POLICY RECOMMENDATIONS

An Inclusive Society that Embraces Regional Diversity:

The Future of a Decarbonized Society Built through a Skeleton-Infill Energy System

Kyushu University
Integrated Initiative for Designing Future Society, Think Tank Unit

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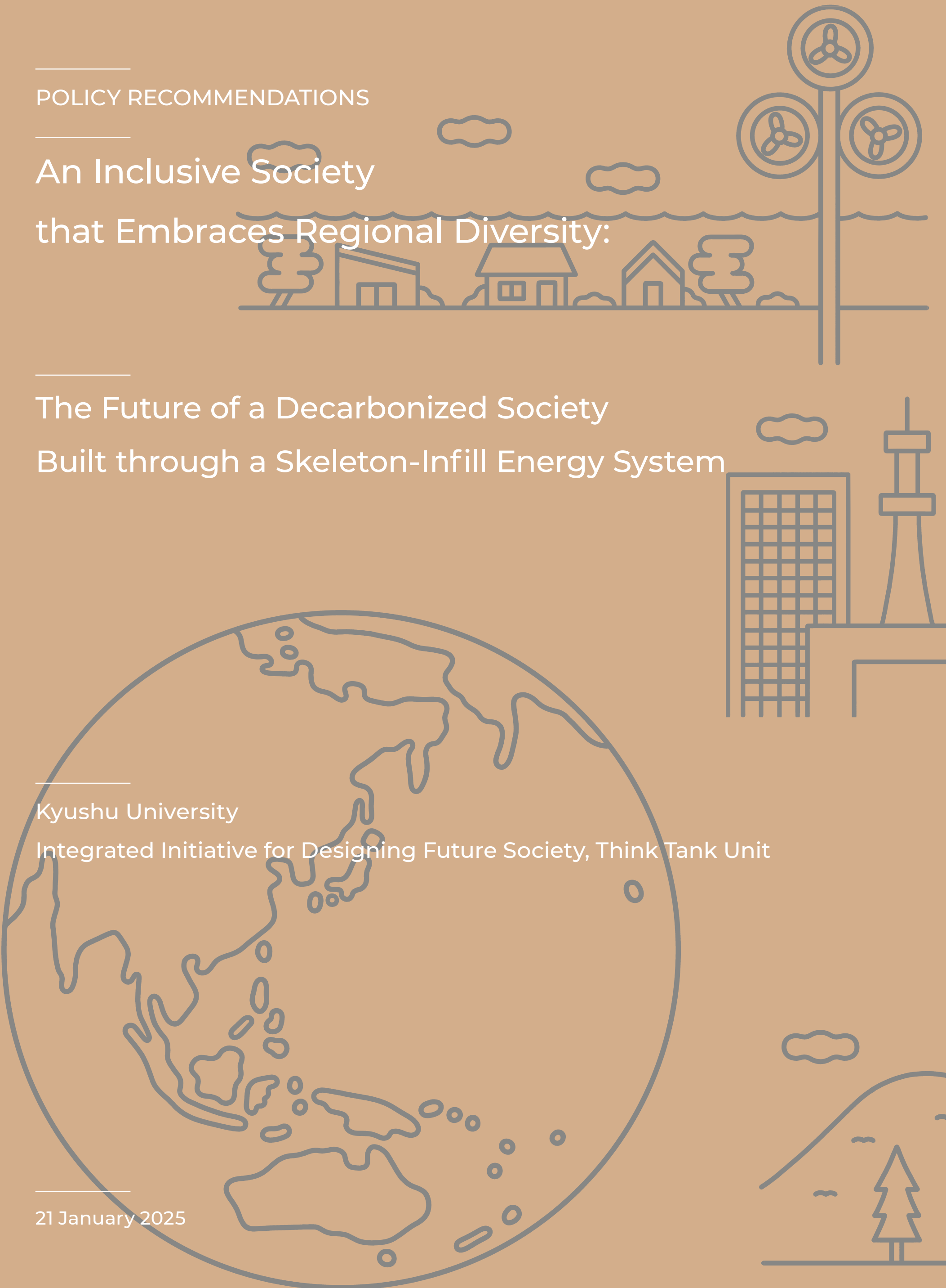

Note to the reader:
This English version has been prepared as a text-only companion to the original Japanese edition, which includes figures and illustrations.
Page references (➢ p.xx) correspond to the page numbers in the Japanese original.

