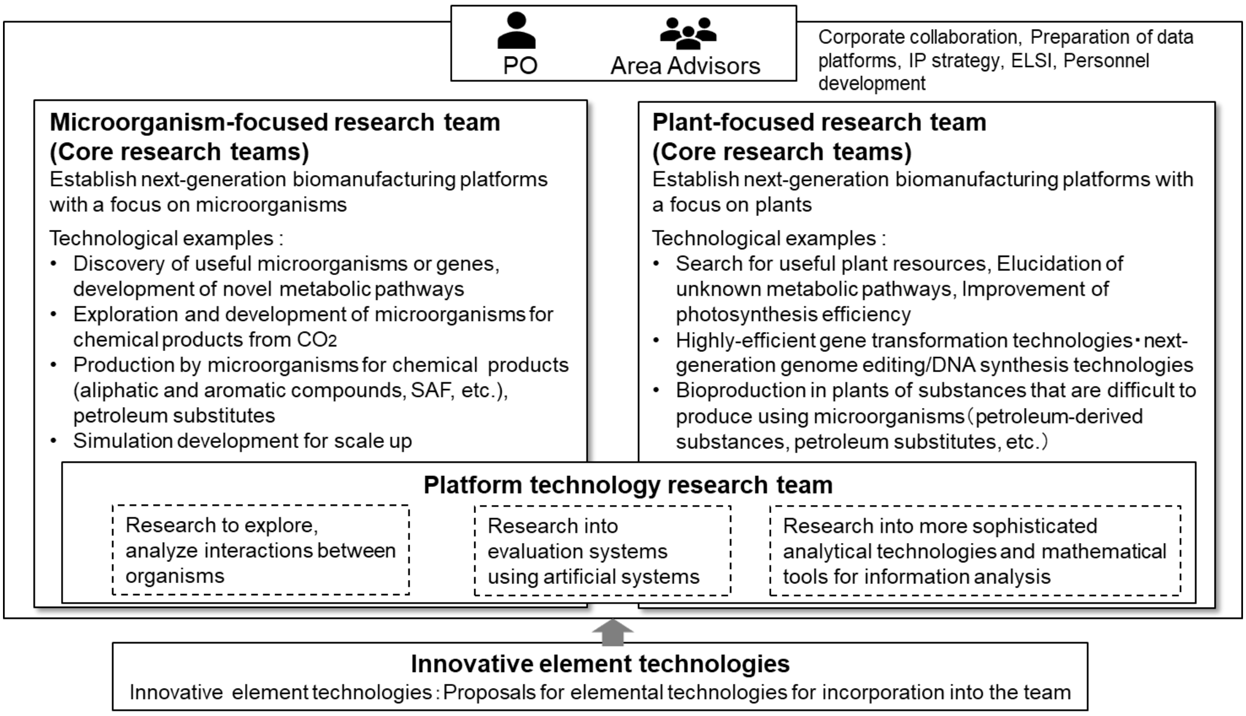
For the mathematical and information science research, the project will work on bioinformation analyses using mathematical science tools, such as AI, for prediction of protein function based on genomic sequences or prediction of genomic sequences based on protein information, or to predict the correlation between function and structure in proteins.

Goals and Milestones for Technical Issues

Over a period of between three and five years, the project is expected to create results to realize simple analytical methods, higher throughputs, and more sensitive analytical technologies (mass spectrometry analysis, structural analysis, etc.) that will contribute to biomanufacturing research. Using these findings, by between five and ten years after the project start, the goal is to have created innovative analytical technologies for genome analysis, in situ structural analysis, or proteomics without the need for mass spectrometry, while also aiming to improve the accuracy of predictions either of protein function from unknown genomic or RNA sequences, or of genomic sequences from proteins. Additional goals are to achieve results from computational science research that will contribute to faster, more accurate cell designs. A further goal is to reduce CO_2 emissions in substance production by using these technologies in the design of metabolic pathways, modification of genomes, and development of bioprocesses. In addition, by the tenth year from the project start, the goals are for these results to be incorporated into data platforms for use in other fields as well, and to progress the Test, Design, and Learn steps of the DBTL cycle to make the processes faster and more accurate.

3-3 Envisioned R&D Structure

In this area, we create a R&D system that maximizes results by integrating and collaborating various fields, integrating innovative technologies related to Themes 1 and 2 above, and constructing and sharing advanced equipment and research infrastructure. In order to construct such a system, we organize the call for proposals based on "team-based research" or "innovative elemental technology research".



Structure of the Biomanufacturing Area

Team-Based Research

- In this field, multiple R&D teams will be formed to pursue the research themes (1) through (3) in Section 3-2 together.
- The R&D teams will be divided into core research teams and platform technology research teams.
- The core research teams will play a role in driving biomanufacturing R&D and personnel training with the goal of consolidating innovative technologies and creating core research outcomes to contribute to green transformation (GX).
- Multiple platform technology research teams will be put into place to conduct basic research

alongside the core research teams, combining multiple individual technologies and developing more sophisticated approaches including overcoming issues that are acting as bottlenecks. These platform technology research teams will coordinate with the core research teams in the pursuit of the R&D.

