World Premier International Research Center Initiative (WPI)
Activities Report of the WPI Academy Center
(FY 2020 – FY 2022)

Host Institution	Kyushu University	Host Institution Head	Tatsuro Ishibashi
Research Center	International Institute for Carbon-Neutral Energy Research (I^{2}CNER)		
Center Director	Tatsumi Ishihara	Administrative Director	Andrew Chapman

Common Instructions:
* Unless otherwise specified, prepare this report based on the current (31 March 2023) situation of your Center.
* Use yen (¥) when writing monetary amounts in the report. If an exchange rate is used to calculate the yen amount, give the rate.
* Prepare this report within 10 pages (excluding the appendices, and including "Summary of State of WPI Academy Center Progress" (within 2 pages)).

Summary of WPI Academy Center's Activities (write within **2 pages**)

As a member center of the WPI Academy, I^{2}CNER has matured into an asset for Kyushu University (KU) and Japan and the world's drive toward "carbon-neutrality" by including this very term in its name and its research project roadmaps and targets, 13 years ago. The institute's momentum and scientific impact continue to increase rapidly. Many metrics support this claim: the number of scientific discoveries and breakthroughs that are reducing identified roadblocks has increased dramatically as have the technology transfers to industries; the number of industrial partnerships has increased with a major one established recently with Mitsui Chemicals Inc., as have the number of international universities seeking partnerships with I^{2}CNER. I^{2}CNER is spearheading KU's globalization and decarbonization efforts within the framework of the "Kyushu University VISION 2030" and the high-impact transformational reforms driven by I^{2}CNER has positioned KU as a designated national university corporation in November 2021. I^{2}CNER is already making vital contributions toward a carbon-neutral society, and the institute's plan for the future is targeted to ensure Japan meets its energy needs while meeting carbon reduction goals by 2050. I^{2}CNER's vision is to contribute to the creation of a carbon-neutral society (CNS) through basic research underpinning technology that will address energy challenges for Japan and the world, and establish a model international academic environment. In executing this vision, I^{2}CNER aims to develop energy materials and systems leading to a deep reduction of greenhouse gas (GHG) emissions by 2050.

Advancing Research of the Highest Global Level

I^{2}CNER's research activities are conducted within its three technical Research Thrusts in partnership with energy analysis, ensuring continuous assessment of techno-economic relevance and research feasibility. Research is organized into projects, each having well-defined milestones on a roadmap toward a final target. A selection of the Institute's breakthrough results/achievements are presented in Appendix 1. A sample of these accomplishments is as follows: <u>Advanced Energy Materials Thrust</u>: Very little is known about the interaction of hydrogen with metals and alloys in high-temperature applications such as electrolysis. I^{2}CNER researchers demonstrated that hydrogen enhances the creep response of materials at 873^{o}K by reducing the activation energy for vacancy formation, enhancing the vacancy density and associated lattice diffusion coefficient, accelerating dislocation climb. Ammonia is a promising future hydrogen fuel and storage medium. I^{2}CNER researchers were the first to find through combined experiments and atomistic simulations that ammonia can act either to suppress or enhance embrittlement, depending on the loading rate and concentration. <u>Advanced Energy Conversion Systems Thrust</u>: Metal halide hybrid perovskites are attracting attention as a light absorber for solar cells because their certified solar power conversion efficiency has already surpassed 25%, comparable to silicon-based solar cell technology. We discovered that degradation of perovskite solar cells is hastened by unreacted PbI_2 crystals under continuous light illumination. In another international study, we discovered that illumination with above-bandgap light of solid-state ionic conductors can decrease grain boundary resistance. This new opto-ionic effect could pave the way for new electrochemical storage and conversion technologies operating at lower temperatures and/or higher efficiencies. <u>Multiscale Science and Engineering for Energy and the Environment Thrust</u>: We demonstrated targeted performance for membrane-based direct air capture (DAC) of CO_2 is achievable with competitive energy expenditure holding great promise for a circular CO_2 economy through a multi-stage separation process enabling preconcentration of atmospheric CO_2 to 40%. Applying robust statistical methods and energy economics thinking, we also found that environmental taxes stimulate technological innovation in high and middle-income countries.

Facilitating Interdisciplinary Research

The partnership with the Institute of Mathematics for Industry (IMI) continues to be productive and constitutes a solid base for fusing applied math with energy science and engineering. Another venue fostering interdisciplinary collaboration are the workshops organized by young scientists sponsored by I^{2}CNER. The partnership with the Illinois satellite is also an important mechanism for the advancement of interdisciplinary research, whereby I^{2}CNER researchers visiting the University of Illinois are engaged in interactions with colleagues in departments including Mathematics, Nuclear, and Electrical Engineering. The disparate nature of the disciplines involved in the I^{2}CNER research fields facilitates interdisciplinary work through collaborations across Thrusts and KU Department boundaries. Examples are the work of IMI Prof. Fukumoto and PI Staykov who explored the optimum design of photo-resisting polymers via AI-Based Machine Learning (ML) algorithm using organic chemistry and graph theory. Under the leadership of PI Staykov, IMI faculty and I^{2}CNER PIs organized a workshop and follow up symposium with academia and industry researchers to discuss intersectional problems of materials physics and information technology.

International Research Environment and Brain Circulation

The environment at I^{2}CNER provides a rich platform to pursue transformative research in non-traditional and highly multi-disciplinary environments, bringing together researchers from domestic and international settings to address issues critical to Japan's transition to a carbon neutral society. Since our induction into the WPI Academy, our researchers produced 329 joint publications with institutions around the world and 20 internationally recognized researchers visited I^{2}CNER for scientific interaction and exchange. The Institute's researchers are globally engaged and have been responsible for organizing, co-organizing, or serving on the scientific committees of 16 international conferences, 30 international conference sessions/symposia or workshops, and 16 I^{2}CNER international workshops. Even during COVID-19, the I^{2}CNER Seminar Series has been held virtually as I^{2}CNER Webinar and attracted speakers and participants from Japan and the rest of the world. We hosted 61 virtual seminars with 1422 participants in FY2022. In the past 3 fiscal years, our brain circulation has included 20 researchers transitioning to world class institutes such as University of Tokyo, Waseda University, Hiroshima University, Kyoto Institute of Technology, Nanyang Technological University, RWTH Aachen University, University of Cambridge, Lurea University in Sweden, Bandung Institute of Technology and University of Dhaka in Bangladesh. I^{2}CNER continues to mentor top-notch scientists who contribute to advancing energy solutions around the world.

Securing the Center's Future Development over the Mid- to Long-term

Under the leadership of PI Ishihara, we launched a new industry-university collaboration in the form of the Mitsui Chemicals, Inc. Carbon Neutral Research Center (MCI-CNRC) in November 2021. The new center is an exciting opportunity that leverages I^{2}CNER's world-class research in production and use of green hydrogen, CO_2 separation and recovery, CO_2 conversion and fixation, and advanced analysis and evaluation alongside Mitsui Chemicals' industry expertise with the goal of incorporating into society the technologies necessary to achieve carbon neutrality. As of March 2023, 9 postdocs have been hired in MCI-CNRC. Under the 'Moonshot for Beyond Zero-Emission Society' R&D Program (MOZES), the multimillion-dollar KU Research Center for Negative Emissions Technologies (K-NETs) launched in April 2021 under the leadership of PI Fujikawa is at the forefront of Japan's decarbonization efforts through engineering innovation underlying the disrupting technology of Direct Air Capture (DAC) of CO_2. It is based on a coordinated effort between KU, Kumamoto University, Kagoshima University, Osaka Institute of Technology, and the University of Illinois Urbana-Champaign (UIUC). Under the leadership of PI Matsumoto, the Center for Energy Systems Design (CESD) was launched in November 2022 through Gaisan-Yokyu and will allow I^{2}CNER to hire 3 associate professors, 3 assistant professors, 6 postdocs, and establish partnerships with 6 institutes: Hokkaido University, Tohoku University, Tokyo Institute of Technology, NIMS, RIKEN, and Kumamoto University.

I^{2}CNER's partnership with UIUC continues its strategic activities. Continued funding from both universities has led to opportunities extending beyond I^{2}CNER: data science and mathematics; environmental economics; humanities; library science and data management; sustainable energy; architecture, and diversity, equity and inclusion (DEI) in an effort to promote inclusivity. These new initiatives, conceived and advanced by leaders of KU and UIUC are examples of brain circulation and the ripple effects of I^{2}CNER.

To summarize, in our third year as a WPI Academy Center and on the other side of that transition, I^{2}CNER has matured into a member center, maintaining our postdoctoral numbers at healthy levels and looking to a productive future that will involve transferring our laboratory results to society. We will advance solutions that are environmentally friendly and continue renewing our PI composition in a way that fosters a diversity of perspectives and scientific approaches—that is, through fusion.

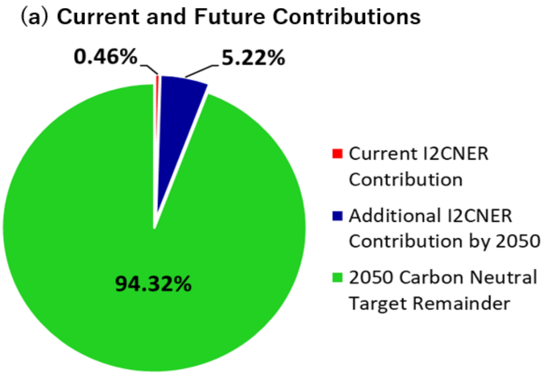
1. Overall Image of Your Center

・Describe the Center's current identity and overall image.
・List the Principal Investigators in Appendix 2, diagram the Center's management system in Appendix 3-1, enter the number of center personnel in Appendix 3-1a, and enter center funding in Appendix 3-2.

* Describe clearly and concisely the progress being made by the Center from the viewpoints below.

- In addressing the below-listed 1-8 viewpoints, place emphasis on the following:
  (1) Whether research standards and operation of the Center is maintaining a "world premier" status.
  (2) Whether the Center participate and cooperate to the activities to advance the overall development of the WPI Program and to promulgate its achievements.