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I. SUMMARY OF THE RECOMMENDATIONS

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Realizing truly sustainable local communities through a vision of future society that looks "beyond" decarbonization, and through the introduction of decarbonization technologies based on that vision.

In 2000, as the world stood on the threshold of the 21st century, a council of the Cabinet Office of Japan discussed what kind of society would be needed to realize “a prosperous and secure life,” and published its findings. The report identified several essential elements: respect for individual freedom and individuality (diversity), solidarity and cooperation within society (cooperation), economic stability for each person (economic well-being), and contact with rich nature and culture (environmental well-being). A quarter century has now passed since that discussion. We must once again discuss what a “flourishing society” means and clarify the vision of the future society we should aim to build.

For this purpose, Kyushu University established the Integrated Initiative for Designing Future Society (In2FS; hereafter "In2FS"). Based on broad discussion about the future shape of society, In2FS seeks to use Kyushu University’s advanced academic research to help realize a flourishing future for humanity. As part of this effort, these recommendations present a model for designing future society through the use of decarbonization technologies, developed jointly by researchers from the In2FS Think Tank Unit and the Decarbonization Unit.

These recommendations proceed in three steps. First, they focus on an “inclusive society that embraces regional diversity” as one possible image of a future “flourishing society,” at a time when inequality and social division have become major challenges. Second, they propose the “Cooperative Region” as a social model that can balance social diversity with cooperation, both of which are necessary to realize such a society. The Cooperative Region draws on the concept of cooperative housing, a form of collective housing in which diverse residents live together, and applies the skeleton-infill method as a framework for providing services that respond to diverse resident needs. Third, the recommendations present concrete Cooperative Region scenarios made possible by decarbonization technologies, offering one example of a future society that could be realized.

These recommendations are intended for the wider public. By proposing a pathway from vision to social implementation - a future social vision (an inclusive society), the framework for realizing it (the Cooperative Region and skeleton-infill model), and the methods and tools to support it (decarbonization technologies) - they aim to serve as a starting point for further discussion among regions, local governments, companies, universities, and other research institutions toward the realization of a flourishing society.

II. Toward a Desired Society: Vision and Guiding Principles

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Vision

1) An Inclusive Society that Embraces Regional Diversity: Envisioning a Desired Society

Thomas Piketty has argued that contemporary society is approaching its limits. The current society, built around capitalism, is at an impasse. “Free competition in the market,” driven by an almost violent form of financial capitalism, has widened economic inequality and poverty, while intolerance and division have spread around the world. Examples of division and intolerance are countless: political and social polarization in the United States; the Israel-Palestine conflict; refusals in Japan to admit homeless people to disaster shelters; the incident at Tsukui Yamayuri En; and remarks by members of the Diet describing LGBT people as “unproductive.”

In this situation, there is a growing need for a society that promotes broader human well-being, such as the “mature society” envisioned by D. Gabor. One alternative model is an inclusive society. An inclusive society is a people-centered concept of social development in which each person’s social value is recognized according to their abilities, and human dignity is accepted and respected. Such a society responds not only to the needs of minorities who have been excluded because of disability, poverty, discrimination, race, nationality, sexual orientation, or other factors. It also provides services that respond to the individual needs of all people, draws out each person’s potential to the fullest, and creates healthy growth and new values of “richness” and well-being.

In recent years, policy initiatives have also moved toward such an inclusive society. Many recommendations and policies have been proposed, including the Ministry of Health, Labour and Welfare’s initiatives for a “Dynamic Engagement of All Citizens” (2016), a “community-based inclusive society” (2017), and a “community-based inclusive society with connection and mutual support” (2023), as well as the Ministry of Land, Infrastructure, Transport and Tourism’s policies on the "Society of Mutual Assistance” (2014) and “community revitalization” (2019). In cultural policy in particular, terms such as “social inclusion” and “inclusive society” appear frequently. The Fourth Basic Policy on the Promotion of Culture and the Arts (2015) stated in its preamble the need “not only to pursue economic growth, but also to build a new social model suited to a mature society.” In addition, the 11th Lifelong Learning Subcommittee of the Central Council for Education (2022) stated that lifelong learning and social education are expected to play roles not only in their conventional areas, but also in realizing well-being and social inclusion, responding to a digital society, and building foundations for local communities. Globally, since 2015, the Sustainable Development Goals (SDGs) have promoted the slogan “leave no one behind,” encouraging the creation of inclusive societies.

