I²CNER

INTERNATIONAL INSTITUTE FOR CARBON-NEUTRAL ENERGY RESEARCH

I²CNER

World Premier International Research Center Initiative

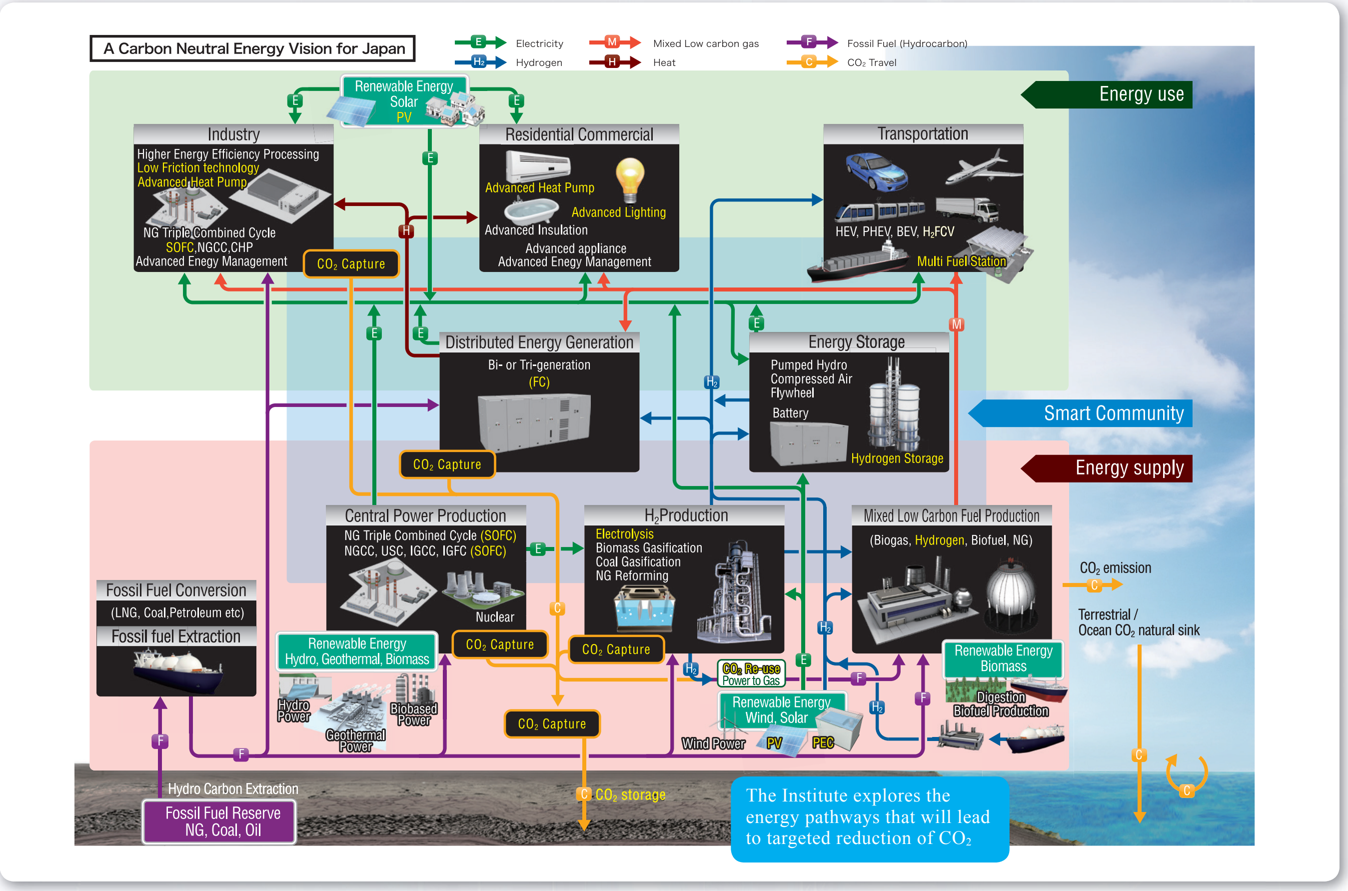
KYUSHU UNIVERSITY

ILLINOIS

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

About I²CNER

I²CNER's mission is to contribute to the advancement of low carbon emission and cost effective energy systems and improvement of energy efficiency. The array of technologies that I²CNER's research aims to enable includes Solid Oxide Fuel Cells, Polymer Membrane based fuel cells, biomimetic and other novel catalyst concepts, and production, storage, and utilization of hydrogen as a fuel. Our research also explores the underlying science of CO_2 capture and storage or the conversion of CO_2 to a useful product. Additionally, central to I²CNER's mission is the establishment of an international academic environment that fosters innovation through collaboration and interdisciplinary research (fusion).



Parameter Space of Technology Options

World Premier International Research Center Initiative (WPI)

World Premier International Research Center Initiative

Background

An intensifying global demand for talented researchers is accelerating the need among the world's nations to develop the best scientific minds. This trend has prompted Japan to establish new research centers that attract top-notch researchers from around the world so as to place itself within the "circle" of excellent human resources.

Program Summary

The World Premier International Research Center Initiative (WPI) provides concentrated support to establish and operate research centers that have at their core a group of top-level investigators. The objective of these centers is to create a research environment of a sufficiently high standard to give them a very visible presence within the global scientific community—that is, to create a vibrant environment that will provide a strong incentive to frontline researchers around the world to want to work at these centers.

The WPI program has four basic objectives: advancing leading-edge research, creating interdisciplinary domains, establishing international research environments, and reforming research organizations. To achieve these objectives, WPI research centers are required to tackle the following challenges:

Critical Mass of Outstanding Researchers
- Bringing together top-level researchers within a host research institution
- Inviting top-notch researchers from around the world

Attractive Research and Living Environment of Top International Standards
- Strong leadership by center director
- English as the primary language
- Rigorous system for evaluating research and system of merit-based compensation
- Strong support function
- Facilities and equipment appropriate to a top world-level research center