I²CNER's vision is to contribute to the creation of a carbon-neutral society through basic research underpinning technology that will address the energy challenge for Japan and the world, and establish a model international academic environment for the 21st century. In executing this vision, I²CNER aims to develop energy materials and systems which, when deployed, lead to a reduction of greenhouse gas (GHG) emissions (90-100% by 2050). This reduction goal is in line with the "net zero" declaration of the government of Japan in October 2020. As a whole, we consider 3E+S (Energy security, Economic efficiency, Environmental protection, and Safety) as basic viewpoints toward this vision.



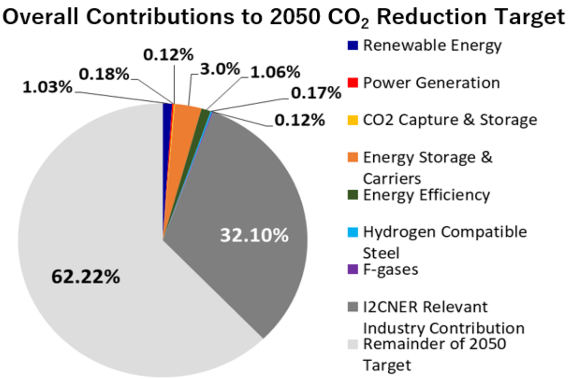


Figure 1. I²CNER's current and future contributions toward the achievement of national GHG emission reductions, cognizant of our scenario and the likely transition pathway of Japan.

In drawing our vision, we consider four major principles: 1) efficiency increase ("EI") in energy conversion and energy use, pursued in energy transformation systems, end use systems including home appliances, and industrial processes, 2) lowering of carbon intensity ("LCI") of fuel and electricity to adopt and develop future technologies. Decarbonization of electricity and fuel supply-use pathways is achieved using renewables and carbon capture and storage (CCS) for industrial sources, 3) significant introduction of hydrogen energy in power generation, manufacturing, and storage, and 4) negative emission ("NE") technologies to realize "removal" must be employed to cancel out the residual GHG emissions in our new vision in accordance with the "net zero" declaration. "NE" is achieved by capturing CO_2 directly from the atmosphere and storing it underground (via DACCS) or capturing CO_2 from the flue gas of combusting biomass and storing it underground (i.e. BECCS).

Based on these principles, we built a technology **decarbonization scenario** that guides the development and structure of our **research projects** within the institute's three **research thrusts**. I²CNER's **research efforts** are intimately tied to this scenario <u>because the short-, mid-, and long-term milestones of each of our **research project roadmaps** were established in consideration of the removal of the roadblocks in the development and deployment timing of the various promising technology options within scenarios</u>. Our roadmaps are continuously updated through a close collaboration between technical research clusters and the Energy Analysis Team; the last update was completed in January 2022. The updating of I²CNER roadmaps and research portfolio is also informed by the Institute's scientific exchanges with a stellar list of distinguished scientists from 25 partnering institutions across the globe.

In line with our decarbonization scenario and based on our analysis of current and future achievements, approximately 0.46% of the total required CO_2 reductions via current achievements, and approximately 5.22% of the total required reductions through our future achievements can be realized by I²CNER technologies and innovations if they are applied to appropriate energy systems in (limiting the contribution of any one technology to 50% of the resultant market (see Fig. 1a)). In addition to I²CNER's direct contributions, development and implementation of technologies that are relevant to I²CNER's technology efforts by other agencies will account for a further 32.1% of the 2050 "carbon-neutral" target (dark grey in Fig. 1b), demonstrating that I²CNER's research efforts underpin impactful energy technologies.

The relevance of the I^2CNER research efforts and objectives to enabling the 2010 Green Innovation Program of the Government of Japan is demonstrated by the large number (203; 81 since induction into the WPI Academy) of collaborative projects in which researchers have been involved with industry.

Evidence of I^2CNER's international stature and relevance can be also seen in its 3,843 publications (1,027 since induction) with 21,054 citations and an h-index of 131, on par or better than that of peer institutes. Our researchers have joint publications with researchers from 1,053 (329 since induction) institutions around the world, and 443 (20 since induction) internationally recognized researchers visited I^2CNER for scientific interaction and exchange. The Institute's researchers are globally engaged and have been responsible for organizing, co-organizing, or serving on the scientific committees of 240 (16 since induction) international conferences, 349 (30 since induction) international conference sessions/symposia or workshops, and 93 (16 since induction) I^2CNER international workshops. In addition, I^2CNER researchers have received a total of 380 (43 since induction) national and international awards from professional societies and institutions.

I^2CNER provides a rich environment for young researchers to pursue transformative research in a non-traditional and highly multi-disciplinary, international setting. Of the 113 (26 since induction) young researchers, 58 (20 since induction) went on to take faculty and postdoc positions at universities in Japan (excluding KU) and the world and 18 (6 since induction) moved to industry positions. In summary, I^2CNER contributes a lot on global brain circulation and be hub of research and cultivation of human resources in a field of green technology.

2. Advancing Research of the Highest Global Level

・Describe what's been accomplished in the Center's research objectives and plans.
・In Appendix 1, list the papers underscoring those research achievement and list the Center's research papers published in 2020-2022 in a manner prescribed in Appendix A.

Despite reduced in-person communications due to the Pandemic over the last three years, I^2CNER continued along its trajectory of high productivity (383, 381, 346, and 272 publications in FY2019, 20, 21, and 22 respectively.) In a significant move, we also updated the Institute's Carbon Neutral Vision and Roadmap, which was based on setting a carbon neutrality target of a 90-100% reduction of GHG emissions by 2050, and for which we considered the four major principles espoused above. I^2CNER's research activities are carried in collaboration with the Energy Analysis Team to continuously assess techno-economic relevance and feasibility. Within the Thrusts, research is organized in projects, with each project having well defined milestones on a roadmap toward a final target. According to I^2CNER's energy scenario, the I^2CNER mission will be realized when all project targets across the three Thrusts are achieved. Toward this goal, within each project, research efforts by individual researchers are targeting the corresponding milestones. In the following, some of our best accomplishments are presented in relation to the advancement of the institute toward its roadmap milestones and targets shown in Appendix 1.

Advanced Energy Materials Thrust: Very little is known about the interaction of hydrogen with metals and alloys in high-temperature applications such as fuel and electrolysis cells. In this pioneering work, I^2CNER researchers demonstrated that hydrogen enhances the creep response of materials at 873K by reducing the activation energy for vacancy formation, thereby enhancing the vacancy density and associated lattice diffusion coefficient, which in turn accelerates dislocation climb [3].

Working on development of low-cost hydrogen compatible steels, we found that addition of nitrogen and grain refinement by a process developed by PI Tsuchiyama increases the hydrogen compatibility and strength of low-Ni austenitic stainless steels. On the other hand, conversion of CO_2 to useful compounds are also strongly required and photocatalytic conversion is promising from realistic application. high activity of high entropy oxide after high pressure torsion is successfully demonstrated [5].

Advanced Energy Conversion Systems Thrust: i) Metal halide hybrid perovskites are attracting attention as a light absorber of solar cells because their highest certified conversion efficiency has surpassed 25%, comparable to silicon-based solar cell technology. However, the commercialization of perovskite solar cells is currently limited by the performance degradation under illumination, in air, or at high temperature. We discovered that degradation of perovskite solar cells is hastened by unreacted PbI_2 crystals under continuous light illumination. Unreacted PbI_2 undergoes photodecomposition under illumination, resulting in the formation of lead and iodine in films [7].

ii) Hybrid perovskite films can show efficient light emission. I^2CNER-led team of researchers used light-emitting perovskite films for LED applications. Managing the excited states generated in light-emitting perovskite films markedly improved electron-to-photon conversion in LEDs. [8].

iii) Perovskite oxynitride semiconductors have recently attracted significant attention, as promising photoelectrode materials for photoelectrochemical (PEC) water splitting. Through a combination of high-

sensitive low-energy ion scattering (LEIS) and X-ray photoelectron spectroscopy (XPS), we developed insights into the surface characteristics and evolution of LaTiOxNy (LTON) and CaNbOxNy (CNON) oxynitride thin films as photoelectrodes for PEC applications [9]
iv) We discovered that illumination with above-bandgap light can decrease the grain boundary resistance in solid ionic conductors. This new opto-ionic effect could pave the way for the development of new electrochemical storage and conversion technologies operating at lower temperatures and/or higher efficiencies [13]
Multiscale Science and Engineering for Energy and the Environment Thrust: i) Based on process simulation, we showed that targeted performance for membrane based direct air capture (DAC) of CO_2 is achievable with competitive energy expenditure relative to other sorbent-based systems. It is shown that application of a multi-stage separation process can enable the preconcentration of atmospheric CO_2 to 40%. This possibility and combination of the membranes with advanced CO_2 conversion may lead to realistic means for opening a circular CO_2 economy [14].
ii) By linking spatiotemporal variations in seismic velocity with pore fluid pressure, we found that our seismic monitoring system is useful in evaluating earthquake triggering processes. In addition, we succeeded in developing a method to distinguish CO_2 injection-induced earthquakes from natural earthquakes [15].
v) Fusing energy analysis and energy economics thinking, we applied robust statistical methods to identify potential positive linkage between environmental taxes and innovation, especially in developed economies. We found that environmental taxes stimulate technological innovation; for example, a 1% increase in environmental taxes was found to increase environment-related technological innovation by 0.57 and 0.78% on average for high and middle-income countries [18].

3. Facilitating Interdisciplinary Research Activities

・Describe the content of measures taken by the Center to facilitate interdisciplinary research activities. For example, measures that create an environment that will facilitate doing joint research by researchers in differing fields.
・Describe the contents and results of interdisciplinary research activities yielded by the measures described above.