- A Team Leader will be appointed for each team and R&D will be pursued through coordination between the core research and platform technology research teams.

Core research teams (R&D Themes 1, 2)

- Two core research teams will be set up: a microorganism-focused research team (R&D Theme 1) and a plant-focused research team (R&D Theme 2)
- The Team Leaders of the microorganism-focused and plant-focused research teams will also integrate research results from the platform technology research teams with the goal of establishing next-generation biomanufacturing platforms.
- The microorganism-focused research team and the plant-focused research team will not focus exclusively on microorganisms or plants, respectively, but will also pursue comprehensive and integrated research into other elements, such as taking novel, useful metabolic pathways originally found in plants and introducing them into microorganisms, and then connecting this work to biomanufacturing. The goal is also to connect the resulting research outcomes to NEDO Green Innovation Fund Projects etc.
- The microorganism-focused research team and the plant-focused research team will need to satisfy a number of conditions including the following:
    - i) Gathering of leading researchers at the forefront of various fields, such as biology, information sciences, or chemistry, in a collaborative organization
    - ii) A hub that functions to combine with other fields and work with industry
    - iii) Of the R&D Themes 1 through 3 discussed above, function to pursue and integrate multiple R&D projects
    - iv) Preparation and sharing of advanced equipment and research platforms (equip with analytical instruments, supply analytical technologies, prepare data platforms, develop and supply more sophisticated engineering technologies such as culture methods and technologies for DNA synthesis and genome editing)
    - v) Systems to factor in industry needs
    - vi) Intellectual property strategy and support functions for ethical, legal, and social issues (ELSI[3])
    - vii) Personnel development function
    - viii) Support for platform technology research teams by complying with the conditions described in points i) through vii)

Platform technology research teams (R&D Themes 3–5)

Teams will be established for research to explore, analyze interactions between organisms (R&D Theme 3), research into evaluation systems using artificial systems (R&D Theme 4), and research into more sophisticated analytical technologies and mathematical tools for information analysis (R&D Theme 5).

The structure will involve participation by leading researchers from a number of institutions who will conduct R&D while also collaborating with core research teams, in order to strengthen the core

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[3] Ethical, Legal and Social Issues

research teams/accelerate research output and promote original research.

Innovative Elemental Technology Research

- While this call for proposals targets team-based research in principle, proposals may be submitted on the premise that the applicant will join a team and conduct research and development as its member after the project adoption. Proposals can be submitted by groups that specialize in a single elemental technology necessary for biomanufacturing from a wide range of fields, including IT and AI, or groups in biomanufacturing field, based on a new principle. These will be coordinated by the PO and others to join the team if selected.

3-4 Proposal Considerations and R&D Management

Data utilization (DX) and collaboration with large synchrotron radiation facilities, etc.

- In order to conduct efficient biomanufacturing research, it is necessary to elucidate the correlation between omics information and substance production in microorganisms and plants, and to link this to modification of genome sequences and metabolic pathways. For this purpose, it is important to develop a data platform that can be shared among participating researchers, because it is necessary to have an infrastructure that enables effective extraction and utilization of these data and feedback of the obtained data.
- For this reason, researchers participating in the project shall, in principle, store the research data to be generated in the designated data platform. However, the specific operation policy of the data (e.g., data format, types of data to be stored, and how the data should be released during and after the project period in consideration of intellectual property strategy, etc.) will be established by JST after discussions between the core research team and JST and other project participants at the start of the research and development. It will also be revised as appropriate based on the progress of the program. From the viewpoint of effective research promotion, the handling of negative data and other issues. will be considered at that time,.
- If you wish to use large research facilities such as large synchrotron radiation facilities or the supercomputer "Fugaku", coordination for shared use will be considered in the GteX program.

Intellectual property management

- We aim to acquire and utilize intellectual property that contributes to strengthening international industrial competitiveness and promoting commercialization. In order to manage intellectual property in a unified manner, a committee for managing intellectual property will be established within JST, led by the PO. After examining the deployment scenario of the project's R&D results, a policy for managing intellectual property in this area will be established and appropriately operated., The committee will determine whether or not rights should be applied for patent prosecution and how the research results should be handled afterwards as necessary, while keeping in mind the open and close strategies of the research results. The R&D organizations will be requested by the committee to handle the intellectual properties based on the committee's decision. For example, in order to obtain a patent with strong exclusivity, the committee may request that additional experiments be conducted as necessary, or that publications or patent applications be withheld for a certain period of time.

The management system

- For smooth information sharing among the teams, meetings will be held with the participation of the PO, area advisors, research participants, and JST personnel. If necessary, participants from

outside of the R&D area can also attend to exchange opinions with industry.
The PO will flexibly review the team structure, direction of R&D, and elements of the project, without being bound by the form in which the R&D project started, based on an accurate understanding of the progress of the R&D project. In addition to stage-gate evaluation, the PO will evaluate and review the team structure, direction of R&D, and other related matters to R&D as necessary in each fiscal year, based on the nature of the research project.