- Housing and support for daily living and education of dependent children

To assist the WPI research centers in carrying out this mandate, the Japanese government provides them with long-term, large-scale financial support.

Message from the Director

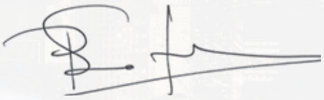
It is a tremendously exciting time to be a part of the efforts that are ongoing at I²CNER. Not only have many of our original basic research projects matured to a point where we are beginning to achieve technology transfer, but we are also in the process of beginning several new thrusts that are extremely relevant to both the I²CNER mission and the energy landscape of the world as a whole.

We have numerous new efforts on fusion of applied math with energy engineering. The Institute's burgeoning relationship with Kyushu University's Institute of Mathematics for Industry (IMI), our access to the best resources of both Kyushu University and the University of Illinois at Urbana-Champaign (UIUC), and our past experience with nurturing new cross-cutting research directions ensures that we are uniquely and ideally positioned to explore such a vital new area. There are a large number of energy pathways that I²CNER is currently addressing from both basic science and engineering perspectives, but the integration of these pathways into the energy infrastructure is a complex issue that will require analysis, compatibility, and optimization, amongst other things. These requirements make synergy with the applied math community an indispensable tool that I²CNER must begin to leverage. Toward this goal, we are currently working to establish the Institute for Applied Math for Energy (IAME) between Kyushu University and the University of Illinois at Urbana-Champaign.

Similarly, we are making a strategic and concerted effort to integrate more computational scientists into our faculty. The idea is to optimize our research efforts by leveraging synergism between computation and experiment to provide an accelerated and more targeted approach to scientific discovery and enhanced performance. We can achieve this by identifying and prioritizing (i) the computational efforts that will accelerate fundamental understanding and (ii) the experimental efforts required to validate and inform the computational/modeling efforts in I²CNER.

Finally, I²CNER has been asked to play a central role in Q-Pit, an umbrella organization within Kyushu University that brings together green-energy engineers with unexpected partners — mathematicians, political scientists, social scientists, and economists — to "solve the global challenges necessary to achieve a balance between emissions caused by humans and the removal of greenhouse gasses in the second half of this century."