Since its inception, the Institute Interest Seminar Series (IISS) has been an important I²CNER event aiming at initiating cross-discipline collaborations. The series has been active throughout the Pandemic and in FY20-22 a total of 65 speakers presented in 61 virtual seminars with a total of 1,422 participants. The partnership with IMI continues to be productive and constitutes a solid base for fusing applied math with energy science and engineering. By way of example, the work of IMI Prof. Fukumoto and PI Staykov explored the optimum design of photo-resisting polymers through an in-house developed Machine Learning (ML) algorithm using organic chemistry and graph theory. Another example of IMI/I²CNER interaction is the joint research between PI Tsuji and IMI Prof. Shirai on the use of persistent homology and ML for the prediction of hydraulic and elastic properties of rock for the purpose of carbon capture and storage (CCS). Another venue that fosters interdisciplinary collaboration is the workshops organized by young scientists (see p. 22 of I²CNER Progress Report for final evaluation) and sponsored by I²CNER. Prof. Cesana and Fukumoto from IMI and PIs Fujikawa, Staykov, and Sofronis invited scientists and researchers from academia and industry to discuss problems at the intersection of materials physics and information technology in a symposium titled "Perspectives on AI and ML in Materials Science," Feb. 4-6, 2022. At this symposium there were 11 student presentations in addition to the 12 invited speakers. A follow up symposium is planned in the 10th International Congress on Industrial and Applied Mathematics (ICIAM 2023) in Tokyo. The partnership with the Illinois satellite is also an important mechanism for the advancement of interdisciplinary research whereby I²CNER researchers visiting the UIUC satellite are engaged in interactions with colleagues in various departments such as Mathematics, Nuclear and Electrical Engineering. In this regard, the broader strategic partnership between UIUC and KU in the areas of Data Science, environmental economics, humanities, library sciences and data management and curation, and sustainable energy also provides an enabling environment for new cross-discipline engagements. Lastly, the importance of interdisciplinary research is emphasized consistently in the communications of the Director with all I²CNER members. In addition, all I²CNER faculty know that interdisciplinary research is a requirement for promotion and tenure within the Institute, a fact that is clearly stated in the Institute's governing document on Faculty Promotion.
A sample of contents and results of interdisciplinary research activities are as follows: Using the apparatus of **persistent homology** the group of PI Tsuji and Prof. Shirai calculated the elastic moduli and CO2 relative permeability of digital rock samples through a Grant-in-Aid program for challenging exploratory research (Suzuki, et al. Scientific Reports 11, 17948, 2021).(*2021 A.28) In the area of **mathematics for energy,** PI Ishihara and Prof. Nguyen investigated the concept of a decentralized peer-to-peer energy

trading system that minimizes the electricity cost for prosumers (producers and consumers) through convexified optimization of electricity and gas networks (International Journal of Electrical Power and Energy Systems, 125, 106522, 2021) (*2021 A.233) PIs Chapman and Tsuji in a joint work (Sustainability, 12, 8232, 2020) (*2020 A.347) investigated the **COVID-19 impact on the future of CO_2 management** through an analysis of the CO_2 emissions reduction due to reduced energy usage and concluded that international cooperation is of critical importance if we are to continue on the path of CO_2 emissions reduction as seen in the Pandemic. A similar study by PI Chapman in collaboration with the University of Queensland reports on lessons learned from the COVID-19 impact on energy use, electricity demand and CO_2 emission reductions (Sustainability, 13, 10836, 2021) (*2021 A.66). PIs Chapman and Stubbins working with Illinois Satellite faculty identified **cultural impacts upon energy affordability, energy policy issues, and energy system factors**. The results (Energy Research and Social Science 80, 102231, 2021) (*2021 A.68) directly address the demographic energy impacts toward energy system design and the importance of education in society. In an elegant study of **combustion for power generation**, Prof. Matalon (Illinois) and Prof. Matsue (I^{2}CNER and IMI) fused mathematics and combustion science to provide the first comprehensive description of flame propagation and morphology for a broad class of mixtures including prospective gas mixtures such as hydrogen and ammonia (Combustion Theory and Modelling, 2023).

[Notes]The number marked with * is the same as the number in Attachment A.

4. Maintaining an International Research Environment

・Describe what's been accomplished in the efforts to raise the Center's recognition as a genuine globally visible research institute, along with innovative efforts proactively being taken, including the following points, for example:
- Efforts being developed to maintain an international research environment based on the analysis of number and state of world-leading, frontline researchers; exchanges with overseas entities
- Proactive efforts to raise the level of the Center's international recognition
- Efforts to make the Center into one that attracts excellent researchers from around the world (such as creating of an environment in which researchers can concentrate on their research, providing startup research funding, supporting efforts that will foster young researchers and contribute to advancing their career paths, and arranging support system for the research activities of overseas researchers.)
- Consolidation of the administrative structures to support implementing the efforts described above

・In Appendix 3-1, describe the state of cooperation with overseas satellites, and list the main international research meetings held by the Center.

The I^{2}CNER Administrative Office, in close communication with KU headquarters, offers support to overseas researchers who are planning to visit I^{2}CNER, including visa application processing, accommodations with easy access to KU, and arrangements for all travel procedure for foreign PIs and distinguished international researchers. To help overseas researchers adapt smoothly into the new culture and research environment, the Administrative Office i) offers additional training and workshop opportunities, ii) introduced an English version of various application forms, guidelines, and university regulations, and iii) introduced an English version of the Web Safety Training Module, which all new I^{2}CNER researcher are required to complete prior to conducting experiments in the laboratory. Additionally, the Administrative Office provides extensive living assistance with medical checkups and introduction to the Japanese social insurance system. Lastly, with use of WPI Academy funds, I^{2}CNER has hired staff members who have been assigned to administrative duties involving use of English in general affairs, human resources, and liaison affairs.

The administrative Offices of Q-PIT and I^{2}CNER were merged to consolidate operations into three groups under the leadership of the Director and Assistant Director of the Support Office: the General Affairs/Human Resources, the Accounting/Contracts Group, and the Research Support/PR group. The merger increased the number of staff members that the I^{2}CNER budget could support and most importantly the office personnel budget is part of KU's central budget. Moreover, the centralization of energy-related operations in KU has enabled not only the sharing of resources and processes, e.g. grant proposal applications, but also of information such as funding opportunity announcements.

In order to create opportunities for hiring postdoctoral researchers, I^{2}CNER introduced the Postdoc Employment Opportunity (PEO) initiative on June 5, 2020. I^{2}CNER faculty who supervise postdocs can apply for I^{2}CNER support to defray 20% of the employment cost through indirect budget funds with the requirement that the postdocs dedicate 20% of their effort exclusively to I^{2}CNER related research. This enables postdocs to broaden their ideas and research. There have been 1, 6, and 6 postdocs hired by this program respectively in FY20, 21, and 22. Part of the WPI Academy Fund is used to assist junior faculty to start their research program. Start-up funds of 1 million JPY per faculty per year were awarded to 4, 3, and 2 assistant professors of I^{2}CNER respectively in FY20, 21, and 22. Supporting international travel for junior faculty has been a tradition of I^{2}CNER since its inception. This program was not implemented in

FY20 and 21 due to the Pandemic. However, one assistant professor's 2-month residence at Forschungszentrum Jülich (FZJ), Germany was supported by I²CNER.
The I²CNER Alumni Network Database was established in July 2021, financially supported by JSPS. This global network of former I²CNER faculty, researchers, students, and staff are kept informed of I²CNER events and activities such as symposia and conferences. 226 alumni have been registered as of March 2023.

5. Making Organizational Reforms and their Ripple Effects

- Describe distinctive effort in managing research operation and administrative organization, such as the strong leadership that the director is giving on the Center's operation, strong performance by the administrative director who provides the center director with strong administrative and managerial support, and division of roles and authority between the Center and its host institution.
- Describe the ripple effects that activities to disseminate experience and know-how accumulated by the Center, such as the followings, have/had on the host institution (or other research institutes, if any):
  - System reforms made through the Center's leading activities to its research operation and administrative organization
  - Experience and know-how accumulated by the Center as it have worked to establish itself as top world-level research institutes.
- Other than the above, give examples, if any, of cooperative activities by the Center and the whole WPI Program or other WPI centers, to disseminate experience and know-how accumulated by the WPI program and/or the WPI centers.

KU regulations and rules give authority for I²CNER operations to the **Institute Director** who is assisted by **two Associate Directors**. The Institute Director has direct access to the Office of the President and the Executive Vice President (EVP) in charge of Research. Regular meetings are held between the Director and the EVP in charge of Research. Advice and counsel from the President is given as needed. The decision-making system of the Institute has been set so that the Director is solely responsible for decisions regarding the planning and conduct of research activities, the formation and composition of research program areas or research Thrusts, potential research Thrust reorganization and redirection of research efforts in response to feedback from the annual site visit reviews of the Institute, the recruitment of postdocs and faculty, the establishment of international collaborations and interactions with top research institutions, the administration of the peer evaluation process of the Institute's research output, and budget implementation – the idea being that the Director's authority will affect future organizational reforms, developments, etc. The Director is also assisted by the **Administrative Director** and the Head of Administration. As of April 1, 2021, PI Chapman, serving as the Administrative Director, has been successfully interacting with his counterparts at other WPI centers and engaging with national agencies and industries in a way that advances the interests of I²CNER and amplifies the WPI program through his expertise and stellar research record on the energy Technology-People-Systems Nexus.
In the spirit of the top-down decision-making system in I²CNER, **KU reviewed operations and increased efficiencies**. By way of example: i) the number of committees in the Council for Education and Research was reduced from 34 to 22; ii) the number of other committees (stipulated by university regulations) was reduced from 34 to 24; iii) The number of committee members in the Council for Education and Research and the Council of Department Managers was reduced from 1028 to 431, and iv) the number of committee members (university-wide committees stipulated by university regulations) was reduced from 619 to 336.
In view of the successful model of former Director Sofronis' cross-appointment case, which was the first ever at KU, the KU Administration institutionalized a **cross-appointment employment system** that offers an excellent way to hire elite young faculty/researchers from the private sector and other universities and institutes. In terms of internal faculty appointments in KU, we have the Intra-University Faculty Transfer system. Since the adoption of this system in 2012, approximately 8 PIs were appointed in I²CNER.
In view of the effectiveness of the **I²CNER's Merit-based Salary System**, KU adopted and introduced this system across all units in 2015. Since then, there have been 252 faculty in 2015, 528 in 2018, and 718 in 2021 that are paid within this system.