Concept

2) Cooperative Region: A Regional Concept for Realizing the Society We Seek

To build an inclusive society, differences among members must be respected as much as possible, and cooperation is needed so that different interests can be considered. To think about what such a region should look like, these recommendations use the architectural concept of “cooperative housing” as an analogy. Cooperative housing is a form of collective housing in which several prospective residents become the project owners and jointly plan and build the building. Because residents create the building together, they deepen mutual understanding and form a community even before moving in, fostering both agency and a spirit of cooperation. Because the residents themselves are the project owners, each household’s circumstances and preferences can be reflected in the plan, enabling diverse needs to be met. Shared spaces and facilities can also be used efficiently. In this way, cooperative housing can accept the diversity of individual households while achieving cooperation and efficiency.

A “Cooperative Region” applies this idea from housing to the scale of a region as an approach to creating an inclusive society. The society realized through this approach stands in contrast to the compact city model, which seeks to concentrate residents in urban areas in order to improve public services. A Cooperative Region assumes distributed settlement patterns, where residents choose where to live according to their diverse ways of thinking and needs. Through a regional skeleton structure, described below, and through infill units that create goods and services, it provides necessary services to spatially dispersed districts and residents across the region.

The actual scale of a region may vary widely: a neighborhood unit, municipality, prefecture, country, or even an international region. In the real world, these units do not simply exist side by side; they are nested within one another and overlap in complex ways. As a model, however, these recommendations imagine a “region” roughly at the scale of a municipality.

Such a region consists of districts with diverse characteristics, such as rural settlements and urban neighborhood units. As with households in cooperative housing, each district becomes a co-designer in regional development and jointly plans, designs, and builds the region. Because districts are diverse, consensus-building may take time. However, through communication among members and a collaborative process of reaching conclusions through mutual compromise, understanding is created. This can lead to a highly inclusive society in which the needs of many people are incorporated into the social system.

Approach

3) Regional Development based on the Skeleton-Infill Model: A Conceptual Framework for Regional Design

In cooperative housing, the “skeleton-infill” approach is used as an architectural method for meeting the diverse needs of residents. Skeleton-infill refers to housing or collective housing designed and built by clearly separating the building’s structural frame (the skeleton) from its equipment, layout, and interior elements (the infill). In ordinary houses, the structure and equipment are usually integrated. By separating them, residents gain more freedom in designing interiors and equipment, making it easier to respond to individual needs. This approach also makes it easier to respond to changes in needs over time.

When this approach is applied to the Cooperative Region, general-purpose infrastructure forms the “skeleton,” while each local area selects and installs businesses, services, and facilities suited to its own circumstances and needs as the “infill.” In the long term, this also has the advantage of making it possible to respond to changing resident composition, changing needs, and new social demands by keeping the skeleton relatively fixed while updating the infill. Infrastructure built as such a regional skeleton must have three characteristics: (1) versatility, meaning that a single infrastructure can be used in various ways; (2) multi-functionality, meaning that it can serve several functions at once; and (3) adaptability, meaning that its functions can be updated as conditions change.

As explained in detail in the next chapter, such a “skeleton” could include infrastructure for transporting and distributing energy, goods, and services. One example is a distributed energy system using microgrids. Distributed energy systems have versatility, multi-functionality, and adaptability. As the regional skeleton, they support the development of diverse businesses, services, and facilities - the infill - in line with local needs. As a result, they can help realize a regionally inclusive society that respects diversity while allowing distributed settlement and sustainability to coexist.

III. The Future of a Decarbonized Society Built through a Skeleton-Infill Energy System

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Application

1) Distributed Energy Systems and Microgrids as the Foundation of Cooperative Regions

Distributed energy systems that use locally produced energy can be expected to strengthen resilience by spreading risks in energy supply and providing energy in emergencies. They can also save energy by producing and consuming energy locally. In addition, building distributed energy systems based on renewable energy is expected to create new local industries. If introduced together with regional development, such systems can help revitalize local areas.

Distributed energy systems can use renewable energy suited to local characteristics efficiently through microgrids. In this sense, they make it possible to combine diversity, cooperation, and sustainability in energy. They are highly compatible with a diverse and inclusive society and should therefore serve as the foundation of Cooperative Regions.

2) Skeleton-Infill Regional Infrastructure that Enables Cooperative Regions

Cooperative housing has many advantages. At the level of physical form, these advantages are supported by an architectural method called "skeleton-infill."