As you can see, the Institute is prioritizing initiatives that will increase our forward momentum. We know that if we are to have a tangible impact upon the acceleration of achieving a carbon-neutral society, we must always consider which projects and directions will accelerate the well-to-wheel implementation of the carbon-neutral technologies that our basic research aims to enable.



Professor Petros Sofronis, Ph.D.
Director, International Institute for Carbon-Neutral Energy Research (I²CNER)

MOLECULAR PHOTOCONVERSION DEVICES

The objective of this division is to reduce carbon emissions through cost effective conversion of solar energy to electricity and hydrogen, energy conservation through organic based lighting devices, and development of new materials for surface molecular brushes for low friction technologies. The division's research projects include new organic materials to convert solar energy into electricity, novel inorganic, organic, and molecular photocatalysts to directly split water into oxygen and hydrogen, new concept molecules as organic light emitting diodes, and new molecules for low friction. The research efforts include unique techniques for the analysis of the interface structure of organic dye and inorganic semiconductors, synthesis of novel molecules for organic light emitters and photoelectrochemical and photovoltaic cells, device fabrication and testing, and theory-based materials development.

HYDROGEN MATERIALS COMPATIBILITY

The goal of this division is to provide the basic science that enables optimization of the cost, performance, and safety of pressurized hydrogen containment systems. In particular, the objectives include: development and use of advanced methods for experimentally characterizing the effects of hydrogen on the fatigue, fracture, and tribological properties of materials; development of models of hydrogen-affected fatigue, fracture, and tribo-interfaces; and development of next-generation monolithic and functionally graded materials having lower cost and improved performance (e.g., higher strength) while retaining resistance to hydrogen-induced degradation.

ELECTROCHEMICAL ENERGY CONVERSION

Electrochemical processes are at the heart of efficient conversion between electrical and chemical energies. The objective of this division is to conduct scientific research and technological development for energy-efficient, low-cost, and robust electrochemical energy conversion in systems including polymer electrolyte fuel cells (PEFC), solid oxide fuel cells (SOFC), and solid oxide electrolysis cells (SOEC). The PEFC is the preferred solution for automotive fuel cell applications. Inefficiencies at low temperatures (ca. 80˚C) are leading to a focus on higher temperature (>100˚C) hydrogen proton exchange membrane (PEM) fuel cells. Research addresses catalyst activity, support durability, and high temperature electrolyte identification and evaluation. SOFCs are utilized for stationary electricity generation at various scales. Research addresses developing a fundamental understanding of electrode and electrolyte materials and electrochemical events taking place in the SOFC, surface/interfacial catalytic processes on metal oxides, and electrode and electrolyte degradation. Electrolysis is used to produce hydrogen from electricity to respond to the forthcoming demand for hydrogen fuel. SOECs and related devices are examined from the perspective of activity and durability of electrolyte and electrode components. Other relevant energy storage concepts, e.g. batteries, are also addressed in division activities.

THERMAL SCIENCE AND ENGINEERING

The objective of this division is to enable the most effective use of materials in carbon-neutral energy technologies and to improve the energy efficiency of thermal processes by expanding our knowledge of material thermophysical properties and thermal science and engineering. More specifically, research in the division aims at: expanding our knowledge-base of the thermophysical properties of hydrogen and alternative refrigerants to enable their most efficient use to reduce CO_2 emissions; improving our understanding of the basic science of heat and mass transfer to enable the development of more efficient energy systems; and researching new thermal energy heat pump and refrigeration systems focused on the use of waste heat and new refrigerants for improved overall energy efficiency and reduced CO_2 emissions.

CATALYTIC MATERIALS TRANSFORMATIONS

The objective of the division is to contribute to the creation of innovative carbon-neutral technologies by developing novel catalysts underlining aspects of both basic science and engineering. The activities are focused on investigating catalysis-related bio-inspired systems for fuel and energy generation and sustainable power circulation systems using tailored inorganic nanocatalysts. Projects in the division address: i) the development of bio-mimetic catalysts for small molecule (e.g., H_2, N_2, CO_2, and H_2O) activation based on naturally occurring enzymes and, ii) production of clean fuels for carbon neutral power generation cycles using bio-derived energy-carrying materials.