6. Effort to Enhance and Amplify the Visibility and Brand of the Overall WPI Program

- Describe how the Center's outreach activities have contributed to enhancing and amplifying the visibility and brand of the WPI program. Describe the successful cases of the Center's outreach activities in Appendix 4, and enter the number of activities in Appendix 4a.
- Other than the above, describe, if any, the activities and their concrete contents that have contributed to the enhancement and amplification of the visibility and brand of the WPI program (such as holding a large international research meeting, collaborative activities with multiple WPI centers). If you have already provided this information, please indicate where in the report.

True to the WPI Academy system, we focused on **developing deeper connections and engaging with collaborating academic institutions around Japan and the world**. Our great achievements over the last three years have been the launching of i) the Center for Energy Systems Design (CESD) through Gaisan-Yokyu; ii) a new industry-university collaboration in the form of the Mitsui Chemicals, Inc.-Carbon Neutral Research Center (MCI-CNRC), and iii) the Research Center for Negative Emissions Technologies(K-NETs) through the 'Moonshot for Beyond Zero-Emission Society' R&D Program.

From Jan. 14 to Mar. 24, 2023, I²CNER hosted a **sabbatical visit** of Dr. Jill Engel-Cox, Director of the Joint Institute for Strategic Energy Analysis of the U.S. National Renewable Energy Laboratory (NREL). This successful sabbatical visit of Dr. Cox was facilitated by the structure and international environment of I²CNER setting the basis for future interactions and student-faculty exchanges between I²CNER and NREL. The **I²CNER Seminar Series** that was launched in 2010 upon the inception of I²CNER serves as a great venue for engaging key members of the international community from academia, national laboratories, industry, and government agencies (policy makers). Due to COVID-19, the I²CNER Seminar Series has been held virtually as **I²CNER Webinar** and attracted speakers and participants from Japan and around the world. The Institute hosted 4 seminars with 400 participants in FY20, 8 seminars with 591 participants in FY21, and 11 seminars with 805 participants in FY22.

Since the Institute's inception, the **I²CNER Annual Symposium** has evolved from an annual event that celebrates the current research achievements of its thematic areas to an exploratory forum that focuses on a single research topic that is highly relevant in I²CNER's research portfolio and the international community (i.e., computation, applied math, etc.). The objective of this series of international symposia is to identify the current state-of-the-art in a research area, establish where I²CNER's research is in comparison with the state-of-the-art, identify the roadblocks and needed advances in the field, and to set new or update existing I²CNER targets accordingly. Each year, the symposium also features more specific workshops organized by each Research Thrust. These workshops allow for opportunities to identify strengths and weaknesses in our research portfolio and explore how we might best accomplish growth.
In FY20 the I²CNER Annual Symposium, "A Virtuous Cycle: Embedding the Energy Transition in Post-COVID-19 Recovery," was held virtually on January 26, 2021. I²CNER and KU welcomed Japanese and U.S. government officials as well as world-class researchers to engage in discussions on post-COVID energy transition policies as they pertain to Japan, the U.S., Europe, and Australia. A roster of 22 early-career I²CNER researchers presented posters and lightning presentations. Academics, industry researchers, and members of the public were in attendance.
In FY21, the I²CNER Annual Symposium, "Carbon Management Including Negative Emission Technologies," was held virtually on January 25, 2022 with the participation of 6 world class engaging presenters. The CO_2 management discussion began with direct air capture of CO_2, followed by CO_2 conversion and storage.

In FY22, the I²CNER Annual Symposium, "Optimal Transitions: From Laboratory Research to Carbon-Neutral Energy Markets," was held in hybrid format on February 1, 2023. The symposium assessed the research portfolio of I²CNER on carbon management in relation to energy solutions in the space of hydrogen production and utilization and CO_2 separation and conversion to useful products. In relation to these themes, MCI-CNRC was featured as a successful example of I²CNER's industrial interactions.

7. Effort to Secure the Center's Future Development over the Mid- to Long-term

・Address each of the following items that have been done to secure mid- to long-term center development:
- Contents of the measures taken by the host institution to support maintaining the activities of the Center (such as securing financial and personnel resources, coordination among host institution to bring together in-house researchers, in-kind provision and/or facilities afforded in terms of usage of building, lab space and other equipment, new management reform carried out after the funding period ends).
- Actions and measures taken to sustain the Center as a world premier international research center.

Since the Institute's inception, I²CNER has been positioned as the only international institute of KU as specified in KU's constitution. This positioning is expected to remain the same regardless of the continuation of I²CNER's status as a WPI Academy Center. KU was selected as a designated national university corporation in November 2021 and promulgated the "Kyushu University VISION 2030." KU aims to become a "university that drives social change with integrative knowledge" toward 2030 and strives to contribute to the solution of social issues and to make transformation of social and economic systems through integrative knowledge. Leveraging the strengths of the university, KU's main focuses are the following three areas: Decarbonization, Medical Care and Health, and Environment and Food. With regard to decarbonization, I²CNER is the research institute that spearheads the KU efforts.

During the past 12 years, I²CNER has been successful at winning and filling tenured positions, and KU will make efforts to secure additional tenured positions for the Institute. By the end of FY22, I²CNER filled a total of 68 Associate and 4 Full Professor positions. I²CNER is currently in the process of hiring 3 tenured Associate Professors to be appointed in the **Center for Energy Systems Design (CESD)**. In addition, through the KU reform and revitalization program, we are hiring a tenure track assistant professor at KU. Under the leadership of PI Matsumoto, CESD is a highly coordinated effort among our PIs and faculty that

replicates I²CNER's structure and objectives. Among its areas of focus is data science, for which we are exploiting data we have generated and plan to generate, as an institute and a research community.
We will continue utilizing the Intra-University Faculty Transfer system of KU. Eight senior professors from the Faculty of Engineering have been appointed as I²CNER PIs for FY23.
By KU President decision I²CNER Buildings I and II have been granted free of charge for approximately 10 years. The space provided by this generous decision of President Ishibashi significantly exceeds the space allotment per researcher under the university's policy. Since FY21, KU has returned to I²CNER a portion of KU's share of the indirect cost on competitive research funds won by I²CNER researchers.

Through the leadership and continuous efforts of PI Ishihara, the **Mitsui Chemicals, Inc.-Carbon Neutral Research Center (MCI-CNRC)** has been working on the development and acquisition of environmental infrastructure technologies that contribute to carbon neutrality as well as pursue the practical use and commercialization of these technologies. The new center is an exciting opportunity to leverage I²CNER's world-class research in the production and use of green hydrogen, CO_2 separation and capture, CO_2 conversion and fixation, and advanced analysis and evaluation alongside Mitsui Chemicals' industry expertise with the goal of incorporating into society the technologies necessary to achieve carbon neutrality. As of March 2023, 9 postdocs have been hired in MCI-CNRC.
The 'Moonshot for Beyond Zero-Emission Society' R&D Program (MOZES) that was launched as a **multimillion dollar Kyushu University Research Center for Negative Emissions Technologies (K-NETs)** under the leadership of PI Fujikawa is at the forefront of Japan's decarbonization efforts through engineering innovation underlying the disrupting technology of Direct Air Capture of CO_2. I²CNER's CO_2 capture research team has been working on the development of new polymeric materials for nanomembranes with high CO_2 permeability and they have discovered several candidate materials in collaboration with KU, Kumamoto University, Kagoshima University, and Osaka Institute of Technology. A collaboration with the University of Tokyo revealed *for the first time* that the intermolecular interactions between gas molecules and the membrane surface play an important role in determining membrane performance. As of March 2023, 3 researchers and 5 postdocs have been hired in K-NETs.
The NEXT-RP (Research Center for Next Generation Refrigerant Properties) was established in 2016 as an affiliated research center of I²CNER at KU under the leadership of Prof. Y. Higashi. The center is a consortium of 7 universities, industrial manufacturers, NIST (USA), and AIST (Japan). Its mission is the development of next-generation refrigerants and is supported by NEDO.

8. Others

・Describe the Center's efforts over the past 3 years in making it a place that expands and accelerates the international circulation of the world's best brains. Give about **5 examples** of their success cases and describe their concrete contents and effect in narrative.
・In addition to the above1-7, note any of the Center's notable efforts and activities.

Impact of the Covid Pandemic

The global Covid pandemic during the last three years presented unprecedented challenges in research communication and collaboration. International travel was halted and Zoom meetings became the norm. This challenge also meant new opportunities, and many activities continued in all aspects. Our Institute Interest Seminar Series (IISS) hosted near-weekly seminars (61 in three years) and our I²CNER Seminar Series (IIS) hosted internationally renowned researchers despite significant distance from Fukuoka. Together, these seminars engaged more than 2,000 scholars. We also witnessed our administration and researchers rise to the challenge. They remained undaunted and their march toward the institute's global energy vision did not slow. In fact, they continuously exceeded expectations in terms of research quality and quantity. The administration did not let up in their efforts to amplify the WPI mission on behalf of Japan, the international community, and our stakeholders. During this time, former Director Sofronis worked diligently with the U.S. Consulate and the Embassy to ensure our research activities, innovation, and talent exchange continued to operate in the best interests of Japan and the U.S. I²CNER was able to transition successfully around the roadblocks that Covid presented, rising to the occasion as members of the WPI Academy.