In cooperative housing, the skeleton, or structural frame, is separated from the infill, meaning equipment and interior elements, although these are integrated in ordinary housing. This allows interiors to be designed freely according to each household's needs, and it also makes interiors and equipment easier to replace. As a result, housing units can be created to match the diverse needs of each household, and renovations can be carried out more easily when family composition changes.

In a Cooperative Region as well, local communities can realize a society where diversity, cooperation, and sustainability coexist by first establishing infrastructure that can be used in many ways and easily updated over time, and then by allowing each local area to actively create and select the businesses, services, and facilities suited to its own circumstances and needs.

3) Three Essential Properties of Skeleton-Infill Regional Infrastructur

Skeleton-infill regional infrastructure needs three characteristics:

Versatility: it can be used in many different ways.

Multi-functionality: it can serve several functions at the same time.
Adaptability: its functions can be updated.

To realize a Cooperative Region where diverse local areas work together, distributed energy systems should serve as the regional skeleton with versatility, multi-functionality, and adaptability. Based on this skeleton, diverse businesses, services, and facilities should then be planned and developed as infill in line with local needs. This will allow decarbonization technologies to truly serve local communities and create new regional strengths in a natural and sustainable way.

Scenarios

4) Examples of Future Society Scenarios based on Regional Microgrids

As examples of future society scenarios based on regional microgrids, these recommendations present skeleton-infill regional infrastructure for a rural community.

In all three scenarios, each module that forms the microgrid - the power generation system, power-balancing unit, mobility system, and electricity storage and hydrogen conversion system - also plays a role different from its original module function. These modules then become platforms on which diverse services can be freely developed.

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(1) Autonomous mobility and community hubs as a platform for daily-life services

In distributed energy systems, using electric vehicles (EVs) and fuel-cell vehicles (FCVs) for energy storage is expected to benefit both grid operators and consumers. As part of the move toward decarbonization, public transport operators such as bus companies have also begun introducing EVs and FCVs.

At the same time, the number of bus drivers is declining, and fixed-route bus services are disappearing from areas with low demand. Autonomous buses are expected to help address driver shortages, and demonstration trials are being conducted in many locations.

Autonomous shared buses can be envisioned as a next-generation public transport system that also helps balance energy supply and demand within a distributed energy system. By making use of this system, diverse functions can be provided in line with local needs.

As the birthrate declines and the population ages, facilities that provide various daily-life services are increasingly being concentrated in urban areas. In areas with small populations, people must travel long distances for everyday purposes such as shopping and medical visits. This is inconvenient and increases dependence on private cars.

If next-generation public transport systems can not only carry people but also deliver various service functions to local areas, people in areas with small populations should be able to live in “walkable communities” without needing to travel long distances in daily life.

There are already many examples of mobility being used as service space, such as food trucks and mobile libraries. By incorporating multi-functional autonomous buses that can be used as diverse service spaces needed for local life, together with public spaces that can receive them, into public transport systems, service hubs for local residents can be created. These recommendations propose that governments and businesses work together to realize such hubs and implement them as platforms for daily-life services.

(2) Solar-sharing systems that also enhance local environmental conditions

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In Japan, where flat land is limited, solar sharing - installing solar power equipment over farmland - is expected to expand the introduction of renewable energy, and it has already been introduced in some areas. However, it does not always function well depending on the crops being grown. In some cases, crops are selected mainly for the purpose of securing income from power generation. For these reasons, solar sharing cannot yet be said to be spreading in a fully healthy way. On the other hand, some crops benefit from the shade created by the equipment, and in winter the equipment can help protect crops from frost. Solar sharing can therefore bring secondary benefits as well.

Solar panels have also been developed that transmit only the visible light needed for crop growth and generate electricity using other wavelengths of light. If the disadvantages of solar sharing are addressed and smart agriculture technologies that use renewable energy are implemented, solar-sharing systems can help improve agricultural productivity and create more comfortable working environments.

Solar sharing is a system in which solar panels are installed over farmland to control the amount of sunlight and share solar energy between agriculture and power generation. Smart technologies create optimal conditions for crop growth by adjusting temperature, humidity, CO_2 concentration, and other factors, and also automate work such as harvesting.

These ideas can be extended beyond farmland to create outdoor light and air environments where local people can spend time comfortably. If solar power technologies are developed that can freely change the wavelengths of light they transmit, they could create cool environments in summer and warm environments in winter. By applying smart technologies, the space under solar panels could be adjusted to comfortable temperature and humidity levels.