CO_2 CAPTURE AND UTILIZATION

The objectives of this division are i) to develop highly efficient materials for CO_2 separation in power generation and industrial processes, and ii) to create energy efficient processes to convert CO_2 into value-added chemicals such as liquid fuels or their intermediates.

In the area of CO_2 separation, the goal is to develop novel membrane technology to separate CO_2 from other gasses in the processes of pre-combustion for Integrated Coal Gasification Combined Cycle (IGCC), post-combustion at power plants, and at natural gas wells. Whereas the CO_2 selectivity of currently available membrane technology is sufficiently high for practical application, these membranes are still plagued by low gas permeability. One approach to overcoming this challenge is thinning the membranes, which are currently on the order of a few microns thick. Thus, the material design and development of thinner membranes for selective gas separation are central research topics in the division.

In the area of electrochemical CO_2 conversion, the division seeks to identify and optimize suitable catalysts, electrodes, and associated operation conditions that allow for energy efficient, and ideally selective, electrolysis of CO_2 into value-added chemicals such as CO, methane, methanol, ethanol, and/or ethylene. Current emphasis is on lowering or eliminating the precious metal loading (typically Ag, Au) in these cathode catalysts, switching to a Cu-based catalyst for the production of multicarbon products (ethylene, ethanol), identifying the best electrolytes (pH, conductivity) for each catalyst, and optimizing the gas diffusion electrodes (durability, quality of catalyst layer, porosity for fast reactant and product transport).

CO_2 STORAGE

The overarching goals of the division include: the development of methods of reservoir characterization for pre-injection site selection and post-injection predictions of CO_2 fate; realization of new effective monitoring of injected/leaked CO_2 to help ensure safe and permanent CO_2 sequestration; and proposition and realization of innovative carbon storage concepts suitable for geological formations and rock types typical in Japan (i.e. a tectonically active area). To accomplish these goals, we are pursuing fundamental research to elucidate key pore-scale processes that drive effective residual, solubility, and mineral CO_2 trapping. We are also developing methods for up-scaling this understanding to inform reservoir-scale predictions.

ENERGY ANALYSIS

The Energy Analysis Division (EAD) plays several vital roles within I²CNER. The EAD tracks and analyzes current and future energy technologies, including those being researched in I²CNER, on the basis of CO_2 emissions, energy efficiency, and cost. It continuously reviews and revises the Institute's vision and roadmap toward a carbon-neutral society (CNS). These efforts help ensure that the I²CNER research efforts are relevant to future energy technology solutions for reducing CO_2 emissions significantly in Japan and globally. In close collaboration with the technical teams, the EAD generates scenarios utilizing the most promising new energy technology options which have the potential for a 70-80% reduction of CO_2 emissions from their 1990 level by 2050 in Japan. I²CNER's research efforts are intimately tied to these scenarios because the short-, mid-, and long-term milestones of each of our research project roadmaps are established in consideration of the development and deployment timing of the various promising technology options in the scenarios. These scenarios and the I²CNER division roadmaps, which are continuously evaluated and updated as I²CNER and global energy research progress, help ensure the relevance of I²CNER's research to a CNS.

In addition to these efforts, the EAD will be analyzing other key hurdles or opportunities to achieve a CNS in Japan. Such analyses could include the electricity infrastructure under operation with variable renewable-based power production and new energy storage technology; infrastructure deployment for the production and delivery of hydrogen for fuel cell vehicles and other potential hydrogen applications; and the import of renewable-based fuels.

INDUSTRIAL RESEARCH UNIT

As part of its efforts to pursue relationships with industry and government programs in order to identify mission-oriented basic science that supports technology implementation in industry, I²CNER established the Industrial Research Division, wherein industry liaisons are embedded in I²CNER to work exploratory research projects and technology transfer. Through this new unit, I²CNER will expand its outreach to promote the deployment of its technology to industries that will fund I²CNER projects.