Processes in place for brain circulation

The Platform for International Collaborations and Partnerships helps I²CNER to maintain its international identity. In the past three years, the platform supported collaborations of Assoc. Prof. Edalati with the Paul Scherrer Institut (PSI) at ETH, Assist. Prof. Leonard with Helmholtz Institute Forschungszentrum (Jülich,) Prof. Itaoka with the University of Queensland, Assist. Prof. Klotz with MIT, PSI, Catalonia Institute for Energy Research-IREC, Imperial College, London, and Assist. Prof. Wang with the University of Edinburgh,

Assist. Prof. Selyanchyn with NTNU in Norway and KTH in Stockholm, and Assoc. Prof. Chapman with Illinois. Importantly all these collaborations resulted in joint publications. In the last 3 years, 20 I^{2}CNER postdocs and faculty took positions at prestigious universities worldwide such as the University of Tokyo, University of Cambridge, and RWTH Aachen University.
The KU-UIUC partnership has become strategic and the two universities broadened their collaborations to other colleges and departments (mathematics, humanities, environmental economics, and others). The Satellite Institute at UIUC continues to facilitate cooperative research activities and personnel exchanges as follows: i) Kyushu faculty, postdoc, and student visits to Illinois are facilitated by departmental and university personnel that assist with visas, visitor accommodations, and sabbaticals, ii) shared facilities and laboratory and office space remain available, iii) Satellite office has been maintained and the director's time has been arranged. A successful example of brain circulation is Prof. Chapman at UIUC from Feb. 2020 to Aug. 2020 through the Progress 100 Program. I^{2}CNER researchers leverage the established infrastructure, research culture, and international partnerships of the Institute to promote researcher exchanges. Examples of such collaborations are: i) PIs Matsumoto and Ishihara through the Core-to-Core Program with Imperial College, London, PSI, and MIT, ii) PI Matsumoto with the University of New South Wales; iii) PI Saha with Aston University, iv) PI Chapman with the Open University and Kyoto University, v) PI Kubota with the University of Göttingen. Lastly, the newly established CESD through Gaisan-Yokyu provides networking opportunities for its researchers and senior scientists to address scientific, technological, and societal challenges with 6 Institutions in Japan.
Several examples of successful brain circulation cases that involve joint archival publications are listed as follows as example:

1) **Assistant Prof. Leonard with researchers from Germany, Spain, and Norway**: Dr. Leonard has traveled back and forth to collaborate with senior scientists in the Institute of Energy and Climate Research (IEK-1) Forschungszentrum Jülich Germany. Julich has long-standing expertise in processing layered ceramic systems using state-of-the-art facilities for highly efficient future energy conversion and storage technologies. The goal of Dr. Leonard and the team in Julich is to accelerate the foundational R&D of innovative ceramic proton-conducting oxides for clean, sustainable, and low-cost hydrogen production using steam electrolysis (ChemElectroChem, 9, e202101663 (1 of 12), 2022; Research Features Physical Science, 141, 4-7, 2022; Solid state Ionics, 379, 115918, 2022).
2) **Associate Prof. Kaveh Edalati with researchers from Germany, Korea, France, Switzerland, UK, and Russia**: Dr. Edalati invited 49 scientists from 18 countries in a joint publication on severe plastic deformation, a technology with high innovation potential in carbon neutrality (Mater. Res. Lett. 10, 163-256, 2022.). Within months from the publication date, this article has received 103 citations and was read about 18,000 times, among the top 6 most-read papers in the history of the journal. The introduction of high-entropy photocatalysts, which show some of the highest activities for CO_2 photoreduction (Chem. Eng. J. 449, 137800, 2022), was selected as a cutting-edge topic in hydrogen technologies by RCS publications.
3) **Associate Prof. Chapman with researchers from U.S. and Germany:** PI Chapman operates a global energy system model, specifically modified within I^{2}CNER to evaluate potential hydrogen penetration into the future energy system with interdisciplinary publications at the global scale. including colleagues at the University of Texas at Austin, Imperial College, and domestic partners (Int. J Hydrogen Energy 44, 6371–82, 2019; 45, 3883–98, 2020.) This research has then been specifically adapted to investigate the barriers to the emergence of a hydrogen economy within the United States in collaboration with UIUC (Clean Prod. Lett. 3, 100012. 2022). Excitingly, building on the success of these publications and interactions, a new international research effort between I^{2}CNER and Julich in Germany was established in 2022 with a visiting scholar situated in I^{2}CNER and a <u>return workshop undertaken in Germany</u> to pursue the potential penetration of hydrogen vehicles in the future vehicle fleets of both Japan and Germany using a discrete choice model interfaced with our global model.
   Building on this work a body of international, interdisciplinary scholarship has been developed and continues to date. Between I^{2}CNER and UIUC, the issues of culture, race, demographics, and preference were investigated to understand how culture plays a strong role in people's energy system choices and lived experience (Energy Res. Soc. Sci. 80, 102231, 2021). Following up on this work, the impact of demographics, existing energy infrastructure and preferences were analyzed to develop a future energy mix allocation for the United States (Energy Econ. 112, 1066141, 2022).

Appendix 1 List of Center's Major Research Achievements

1. List of Major Refereed Papers

*List **up to 20 papers** representative of the Center's research activities during the period between FY 2019 and FY 2022, and give brief descriptions (within 5 to 10 lines) of them.
*For each, write the author name(s); year of publication; journal name, volume, page(s) (or DOI number), and article title. Any listing order may be used as long as format is the same. If a paper has many authors, underline those affiliated with the Center.
*If a paper has many authors (say, more than 10), all of their names do not need to be listed.

1. The first synthesized [NiFe] model complex that plays three functional roles of naturally occurring enzymes: [NiFe], [FeFe], and [Fe] hydrogenases

Ogo S., Kishima T., Yatabe T., Miyazawa K., Yamasaki R., Matsumoto T., Ando T., Kikkawa M., Isegawa M., Yoon K.-S., Hayami S. (2020), [NiFe], [FeFe], and [Fe] hydrogenase models from isomers, Science Advances, (6)24, 10.1126/sciadv.aaz8181.

The study of hydrogenase enzymes (H_2ases) is necessary because of their importance to a future hydrogen energy economy. These enzymes come in three distinct classes: [NiFe] H_2ases, which have a propensity toward H_2 oxidation; [FeFe] H_2ases, which have a propensity toward H_2 evolution; and [Fe] H_2ases, which catalyze H^- transfer. Modeling these enzymes has so far treated them as different species, which is understandable given the different cores and ligand sets of the natural molecules. Here, we demonstrate, using x-ray analysis and nuclear magnetic resonance, infrared, Mössbauer spectroscopies, and electrochemical measurement, that the catalytic properties of all three enzymes can be mimicked with only three isomers of the same NiFe complex. *These results meet the short- and a mid-term milestone for molecular modification of biological and synthetic H_2-catalysts [1-3] in Project 1 of the Advanced Energy Materials Thrust's roadmap.*

2. Safe, one-pot, homogeneous direct synthesis of H_2O_2

Ogo S, Yatabe T, Tome T, Takenaka R, Shiota Y, Kato K. (2023), Safe, One-Pot, Homogeneous Direct Synthesis of H_2O_2., Journal of the American Chemical Society, (145)8, 4384 -4388.

Hydrogen peroxide is an environmentally friendly oxidizing agent but current synthetic methods are wasteful. This is a result of the high flammability of H_2/O_2 mixtures and/or the requirement for cocatalysts. In this paper, we report the synthesis of H_2O_2 by means of a homogeneous catalyst, which allows a safe, one-pot synthesis in water, using only H_2 and O_2. This catalyst is capable of removing electrons from H_2, storing them for the reduction of O_2, and then permitting the protonation of the reduced oxygen to H_2O_2. The turnover number (TON) is 910 under an H_2/O_2 (95/5) atmosphere (1.9 MPa) for 12 h at 23°C, which is the highest of any homogeneous catalyst. Furthermore, we propose a reaction mechanism based on two crystal structures. *These results meet the short- and a mid-term milestone for molecular modification of biological and synthetic H_2 and CO_2 catalysts in Project 1 of the Advanced Energy Materials Thrust's roadmap.*

3. Effects of hydrogen on elevated-temperature creep in stainless steel alloys

Takazaki D., Tsuchiyama T., Komoda R., Dadfarnia M., Somerday B.P., Sofronis P., Kubota M. (2021), Effect of Hydrogen on Creep Properties of SUS304 Austenitic Stainless Steel, Corrosion, (77)3, 256-265.

It is expected that high-temperature hydrogen technologies such as solid oxide fuel cells and high-temperature water electrolysis cells will play an important role in the future of a carbon-neutral energy system in view of their promising features, such as high efficiency and no reliance on platinum. However, our understanding of the effect of hydrogen on the creep behavior of metals and alloys is very limited. In this work, we investigated the creep life of the SUS304 austenitic stainless steel at 873°K both in hydrogen gas, 0.1.MPa, and in argon. This work found that the creep life of this steel was significantly reduced in hydrogen gas. Interestingly, the uniaxial tension ductility increased in hydrogen in comparison to that in argon, which is opposite to room temperature behavior. Examination of the fracture surfaces showed that the transition of the fracture mode from transgranular microvoid coalescence to intergranular fracture was delayed in hydrogen. Our examination and analysis of the experimental data confirmed that none of the following mechanisms could be responsible for the reduced creep life at 873°K: i) the hydrogen enhanced localized plasticity, the room temperature mechanism for hydrogen-induced material degradation, ii) the high temperature hydrogen attack decarburization mechanism, and iii) carbide formation. From our analysis of the steady-state creep data in both hydrogen and argon, it was inferred that the same creep deformation mechanism operated in the two environments, which was dislocation creep. Our analysis supports the colorable argument that hydrogen reduces the activation energy for vacancy formation, thereby enhancing the vacancy density and associated lattice diffusion coefficient, which in turn accelerates dislocation climb. Consequently, hydrogen accelerates the creep response and shortens the creep life. *These results address the short-term milestone of Project 3 of the Advanced Energy Materials Thrust's roadmap toward developing predictive models of H2-assisted cracking in structural materials.*

4. Ammonia mitigation and induction effects on hydrogen embrittlement of SCM440 low-alloy steel

Zhang N., Komoda R., Yamada K., Kubota M., Staykov A. (2022), Ammonia mitigation and induction effects on hydrogen environment embrittlement of SCM440 low-alloy steel, International Journal of Hydrogen Energy, (47)33, 15084-15093.