Self-driving robots used for harvesting could also be given an assistive mobility function, carrying luggage for people as they walk.

(3) Data centers as local information infrastructure and a data-driven food and health industry

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Distributed energy systems need functions that adjust electricity demand in order to operate microgrids stably. Data centers, which consume large amounts of electricity, are expected to serve as facilities that can provide this power-balancing function. Demand for data centers is rising worldwide, and Japan is also promoting the decentralization of data centers as a way to prepare for risks such as disasters. Attracting data centers as power-balancing units can therefore also benefit local communities.

If a region can do more than simply attract data centers - if it can also build systems to manage diverse local data, such as public administration, transport, medical care, and purchasing data, and use that data in many ways - data centers can become a foundation for creating new regional strengths.

In the field of medicine, research is advancing toward “data-driven precision medicine,” which uses various types of health-related data, including medical data, genomic data, and lifestyle data, to predict and prevent disease and to identify the most effective treatments.

In agriculture as well, research is progressing on “data-driven agriculture,” which uses data obtained from environmental monitoring devices, sensors, and related tools to improve productivity and profitability and to provide a stable supply of foods that match consumer needs.

By combining data centers as local information infrastructure with the results of this research, it is possible to envision a “data-driven food and health industry” that produces foods suited to individual preferences from ingredients optimized for each person’s health condition. Such foods could not only help protect the health of local residents, but also enrich the region by creating a new industry.

IV. Research Structure and Case Studies Toward the Realization of These Recommendations

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Kyushu University is conducting the following research on technologies needed to realize the regional concepts and future society scenarios proposed in these recommendations.

In the In2FS Decarbonization Unit, Kyushu University brings together research groups in areas such as materials and devices, systems, and urban living environments in order to realize the decarbonization of society by 2050. The unit is working with a view to the social implementation of decarbonization. In addition, the Kyushu University Platform of Inter-/Transdisciplinary Energy Research (Q-PIT) promotes inter-/transdisciplinary project research in which researchers with different specialties collaborate toward the decarbonization of energy. It serves as a foundation for research aimed at developing innovative technologies and creating a new energy society. To realize the proposals in these recommendations, it will be necessary to conduct further research on the issues and potential of partner municipalities, build scenarios suited to each region, and then promote social implementation and commercialization of the diverse research being developed by the above organizations and others.

<u>Recommendation item</u>
Distributed energy system
<u>Research area</u>
Energy generation and transmission
<u>Research topic [Group, Unit, or Laboratory]</u>
- Solar power generation and artificial photosynthesis through upconversion [Photochemical Technology Innovation Group]
- Fisheries-compatible small wind power generation using wind-lens turbines [Remapping a Sustainable Energy Future Group]
- Geothermal power generation [Remapping a Sustainable Energy Future Group]
- Small hydropower generation[Disaster Risk Reduction Research Center]
- DC microgrid system [Platform of Inter-/Transdisciplinary Energy Research]

<u>Research area</u>
Hydrogen production, storage, and transport
<u>Research topic [Group, Unit, or Laboratory]</u>
- Hydrogen production technology using water electrolysis [Reduction of Energy Consumption Through Hydrogen]
- Hydrogen storage, transport, and supply system [Reduction of Energy Consumption Through Hydrogen]

<u>Research area</u>
Urban and regional planning
<u>Research topic [Group, Unit, or Laboratory]</u>
- Design of self-reliant, circular-energy cities and regions [New Urban Models Group]

<u>Recommendation item</u>
Scenario 1: Autonomous mobility and community hubs as a platform for daily-life services
<u>Research area</u>
Autonomous public transportation
<u>Research topic [Group, Unit, or Laboratory]</u>
- Transportation planning and urban planning [Urban and Transportation Engineering Laboratory]
- Autonomous driving systems and control systems [Faculty of Information Science and Electrical Engineering, etc.]
- Mobility design [Think Tank Unit]

<u>Research area</u>
Service design and spatial design
<u>Research topic [Group, Unit, or Laboratory]</u>
- Operation management for service mobility [Research Institute for Information Technology]
- Service design [Think Tank Unit]
- Design of regional hubs [New Urban Models Group]

<u>Recommendation item</u>
Scenario 2: Solar-sharing systems that also enhance regional environmental control
<u>Research area</u>
Solar sharing
<u>Research topic [Group, Unit, or Laboratory]</u>
- Design of agrivoltaic solar power systems [Irrigation and Water Management Laboratory]
- Wavelength-selective solar power generation and artificial photosynthesis [Photochemical Technology Innovation Group]

<u>Research area</u>
Smart agriculture
<u>Research topic [Group, Unit, or Laboratory]</u>
- Development of environmental control systems [Carbon Capture and Conversion Group]
- Development of agricultural support robots [Agricultural Machinery and Production Systems Design Lab.]
- Smart farm management [Agricultural and Farm Management Lab.]