RESEARCH CENTER FOR NEXT GENERATION REFRIGERANT PROPERTIES (NEXT-RP)

In this center, researchers from I²CNER's Thermal Science and Engineering Division play a central role in organizing national/international research institutes and conducting infrastructure research for accurate evaluation of thermophysical properties, fundamental performance of heat transfer, and ACR cycle for zero-ozone depletion potential (ODP) and low-global warming potential (GWP) refrigerants to contribute to future energy-saving technology for vehicles and houses in support of the continuous global development that will enable the low carbon society.

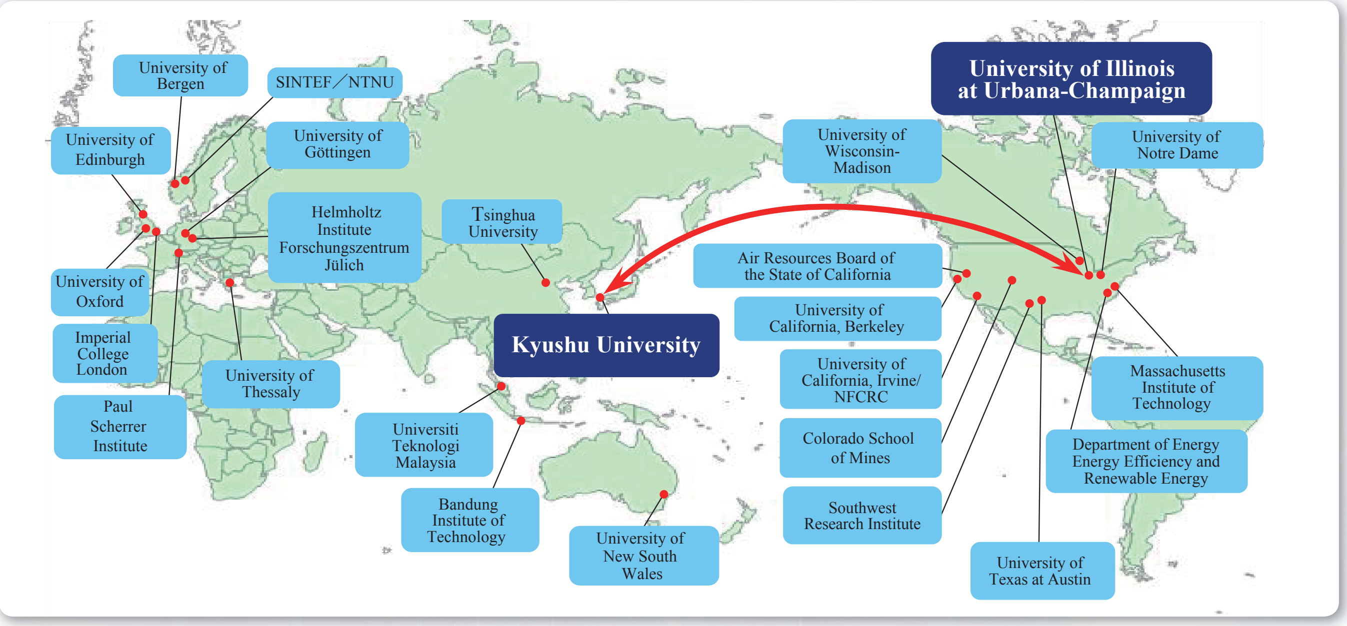
INITIATIVES ON APPLIED MATH FOR ENERGY

I²CNER has begun exploratory projects that are situated precisely at the intersection of applied math and engineering because we believe this area has enormous potential to impact all of the Institute's research areas and the general scientific community. In general, I²CNER's Applied Math initiatives are aimed at integrating the vast number of energy pathways into the energy infrastructure from various perspectives, such as analysis, compatibility, and optimization, among other things. Since we are interested in both basic science and engineering perspectives of energy pathways, we are also exploring new investigative techniques. The Institute currently has ongoing projects on modeling the smart electric grid based upon a thorough understanding of how energy generation, demand, and storage interact with the electric grid, especially in the residential energy sector, and using persistent homology to characterize the properties of porous materials, which is critically important for CO_2 storage in rock formations. Our foremost aim in these initiatives is to explore high-priority, high-reward areas that will inform the future research directions of I²CNER in the general area of applied math for energy.