This work reports two conflicting ammonia (NH_3) effects, namely mitigation of hydrogen embrittlement (HE) and induction of HE during fracture toughness testing of a low alloy steel in NH_3-added hydrogen and nitrogen gases, and the plausible underlying mechanisms of the effects. The mitigation of HE by NH_3 was achieved by preferential adsorption of NH_3 on the Fe surface resulting in deactivation of catalytic action of the Fe surface for H_2 molecule dissociation into H atoms. In other words, NH_3 mixed in H_2 gas prevented hydrogen uptake in the material, and thus HE was mitigated. On the other hand, NH3 adsorbed on the catalytic Fe surface was decomposed into hydrogen and other compounds such as NH_2. The created hydrogen induced HE. Whether mitigation or induction of HE is the case is determined by the reaction rates of NH_3 with Fe surface and NH_3 decomposition, respectively. The former is significantly faster than the latter. When the loading rate is high, the crack propagates only under only the NH_3 effect hindering hydrogen uptake, and HE is mitigated. When the loading rate is low, the NH3 decomposition occurs and hydrogen is supplied during crack propagation resulting in HE. We also investigated the dependence of both effects on the NH_3 concertation. An increase in NH_3 concentration increased the HE mitigation effect by providing higher NH_3 coverage of the Fe surface. This is in contrast to the expectation that a higher NH_3 concentration may increase hydrogen supply, thus increasing the susceptibility to HE. This inverse dependence of HE on NH_3 concentration is due to the fact that vacant sites on the Fe surface adjacent to the NH_3-adsorbed sites are required for the NH_3 decomposition. Increased NH_3 surface coverage reduces the number of vacant sites, which results in less NH_3 decomposition. *This effort is directed toward the short-term milestone "Establish validated physical descriptions of effects of gas impurities on H_2 assisted cracking" in Project 3 "Predictive models of H_2-assisted cracking" of the Thrust's roadmap*.

5. Recycling of CO_2 as useful compound

Akrami S., Murakami Y., Watanabe M., Ishihara T., Arita M., Fuji M., Edalati K. (2022), Defective high-entropy oxide photocatalyst with high activity for CO_2 conversion, Applied Catalysis B: Environmental, (303). 10.1016/j.apcatb.2021.120896

This work reported high pressure torsion for high entropy oxide for active CO_2 reduction photocatalyst. High-entropy oxides (HEOs), as a new family of materials with five or more principal cations, have shown promising properties for various applications. In this work and inspired by inherent defective and strained structure of HEOs, photocatalytic CO_2 conversion is examined on a dual-phase $TiZrNbHfTaO_{11}$ synthesized by a two-step high-pressure torsion mechanical alloying and high-temperature oxidation. The HEO, which had various structural defects, showed simultaneous photocatalytic activity for CO_2 to CO and H_2O to H_2 conversion without the addition of a co-catalyst. The photocatalytic activity of this HEO for CO_2 conversion was better than conventional photocatalysts such as anatase TiO_2 and $BiVO_4$ and similar to P25 TiO_2. The high activity of HEO was discussed in terms of lattice defects, lattice strain, light absorbance, band structure, photocurrent generation and charge carrier mobility to activation centers. This study reveals that the high potential of HEOs as a new family of photocatalysts for CO_2 conversion.

6. **Dynamic behavior of lubricants under extreme conditions (GPa)**
Yagi K., Nishida K., Sugimura J. (2020), Relationship between the molecular structure of lubricants and appearance of anomalous film shapes in elastohydrodynamic lubrication conditions, Tribology International, (152), 10.1016/j.triboint.2020.106574.

Elastohydrodynamic lubrication (EHL) provides smooth operation and prevents surface damage in concentrated contacts in many machine components such as rolling element bearings and gears. Although the fundamental mechanics of EHL is well understood, the dynamic behavior of lubricants under high pressures on the order of GPa is largely unexplored. In this work, the behavior of lubricants under extreme conditions, i.e. of high pressure viscosity and liquid to solid transformation, was investigated. In particular, the relationship between the molecular structure of lubricants and the appearance of anomalous film shapes in elastohydrodynamic lubrication conditions were investigated. A ball-on-disc type test rig was used, which produced a point contact area between a rotating glass disc and rotating steel ball. Several pure liquids such as alkanes, alcohols, and others with a single polar site were used as lubricants. Linear chain lubricants caused solid-like behavior in the film formation, traction coefficient and flow out time of entrapped lubricant in shock loading tests whereas complexly shaped lubricants caused liquidlike behavior. The clear dependence on lubricant type appears to indicate that the anomalous film shapes formed due to the solidification of the lubricant.

7. **Understanding degradation of metal halide hybrid perovskite solar cells**
Tumen-Ulzii G., Qin C., Klotz D., Leyden M.R., Wang P., Auffray M., Fujihara T., Matsushima T., Lee J.-W., Lee S.-J., Yang Y., Adachi C. (2020), Detrimental Effect of Unreacted PbI_2 on the Long-Term Stability of Perovskite Solar Cells, Advanced Materials, (32)16, 10.1002/adma.201905035.

An understanding of intrinsic degradation mechanisms of perovskite solar cells containing unreacted PbI2 has been still insufficient and, therefore, needs to be clarified for better operational durability. Here, it is shown that degradation of perovskite solar cells is hastened by unreacted PbI2 crystals under continuous light illumination. Unreacted PbI2 undergoes photodecomposition under illumination, resulting in the formation of lead and iodine in films. Thus, this photodecomposition of PbI2 is one of the main reasons for accelerated device degradation. Therefore, this work reveals that carefully controlling the formation of unreacted PbI2 crystals in perovskite films is very important to improve device operational durability for diverse opto-electronic applications in the future. *These results contribute to the short-, mid-, and longterm milestones for environmentally friendly solar power harvesting in Project 5 of the Advanced Energy Conversion Systems Thrust's roadmap.*

8. **Light-emitting perovskites**
Qin C., Sandanayaka A.S.D., Zhao C., Matsushima T., Zhang D., Fujihara T., Adachi C. (2020), Stable room-temperature continuous-wave lasing in quasi-2D perovskite films, Nature, (585)7823, 53-57.

Optically pumped CW lasing is highly desired for practical applications in high-density integrated optoelectronics devices and constitutes a key step towards electrically pumped lasers. However, CW lasing has not yet been realized at room temperature because of the lasing death phenomenon (the abrupt termination of lasing under CW optical pumping), the cause of which remains unknown. Here we study lead halide-based quasi-2D perovskite films with different organic cations and observe that long-lived triplet excitons considerably impede population inversion during amplified spontaneous emission and optically pumped pulsed and CW lasing. Our results indicate that singlet–triplet exciton annihilation is a possible intrinsic mechanism causing lasing death. By using a distributed-feedback cavity with a high quality factor and applying triplet management strategies, we achieve stable green quasi-2D perovskite lasers under CW optical pumping in air at room temperature. We expect that our findings will pave the way to the realization of future current-injection perovskite lasers. *On the basis of these results, we have accomplished the three milestones for a light-emitting system with low power consumption in Project 6 of the Advanced Energy Conversion Systems Thrust's roadmap.*

9. **Perovskite oxynitride semiconductors for photoelectrochemical (PEC) water splitting**
Haydous F., Luo S., Wu K.-T., Lawley C., Döbeli M., Ishihara T., Lippert T. (2021), Surface Analysis of Perovskite Oxynitride Thin Films as Photoelectrodes for Solar Water Splitting, ACS Applied Materials and Interfaces, (13)31, 37785-37796.

Perovskite oxynitride semiconductors have recently attracted significant attention, as promising photoelectrode materials for photoelectrochemical (PEC) water splitting, as demonstrated by the extensive studies of the PEC activity of oxynitride powder-based photoelectrodes and/or deposited thin film electrodes. High crystalline quality, oxynitride thin films grown by physical vapor deposition are ideal for PEC water splitting. Our team studied the fundamental physical and chemical properties of the surface of these materials, including their evolution. In particular, using a combination of high-sensitive low-energy ion scattering (LEIS) and X-ray photoelectron spectroscopy (XPS), we monitored the surface evolution of LaTiOxNy (LTON) and CaNbOxNy (CNON) thin films. *These results directly address the short- and mid-term milestones under Project 4 for "Catalyst design for photochemical water splitting" in the Thrust's roadmap.*

10. **Performance and degradation of air electrodes in high-temperature electrochemical devices: acidity of surface infiltrated oxides as a sensitive descriptor of oxygen exchange kinetics in mixed conducting oxides**
Nicollet C., Toparli C., Harrington G.F., Defferriere T., Yildiz B., Tuller H.L. (2020), Acidity of Surface-Infiltrated Binary Oxides as a Sensitive Descriptor of Oxygen Exchange Kinetics in Mixed Conducting Oxides, Nature Catalysis, (3)11, 913-920.

Improving the kinetics of O_2 reduction on oxide surfaces is critical in many energy and fuel conversion technologies. Here we show that the acidity scale for binary oxides is a powerful descriptor for tuning and predicting oxygen surface exchange kinetics on mixed conducting oxides. By infiltrating a selection of binary oxides from strongly basic (Li_2O) to strongly acidic (SiO_2) onto the surface of $Pr_{0.1}Ce_{0.9}O_{2-\delta}$ samples, it was possible to vary the surface exchange coefficient kchem by 6 orders of magnitude, with basic oxides such as Li_2O increasing kchem= $A{\sim}\exp(-E_a/k_bT)$ by nearly 1000 times, with surface concentrations as low as 50 ppm already impacting k_{chem}. Strikingly, while log A scales linearly with the acidity of the infiltrated binary oxide, there is nearly no change in E_a. The origin of these dramatic changes is proposed to arise from the systematic increase in electron concentration at the $Pr_{0.1}Ce_{0.9}O_{2-\delta}$ surface with decreasing acidity of the infiltrated binary oxide. *These results meet the short- and midterm milestones for solid oxide cells in Project 1 of the Advanced Energy Conversion Systems Thrust's roadmap.*

11. **Development of proton conductive polymer membrane for next generation**
Han H., Miura H., Motoishi Y., Tanaka N., Fujigaya T. (2021), Development of a proton exchange membrane based on trifluoromethanesulfonylimide-grafted polybenzimidazole, Polymer Journal, (53)12, 1403-1411.