Research area

Environmental design

Research topic [Group, Unit, or Laboratory]

- Regional landscape formation / landscape design [Regional landscape formation / landscape design]
- Design of smart-enabled spaces [New Urban Models Group]

Recommendation item

Scenario 3: Data centers as regional information infrastructure and data-driven food and health industry

Research area

Creation of new industries

Research topic [Group, Unit, or Laboratory]

- Support for industry creation and development [Kyushu University OIP (Kyushu University Open Innovation Platform Co., Ltd.)]
- Development of an integrated LHS (learning health system) platform [Medicine and Health Unit]
- Development of genome-edited crops [Environment and Food Unit]
- Development of tailor-made foods [Laboratory of Food Chemical Biology]
- Food design [Think Tank Unit]
- Development of food processing technologies [Laboratory of Food Process Engineering]
- Food distribution and marketing [Laboratory of Post Harvest Science]

1) Research Structure 1: In2FS Decarbonization Unit

Proposing innovative technologies and social visions that can bring discontinuous innovation toward decarbonization

To achieve Japan's goal of decarbonizing society by 2050, it is not enough simply to extend or optimize existing research and technologies. We must create innovative technologies that make it possible to decarbonize society as a whole, and we must present the shape and design of the future society we should aim for. The Decarbonization Unit brings together research groups in fields such as materials and devices, systems, and urban living environments, and carries out work with a view to the social implementation of decarbonization. The unit aims to become a green innovation hub in cooperation with Fukuoka and the wider Kyushu region, where decarbonization efforts are advancing. It seeks to contribute to the creation of innovative technologies, policy recommendations such as regional growth strategies and models for a decarbonized society, and the development of highly skilled people who can drive innovation.

<Research groups in the Decarbonization Unit>

Reduction of Energy Consumption Through Hydrogen

- Research into Hydrogen Energy through Industry, Academia, Government and Local Community Cooperation
- Research into Hydrogen Industrial Use and Storage
- Joint Industry-Academia Research into Next-Generation Fuel Cells
- Hydrogen Energy Systems Education
- Carbon Energy Research
- Hydrogen Energy Materials Research

Carbon Capture and Conversion

- Research and Development of CO_2 Capture and Conversion from the Atmosphere Using Membranes
- Research and Development of CO_2 Conversion Using Recovered CO_2 and Renewable Resources
- Research and Development of the Capture and Utilization of CO_2 from Various Emissions Sources
- Research and Development of the Capture and Utilization of CO_2 in Greenhouse Horticulture and Agriculture
- Research and Development of the Biomethanation of Captured CO_2 Solutions and Geosequestered CO_2
- Research and Development of CO_2 Resource Conversion and the Manufacture of High-Value-Added Raw Materials Through Renewable Energy and DX

New Urban Models

- Design and Construct Zero Energy Buildings by Simulating the Built Environment Using Building Data Exchange Technology
- Develop and Implement the BeCAT Program to Integrate Urban and Built Environment Technology with Design
- Develop Optimal Control and Nudge Systems for Built Environments and Energy Using IoT/AI for the Era of Society 5.0
- Develop an Urban Energy Supply and Demand Simulator and Formulate a Future Energy Plan for Fukuoka
- Plan the Infrastructure of Future Cities and Conduct Regional Design to Achieve a Carbon-Neutral Society

Remapping a Sustainable Energy Future

- Research and Develop Offshore Wind Power Generation
- Research and Development of a Sustainability Value Assessment Model for Energy Technologies

- Research and Development of the Socioeconomic Evaluation of Energy Conversion
- Research and Development into Achieving Geothermal Goals under the Sixth Strategic Energy Plan
- Research and Development into Achieving Nuclear Power Generation Goals under the Sixth Strategic Energy Plan