I²CNER's Network of International Collaborations

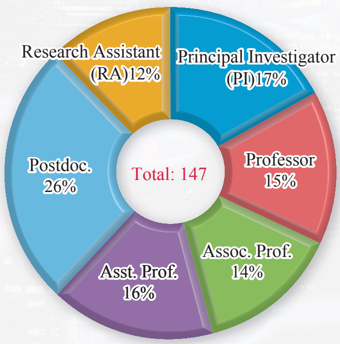
To carry out its mission, the Institute established collaborations with internationally recognized research centers, universities, and national and international laboratories. These collaborations involve and promote research interactions and researcher exchanges and visits between the institutions.

- University of Edinburgh (UK)
- Imperial College London (UK)
- University of Oxford (UK)
- University of Thessaly (Greece)
- Paul Scherrer Institute (Switzerland)
- University of Göttingen (Germany)
- Helmholtz Institute Forschungszentrum Jülich (Germany)
- NTNU (Norway)
- SINTEF (Norway)
- University of Bergen (Norway)
- Tsinghua University (China)
- Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia (Malaysia)
- Bandung Institute of Technology (Indonesia)
- University of New South Wales (Australia)
- Colorado School of Mines (USA)
- University of Wisconsin-Madison (USA)
- University of California, Berkeley (USA)
- University of California, Irvine／NFCRC (USA)
- Southwest Research Institute (USA)
- University of Texas at Austin (USA)
- University of Notre Dame (USA)
- Massachusetts Institute of Technology (USA)
- Air Resources Board of the State of California (CARB) (USA)
- Department of Energy (USA)