Trifluoromethanesulfonylimide-grafted polybenzimidazole (PBI-TFSI) was synthesized for PEM applications. Its proton conductivity was a) less dependent on humidity and b) higher than that of conventional fluorine-based PEM (Nafion) and propanesulfonic acid-grafted PBI (PBI-PS) at a relative humidity of 40%. The chemical structure of PBI-TFSI was investigated using 1H and 19F nuclear magnetic resonance and Fourier transform infrared spectroscopy. The membranes exhibited good transparency, flexibility, and thermal stability up to 350 °C. Membranes with different side chain grafting ratios were prepared, and the water uptake and hydration number of the PBI-TFSI membranes were lower than those of the PBI-PS membranes, most likely because of the hydrophobicity of the side chain. The higher proton concentration provided by TFSI with stronger acidity than PS might be the reason for the higher proton conductivities of PBI-TFSI. *These results contribute to the short-, mid-, and long-term milestones for low temperature energy conversion in Project 2 of the Advanced Energy Conversion Systems Thrust's roadmap.*

12. **Toward highly efficient solid oxide protonic electrolysis cells for large-scale hydrogen production**
Leonard K., Okuyama Y., Ivanova M.E., Meulenberg W.A., Matsumoto H. (2022), Tailored and Improved Protonic Conductivity through $Ba(Z_xCe_{10-x})_{0.08}Y_{0.2}O_{3-\delta}$ Ceramics Perovskites Type Oxides for Electrochemical Devices, ChemElectroChem, (9)4, 10.1002/celc.202101663.

On the electrode front, air electrodes tailored explicitly for protonic electrolytes have been hindered by difficulties finding highly efficient mixed proton-electron conductors (MPECs) with effective catalytic activity toward oxygen reduction and evolution reactions (ORR/OER). We Investigate the origin of catalytic activity in $LnCo_{0.5}Ni_{0.5}O_{3-\delta}$ (Ln=Pr and La) perovskites as air electrodes for protonic electrochemical devices by experiment and computation. The results reveal that PCNO and LCNO show predominantly p-type electronic conductivity with metallic-like behavior, and the conductivity of LCNO is almost an order of magnitude higher than that of PCNO. The results also suggest that the catalytic activity and electronic properties of $LnCo_{0.5}Ni_{0.5}O3$ (Ln= La, Pr) depend on the valence shell structure of the A-site cation. *These results pave the way for low-cost fabrication of large-sized protonic electrolysis cells and are directed to the midterm milestone of Project 1 "Solid oxide cells for power and fuel generation (Development of highly efficient oxide-ion-conductor-based SOFC and SOEC)."*

13. **Photo-enhanced ionic conductivity across grain boundaries in polycrystalline ceramics**
Defferriere T., Klotz D., Gonzalez-Rosillo J.C., Rupp J.L.M., Tuller H.L. (2022), Photo-enhanced ionic conductivity across grain boundaries in polycrystalline ceramics, Nature Materials, (21)4, 438-444.

Grain boundary conductivity limitations are ubiquitous in material science. We show that illumination with above-bandgap light can decrease the grain boundary resistance in solid ionic conductors. Specifically, we demonstrate the increase of the grain boundary conductance of a 3 mol% Gd-doped ceria solid oxide electrolyte thin film by a factor approximately 3.5 at 250 °C and the reduction of its activation energy from 1.12 to 0.68 eV under illumination. The presented model predicts that photo-generated electrons decrease the potential barrier heights associated with space charge zones depleted in charge carriers between adjacent grains. The discovered opto-ionic effect could pave the way for the development of new electrochemical storage and conversion technologies operating at lower temperatures and/or higher efficiencies and could be further used for fast and contactless control or diagnosis of ionic conduction in polycrystalline solids. *This accomplishment progresses us toward achieving the short-term and mid-term milestones of Project 1 "Solid oxide cells for power and fuel generation" in the Thrust's roadmap.*

14. **Direct air capture by nanomembrane**
Fujikawa S., Selyanchyn R., Kunitake T. (2021), A new strategy for membrane-based direct air capture, Polymer Journal, (53)1, 111-119.
Fujikawa S., Selyanchyn R., Kunitake T. (2021), Correction: A new strategy for membrane-based direct air capture (Polymer Journal, (2021), 53, 1, (111-119), 10.1038/s41428-020-00429-z), Polymer Journal, (53)1, 219-.
Fujikawa S., Selyanchyn R. (2022), Direct air capture by membranes, MRS Bulletin, (47)4, 416-423.

Direct CO_2 capture from the air, so-called direct air capture (DAC), has become inevitable to reduce the concentration of CO_2 in the atmosphere. Recently, there have been reports that show ultrahigh CO_2 permeances in gas separation membranes and thus membrane separation could be a potential new technology for DAC in addition to sorbent-based CO_2 capture. The simulation of chemical processes has been well established and is commonly used for the development and performance assessment of industrial chemical processes. These simulations offer a credible assessment of the feasibility of membrane-based DAC (m-DAC). In this paper, we discuss the potential of m-DAC considering the state-of-the-art performance of organic polymer membranes. The multistage membrane separation process was employed in process simulation to estimate the energy requirements for m-DAC. Based on the analysis, we propose the target membrane separation performance required for m-DAC with competitive energy expenses. Finally, we discuss the direction of future membrane development for DAC. *This accomplishment is toward the milestone "Development of nanomembrane materials with high CO_2 permeance" of the Multiscale Science and Engineering for Energy and the Environment Thrust's roadmap aiming at "Capture of CO_2 at multiple concentration levels."*

15. Monitoring pore pressure variation for the mitigation of CO_2-injection induced earthquakes

Chhun C., Tsuji T. (2020), Pore pressure analysis for distinguishing earthquakes induced by CO_2 injection from natural earthquakes, Sustainability (Switzerland), (12)22, 1-12.

It is important to distinguish between natural earthquakes and those induced by CO_2 injection at carbon capture and storage sites. For example, the 2004 Mw 6.8 Chuetsu earthquake occurred close to the Nagaoka CO_2 storage site during gas injection, but we could not quantify whether the earthquake was due to CO_2 injection or not. The approach we developed in this study could be used to distinguish natural earthquake from CO_2 injection-induced earthquake. In this approach, we use pore pressure variation predicted from seismic velocity variation in order to distinguish two types of the earthquakes. The approach weas demonstrated by simulating and comparing changes in pore pressure during CO_2 injection at the Nagaoka site with estimated natural seasonal fluctuations in pore pressure due to rainfall and snowmelt, as well as estimated pore pressure increases related to remote earthquakes. Changes in pore pressure due to CO_2 injection were clearly distinguished from those due to rainfall and snowmelt. The simulated local increase in pore pressure at the seismogenic fault area was much less than the seasonal fluctuations related to precipitation and increases caused by remote earthquakes, and the lateral extent of pore pressure increase was insufficient to influence seismogenic faults. *This accomplishment is directed to the short-term milestone "Distinguish natural earthquakes and CCS induced earthquakes" and the mid-term milestone "Prevention of CO_2 injection induced earthquakes" of the Multiscale Science and Engineering for Energy and the Environment Thrust's roadmap on carbon storage and management using the earth.*

16. CO_2 uptake by biomass-derived activated carbons

Pal A., Uddin K., Saha B.B., Thu K., Kil H.-S., Yoon S.-H., Miyawaki J. (2020), A benchmark for CO_2 uptake onto newly synthesized biomass-derived activated carbons, Applied Energy, (264), 10.1016/j.apenergy.2020.114720.

This study focuses on the development of novel activated carbons (ACs) with extremely large pore volume and high surface area from environment-friendly and abundantly available biomass precursors seeking higher CO_2 adsorption capacity. Synthesized ACs are characterized using a scanning electron microscope (SEM) and N2 adsorption/desorption measurement. The porous properties of newly synthesized ACs are compared to other ACs. Two performance indicators, such as the net or effective uptake and energy density, are calculated for all synthesized ACs/CO_2 pairs. The results of the present study are useful resources for industrial scientists and academics interested in producing ACs from the waste biomass precursor for CO_2 capture/storage and AHP applications. *These results contribute to the short-term milestones for "Heat mass transfer: adsorption" in Project 3 of the Multiscale Science and Engineering for Energy and the Environment Thrust's roadmap.*

17. Energy Transitions and the People-Technology-Systems Nexus

Chapman A., Shigetomi Y., Chandra Karmaker S., Baran Saha B., Huff K., Brooks C., Stubbins J. (2021), The cultural dynamics of energy: The impact of lived experience, preference and demographics on future energy policy in the United States, Energy Research and Social Science, (80), 10.1016/j.erss.2021.102231.

This paper highlights the difference in knowledge, behavior, and preferences toward the energy system within a single society. The impact of culture highlights the need to consider the energy system comprehensively, i.e., from the point of view of age, education, income etc. This initial attempt uncovered the linkages between culture, income, education and energy affordability and energy system and policy preferences. In addition, this research has led to policy findings and recommendations for the energy system which are cognizant of culture, and recognition issues within energy justice. *This research relates to our energy transitions target "Theoretical and quantitative evaluation of national and global transitions", and aims to further our understanding of the energy transition such that it is sustainable from an economic, environmental and social point of view.*

18. Econometric evaluation of environmental taxes on innovation
Karmaker S.C., Hosan S., Chapman A.J., Saha B.B. (2021), The role of environmental taxes on technological innovation, Energy, (232), 10.1016/j.energy.2021.121052.

The main focus of this study is to investigate the causal relations between environmental taxes and environment-related technological innovation with a holistic, robust model with significant statistical power. This model consists of panel cointegration analysis considering the cross-sectional dependence, applied to quantify the effects of environmental taxes on environment-related technological innovation in high and middle-income 42 countries from 1995 to 2018. The long-run results suggest that environmental taxes stimulate technological innovation; for example, a 1% increase in environmental taxes was found to increase environment-related technological innovation by 0.57 and 0.78% on average for high and middle-income countries using the common correlated effects mean group (CCEMG) and augmented mean group (AMG) techniques, respectively. The policy implications of this study suggest that imposing environmental taxes can accelerate the advancement of environmental-related technologies for reducing carbon emission and sustainable development in high and middle-income nations, with possible applications in a broad range of nations, particularly as an evidence base for developing nations to shorten energy transition timelines. *This research contributes to short- and medium-term milestones of the Project (iv) "Socio-techno-economic and policy analysis" of the section "Global hydrogen and energy system modeling" of the Multiscale Science and Engineering for Energy and the Environment" Thrust roadmap.*

19. Perovskite-based bidirectional optical wireless power transfer systems
Nguyen D.H., Matsushima T., Qin C., Adachi C. (2021), Toward Thing-to-Thing Optical Wireless Power Transfer: Metal Halide Perovskite Transceiver as an Enabler, Frontiers in Energy Research, (9), 10.3389/fenrg.2021.679125.