Photochemical Technology Innovation
- Develop and Elucidate the Mechanism of CO_2 Photoreduction Catalysts that Function Harmoniously
- Research on Triplet Functional Chemistry
- Develop CO_2 Sensing and Conversion Technologies
- Create Organic Devices that Can be Manufactured at a Low Cost

Promoting Regional Collaboration
- Direct Current (DC) Microgrids
- Sustainability Assessment Model
- Implementation of University Technology
- Implementation Throughout the Region

2) Research Structure 2: Kyushu University Platform of Inter-/Transdisciplinary Energy Research (Q-PIT)

Inter-/transdisciplinary projects in which leading researchers collaborate toward energy decarbonization

The Kyushu University Platform of Inter-/Transdisciplinary Energy Research (Q-PIT) is a university-wide platform that promotes research and education related to energy. In research promotion, more than 200 researchers from diverse energy-related fields participate as cooperating faculty members. Q-PIT plans and promotes “module research,” an advanced form of inter-/transdisciplinary project-based research in which researchers with different specialties collaborate to create innovative decarbonization technologies and next-generation energy societies.

Examples of inter-/transdisciplinary project research (module research)

(1) Research on materials useful for energy decarbonization
- M1 Removal and utilization of CO_2 using artificial intelligence (AI)
- M2 Collaborative research integrating science and engineering toward the realization of artificial photosynthesis
- M3 Advanced plastic recycling research using the principle of microwave technology

(2) Research on energy systems that realize decarbonization
- M4 Capturing and using CO_2 emitted from agricultural greenhouses with advanced technologies
- M5 Producing clean hydrogen using unused underground coal and oil resources

(3) Research for building a sustainable energy society
- M6 Evaluating the impacts of introducing energy technologies into cities
- M7 Analyzing CO_2 emissions from automobiles and housing to support effective policy-making
- M8 Developing sustainability evaluation models for energy technologies

3) Case Study 1: In2FS Decarbonization Unit, Photochemical Technology Innovation Group

Energy up-conversion and artificial photosynthesis technologies made possible by flexible conversion of light energy

Photochemistry is the study of chemical changes caused by light energy. For example, in plant photosynthesis and solar power generation, sustainable energy from sunlight is converted into chemical energy or electrical energy, respectively. Such energy conversions are important in terms of the growth or daily life.

Technologies that flexibly convert light energy are advancing. A technology that dramatically improves the efficiency of organic light-emitting diodes (OLEDs), which has attracted worldwide attention, was invented at Kyushu University. Other technologies originating from Kyushu University are also being actively studied, including “artificial photosynthesis,” which can help solve the major social challenges of resource shortage and CO_2 reduction at the same time, and “photon up-conversion,” which converts low-energy light into high-energy light.

By making full use of Kyushu University’s strengths in light-related technologies, it becomes possible to flexibly convert light energy and generate energy without loss in the places where it is needed. This opens broad possibilities for realizing an ultimate energy-saving, high-efficiency future society.

4) Case Study 2: Kyushu University Platform of Inter-/Transdisciplinary Energy Research (Q-PIT), Energy System Cluster

Integrating smart greenhouses with advanced CO_2 capture and utilization technologies -Future agriculture that aims to achieve both higher productivity and sustainability-

Smart greenhouses are a form of agriculture that achieve significantly higher productivity compared with open-field farming by environmental control systems driven by plant and environmental data. Examples include heating at night to raise air temperature and supplying CO_2 during the day to promote plant photosynthesis.

However, CO_2 emissions associated with these environmental controls have been identified as an environmental issue. For agriculture looking toward a sustainable future, it is essential not only to improve productivity, but also to ensure sustainability through decarbonization.

To address this issue, interdisciplinary research is underway that uses Kyushu University's advanced CO_2 capture and storage technologies and integrates them with smart greenhouses. This research adopts two approaches.

The first approach is a technology that efficiently captures CO_2 emitted by nighttime heating using a new material, an amine-containing gel, and then reuses the captured CO_2 for daytime CO_2 enrichment. This technology aims to create a circular supply of CO_2, which is a key factor in improving productivity.

The second approach is a technology that uses polymer separation membranes to recover CO_2 that was applied during the daytime but remained in the greenhouse without being absorbed by the plants through photosynthesis. This technology makes it possible to capture CO_2 before it leaks outside the greenhouse, opening a new path to resolving the long-standing challenge of balancing greenhouse ventilation with CO_2 enrichment.