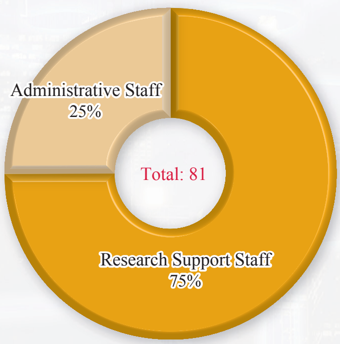


Personnel

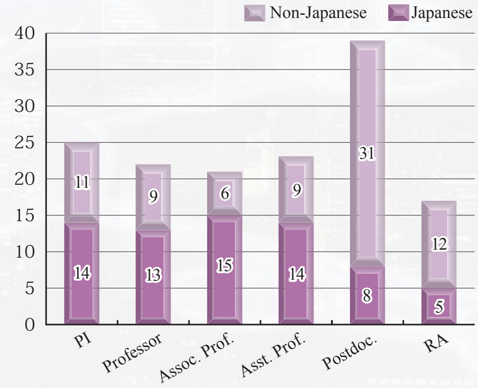
Researchers



Support Staff

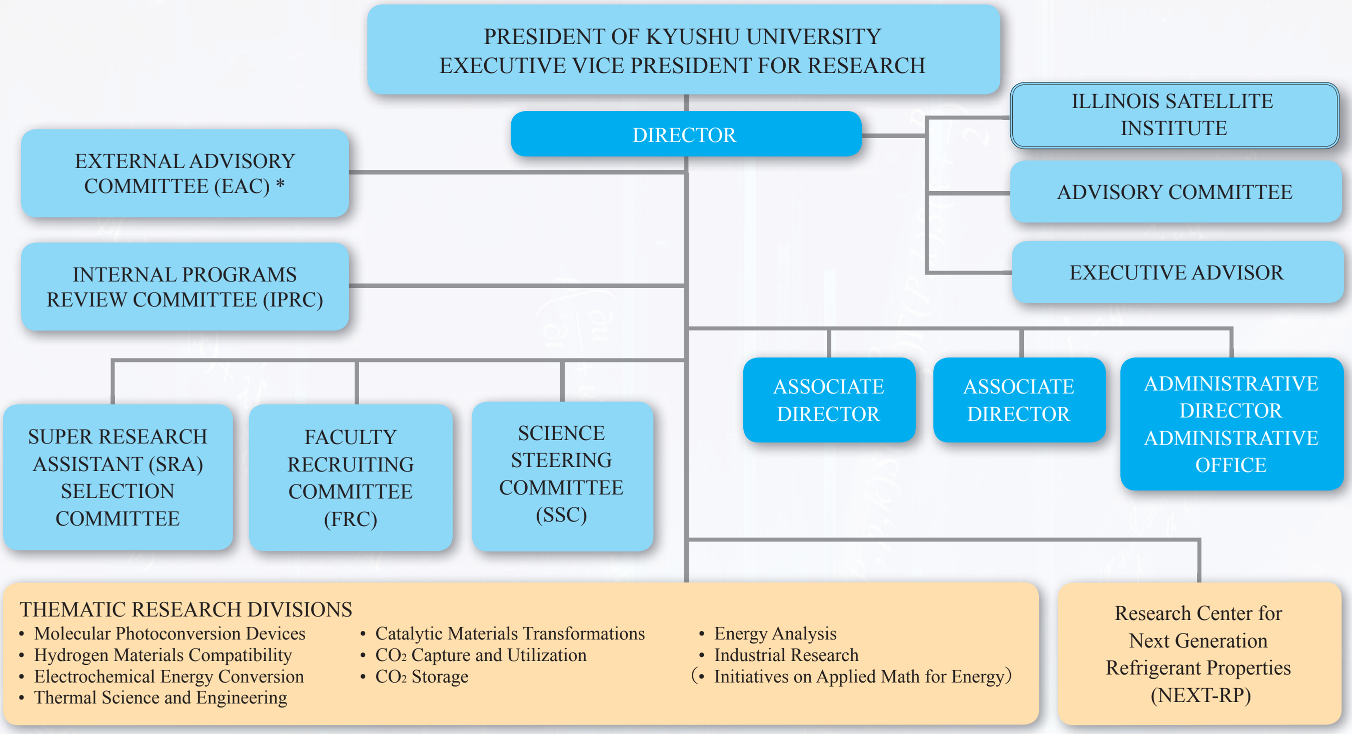


Japanese/Non-Japanese Researchers



(As of April 1, 2017)

I^{2}CNER Organizational Structure

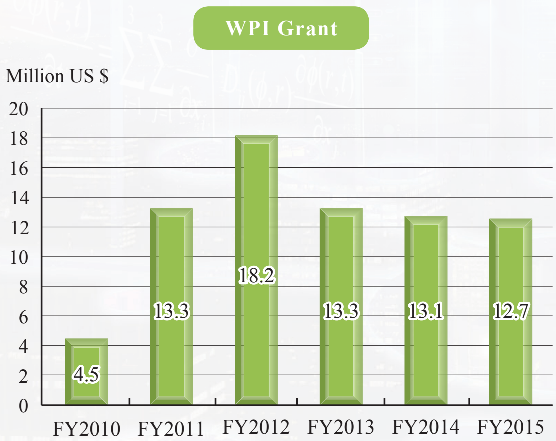


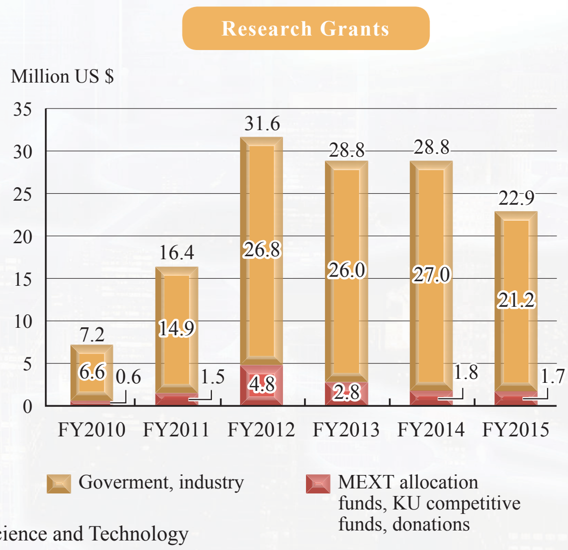
* External Advisory Committee (EAC)

The External Advisory Committee (EAC) makes recommendations on the current status of the Institute and its future directions. The EAC members are national and international leaders who are identified and selected by the Director.