By accelerating research and development on these two approaches, Kyushu University aims to realize CO_2 zero-emission smart greenhouses that achieve both higher productivity and sustainability. This technology is an innovative proposal that can open the way to the future of sustainable agriculture.

5) Case Study 3: Open Science Platform

A data-driven life-care system that forms the foundation of a networked society and promotes well-being

Society is rapidly shifting toward network-driven capitalism, in which online information influences individual decision-making. In a network-driven society, competitiveness depends on how much data can be used and how effectively it can be connected to individuals. In future society, people's ultimate goal will be well-being, and industries that support well-being will become the largest market. From this perspective, the network that can most strongly influence individual decision-making and most effectively connect to industrial competitiveness is the medical, or life-care, network. At the same time, lifestyle-related diseases, cancer, dementia, allergies, autoimmune diseases, and other serious social problems are difficult to treat after onset. If medicine remains centered only on treatment after disease occurs, social security systems will become unsustainable. From now on, it will be essential to use networks to accurately understand information about each individual's body and shift medicine from treating disease to preventing disease.

In a society with a declining population, creating markets and securing the competitiveness needed to generate value continuously will require a strong healthcare network. It will also require linking that network with value creation processes and building a new social security network foundation that can support economic independence. Data analysis through networks can rapidly repeat the PDCA cycle - plan, do, check, and act. When people continuously send their own data to data centers, it becomes possible to provide rapid, evidence-based feedback in the form of advice and products that are effective only for each individual, helping maintain well-being. In addition, new value can be created on an evidence-based basis from various factors identified through this data analysis. By linking business to this process, it may even be possible to build an industrial foundation that can generate innovation quickly.

To make this possible, three foundations are needed. The first is an engagement network that uses identified data linked to individuals. The second is a large-scale analysis network that connects this data with large-scale anonymized real-world data on medicine and daily life. The third is a field for intervention demonstrations, where the value created from these networks and new business models that use it can be tested. In a future society, these three functions will be essential foundations. In addition, a cloud system under the community's own control will be an indispensable part of social infrastructure for operating them. A networked society based on medical networks should be able to rapidly transform people's lives, product distribution, and value creation processes. Kyushu University's Open Science Platform, in collaboration with the Medical Information Group of the In2FS Medicine and Health Unit and the doctoral fellowship program, is working to build these three foundations, create value through data analysis, and establish a demonstration site for the "Immune Village" concept in partnership with Itoshima City.

ABOUT THE INTEGRATED INITIATIVE FOR DESIGNING FUTURE SOCIETY (In2FS)

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In "Kyushu University VISION 2030," Kyushu University sets forth its goal of becoming "a university that drives social transformation with integrative knowledge." To realize this goal, the university has declared its commitment to solving social challenges and promoting DX (Digital Transformation).

As one of Japan's leading comprehensive universities, Kyushu University covers a wide range of academic fields, from the natural sciences to the humanities and social sciences. It also uniquely includes design - an academic field that designs and proposes new systems for society - through its Faculty of Design. Using this distinctive foundation of people, systems, and campuses that create new social value not found at other universities, Kyushu University established the Integrated Initiative for Designing Future Society (In2FS) in April 2022. Its goal is to generate integrative knowledge needed to solve social challenges and contribute to transformation toward a better society.

By bringing together knowledge across Kyushu University's diverse research domains, including the natural sciences, humanities and social sciences, and design, In2FS focuses on social challenges in decarbonization, medicine and health, and environment and food. It designs both the "ideal future society" needed to solve these challenges and the "process for reaching that future society." By combining Kyushu University's research outcomes and deploying and implementing them in society, In2FS aims to address increasingly diverse and complex social challenges.

In addition, based on the framework of Japan's Designated National University Corporation initiative, In2FS identifies social challenges, compiles measures that contribute to their solution, and will publish five or more items as policy recommendations during Kyushu University's fourth medium-term objectives period. These recommendations are the first in that series. Toward the realization of a decarbonized society, they design an ideal future society and propose a process design for solving social challenges through related research elements held by Kyushu University, sharing this vision with society.

For details on the Integrated Initiative for Designing Future Society (In2FS), please refer to the following URL:
https://in2fs.kyushu-u.ac.jp/

COLOPHON

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POLICY RECOMMENDATIONS

An Inclusive Society that Embraces Regional Diversity:
The Future of a Decarbonized Society Built through a Skeleton-Infill Energy System

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