- Dr. Deborah Myers (Chair), Argonne National Laboratory, USA
- Dr. Kevin Ott (Vice-Chair), Los Alamos National Laboratory, USA
- Prof. Ronald J. Adrian, Arizona State University, USA
- Dr. Robert J. Finley, Illinois State Geological Survey, USA
- Prof. Reiner Kirchheim, University of Göttingen, Germany
- Prof. Robert McMeeking, University of California, Santa Barbara, USA
- Prof. Tetsuo Shoji, Tohoku University, Japan
- Prof. Fraser Armstrong, University of Oxford, UK
- Prof. Michael Celia, Princeton University, USA
- Dr. Monterey Gardiner, BMW AG, Germany

Finances





1USD = 100JPY

* MEXT is an acronym for Ministry of Education, Culture, Sports, Science and Technology

** KU is an acronym for Kyushu University

The I^{2}CNER Buildings

Three years after its inception as the sixth WPI center, in January 2013, I^{2}CNER celebrated the inauguration of its first building, located at the center of the Ito Campus of Kyushu University. Since the start of the I^{2}CNER project, the number of researchers from all over the world has increased significantly, making it necessary to secure additional research space in order to maintain the high quality research environment indicative of a top-level research center.

For this reason, I^{2}CNER Building 2, which is 4 stories tall and has a total floor space of 5,000m^2, was completed in February 2015. Holding true to the I^{2}CNER mission and vision for creating a carbon-neutral society, I^{2}CNER Building 2 was designed around the concepts of sustainability, harmonization, and consciousness of environmental impact.

Left: I^{2}CNER Building 2, Right: I^{2}CNER Building 1

Access Map

From Fukuoka Airport to Kyudaigakkentoshi Station (35 min.)

Take a train on the Fukuoka City Subway Line bound for "Meinohama" or "Chikuzen-Maebaru/Karatsu/Nishi-Karatsu" at Fukuoka Airport Station.
For Meinohama: Change trains to the JR Chikuhi Line bound for "Chikuzen-Maebaru/Karatsu/Nishi-Karatsu" at Meinohama Station. Get off at Kyudaigakkentoshi Station.
For Chikuzen-Maebaru/Karatsu/Nishi-Karatsu: Get off at Kyudaigakkentoshi Station.

From Hakata Station to Kyudaigakkentoshi Station (30 min.)

Take a train on the Fukuoka City Subway Line bound for "Meinohama" or "Chikuzen-Maebaru/Karatsu/Nishi-Karatsu".
For Meinohama: Change trains to the JR Chikuhi Line bound for "Chikuzen-Maebaru/Karatsu/Nishi-Karatsu" at Meinohama Station. Get off at Kyudaigakkentoshi Station.
For Chikuzen-Maebaru/Karatsu/Nishi-Karatsu: Get off at Kyudaigakkentoshi Station.

From Tenjin Station to Kyudaigakkentoshi Station (25 min.)

Take a train on the Fukuoka City Subway Line bound for "Meinohama" or "Chikuzen-Maebaru/Karatsu/Nishi-Karatsu".
For Meinohama: Change trains to the JR Chikuhi Line bound for "Chikuzen-Maebaru/Karatsu/Nishi-Karatsu" at Meinohama Station. Get off at Kyudaigakkentoshi Station.
For Chikuzen-Maebaru/Karatsu/Nishi-Karatsu: Get off at Kyudaigakkentoshi Station.

From Kyudaigakkentoshi Station to Ito Campus (15 min.)

Take the Showa Bus going to Kyushu University's Ito Campus and get off at "Kyudai Big Orange-mae."

Contact us

International Institute for Carbon-Neutral Energy Research (I^{2}CNER), Kyushu University
744 Motooka, Nishi-ku, Fukuoka 819-0395 JAPAN
Phone: +81(0)92 802 6935
Fax: +81(0)92 802 6939
E-mail: wpisyogai@jimu.kyushu-u.ac.jp