Optical power transfer provides a way of transmitting power through long distances without using wires. This is done by means of optical waves, in which solar cells serve as optical receivers converting optical energy to electricity. In our proposed novel system of bidirectional optical wireless power transfer, solar cells are employed as optical transceivers, i.e. devices capable of both absorbing and emitting light. To achieve that, perovskite solar cells are selected owing to their numerous advantages including small Stokes shift that make them suitable to be optical transceivers. This paper is the first to propose the novel concept of optical wireless power transfer systems, which is different from the existing optical wireless power transmission (OWPT) systems such that a single device – an optical transceiver – is employed. This optical transceiver, which is capable of both absorbing and emitting light, is fabricated from a metal halide perovskite known for its superior features that can help significantly reduce the whole system size and cost. The proposed system contributes to realizing a thing-to-thing optical wireless power transfer network, in which surfaces of objects/things are covered by perovskite transceivers (fully or partially), enabling them to wirelessly charge or discharge from the others. *This research is at the intersection of materials science, photonics, and power and energy systems. It has a great potential to be used in a vast number of applications including internet of things (IoT) devices, wearables and consumer electronics, transportation electrification, and wireless power networks.*

20. Combustion studies for efficient power generation
Matsue, K., Matalon, M. (2023), Dynamics of hydrodynamically unstable premixed flames in a gravitational field–local and global bifurcation structures, Combustion Theory and Modelling, 10.1080/13647830.2023.2165968.

This paper provides the first comprehensive description of flame morphology under variance of combustible mixtures, the state of the initial mixture, the diffusion properties of the reactants, as well as the gravitational parameter representing the ratio of buoyancy to inertial forces. These effects generally induce a spontaneous change in the flame structure, such as generation of cellular flames, pulsation and/or oscillating fronts, with dramatic consequences on the propagation speed. Complete understanding has been hampered because of the difficulties of laboratory-controlled experiments and accurate mathematical/numerical studies. The present work firstly achieves a comprehensive description of flame propagation in a gravitational field using asymptotic methods to systematically derive a simpler mathematical model with fewer physicochemical parameters and bifurcation theory for its analysis. Relevant (steady or oscillatory) flame morphologies are described for all parameter values in typical ranges including persistence under the change of physicochemical environments. The results provide an expectation of flame morphology for a broad class of mixtures including prospective gas mixtures such as hydrogen and ammonia.

2. Major Invited Lectures, Plenary Addresses (etc.)

*List up to 10 main presentations made between FY 2019 and FY 2022 in order from most recent.
*For each, write the date(s), lecturer/presenter's name, presentation title and conference name.

Date(s)	Lecturer/Presenter's name	Presentation title	Conference name
2023/3/28	Junji Nakamura	Reaction intermediates of methanol synthesis from CO2 on a Cu(111) model catalyst	American Chemical Society
2022/7/21	Tatsumi Ishihara	Strain Effects on Surface Activity and Oxide Ion Conductivity	23rd International Conference on Solid State Ionics (SSI-23),
2022/07/15	Chihaya Adachi	The past, present and future prospects of organic light emitting diodes	ICPOC-25
2022/5/29	Tomohiro Shiraki	Ortho-Substituent Structure Design in Aryldiazonium Salts for Defect Photoluminescence Modulation of Locally Functionalized Single-Walled Carbon Nanotubes	the 241st ECS Meeting
2022/4/20	Shigenori Fujikawa	Direct Air Capture by Membranes	MRS Webinar “Materials for Carbon Capture Technologies”
2021/12/14	Ikuo Taniguchi	CO2 Capture by Polymeric Membranes for demonstration	Materials Research Meeting 2021
2021/9/20-23	Tomohiro Shiraki	Near infrared photoluminescent nanomaterials: defect-engineered carbon nanotubes based on molecular functionalization	European Materials Research Society (E-MRS) 2021 Fall meeting
2021/6/15−16	Toshinori Matsushima and Chihaya Adachi	Metal halide hybrid perovskites for high-performance LED and laser devices	The 38th International Conference of Photopolymer Science and Technology (ICPST-38)
2019/6/21	J.A.Kilner	The Air Electrode Surface, a Complex Conundrum?	International Conference on Solid Satate Ionics
2019/4/3	Atsushi Takahara	Applications of synchrotron x-ray scattering to structure analyses of polymers under deformation	257th ACS National Meeting and Exposition

3. Major Awards

*List main awards received between FY 2019 and FY 2022 in order from the most recent.
*For each, write the date issued, recipient's name and the name of award. In case of multiple recipients, underline those affiliated with the Center.

Date	Recipient's name	Name of award
2023/2/8	Chihaya Adachi	Kenjiro Sakurai Memorial Award
2022/10/18	Yukina Takahashi	Masao Horiba Award
2022/3/15	<u>Toshihiro Tsuchiyama</u>, T.Sakamoto, S.Tanaka, <u>Takuro Masumura</u>	Sawamura Award, The Iron and Steel Institute of Japan
2021/5/26	Zhenying Wang	Young Researcher Award of the Heat Transfer Society of Japan
2021/1/1	Tatsumi Ishihara	Catalysis Society of Japan Award (Academic field)
2020/9/8	<u>Toshinori Matsushima</u>, <u>Chihaya Adachi</u>	Best Paper Award, The Japan Society of Applied Physics
2020/5/15	Petros Sofronis	2020 Frank Kreith Energy Award, American Society of Mechanical Engineers (ASME)
2019/12/6	Stephen Lyth	NICE STEP Researcher Award, NISTEP, MEXT
2019/8/29	Chihaya Adachi	The Japan Minister of Economy, Trade and Industry JST Academic Startups Award
2019/8/1	Nguyen Dinh Hoa	Masao Horiba Awards, The Horiba Group

Appendix 2 FY 2022 List of Principal Investigators

NOTE:
*Underline names of principal investigators who belong to an overseas research institution.
*Indicate newly added researchers for FY 2019-2022 in the "Notes" column.

<Principal Investigators at the end of FY 2022> **Principal Investigators Total: 24**

Name	Age	Affiliation (Position title, department, organization)	Academic degree, Specialty	Effort (%)*	Starting date of participation	Status of participation (Describe in concrete terms)	Note
Center director Petros Sofronis	65	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University University of Illinois at Urbana-Champaign, USA	Ph.D., Micromechanics of materials, Environmental degradation of materials	90%	2010, Dec. 1st	・Directs and administers the Institute ・Travels to Kyushu University to participate in events and engage with researchers (38.8% time) ・Promotes I^{2}CNER's interests worldwide to various universities, government agencies, laboratories, and industries on a daily basis ・Intensive trans-Pacific electronic communication via email, Skype, videoconferencing, etc. ・Increased, continuous contact with individual faculty during the pandemic.	
Tatsumi Ishihara	61	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr., Catalyst and solid state electrochemistry	95%	2010, Dec. 1st	・Located at I^{2}CNER ・Executes duties of Associate Director ・Leads research activities of his group	
Chihaya Adachi	59	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr., Materials science and device physics	40%	2010, Dec. 1st	・Located at I^{2}CNER ・Leads research activities of his group	
Seiji Ogo	59	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Science, Green Chemistry	95%	2010, Dec. 1st	・Located at I^{2}CNER ・Leads research activities of his group	
Kazunari Sasaki	58	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Science and Technology, Fuel cell materials, Inorganic materials	95%	2010, Dec. 1st	・Located at I2CNER ・Leads research activities of his group	
Harry L. Tuller	77	Prof., Department of Materials Science and Engineering, Massachusetts Institute of Technology, USA	Engr. Sc. D., Functional electroceramic materials	40%	2010, Dec. 1st	・Primarily located at partner institution ・Leads research activities of his group ・Visited I^{2}CNER for four weeks to participate in events and work on collaborative research projects ・Participates in research discussions via internet	
John A. Kilner	76	BCH Steele Chair in Energy Materials, Department of Materials, Imperial College, London, UK	Ph.D., Materials for solid oxide fuel cells and electrolysers	55%	2010, Dec. 1st	・Primarily located at partner institution ・Leads research activities of his group ・Visited I^{2}CNER for five weeks to participate in events and work on collaborative projects ・Participates in research discussions via internet	

Joichi Sugimura	65	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr., Tribology and Machine Design	100%	2010, Dec. 1st	・Located at I^2CNER ・Leads research activities of his group	
Brian P. Somerday	54	Adj. Research Assistant Prof., University of Illinois at Urbana-Champaign, USA	Ph.D., Materials Science and Engineering	20%	2010, Dec. 1st	・Primarily located at partner institution ・Leads research activities of his group ・Visited I^2CNER for one week to participate in events and work on collaborative projects ・Participates in meetings/events via internet and videoconferences	
Reiner Kirchheim	79	Prof., The Institut für Metallphysik, University of Göttingen, Germany	Ph.D., Hydrogen in Metals, Thermodynamics of alloys, Interstitial solution and diffusion in glasses	40%	2011, Apr. 1st	・Primarily located at partner institution ・Leads research activities of his group ・Visited I^2CNER for one week to participate in events and work on collaborative projects ・Participates in research discussions via internet	
Miho Yamauchi	49	Prof., Department of Applied Molecular Chemistry Institute for Materials Chemistry and Engineering, Kyushu University	Dr. of Science, Chemistry	100%	2012, Jan. 1st	・Located at I^2CNER ・Leads research activities of her group	
Andrew A. Gewirth	63	Prof., Department of Chemistry, University of Illinois at Urbana Champaign, USA	Ph.D., Chemistry	25%	2012, April. 1st	・Primarily located at partner institution ・Leads research activities of his group ・Serves as a member of the Illinois Satellite Advisory Committee and IPRC ・Participates in research discussions via internet	
Shigenori Fujikawa	52	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr., Nanoscience and engineering	100%	2013, June. 1st	・Located at I^2CNER ・Lead PI of the Multiscale Science and Engineering for Energy and the Environment Thrust	
Takeshi Tsuji	43	Prof., Department of Systems Innovation, Faculty of Engineering, The University of Tokyo	Dr. of Science, Earth and planetary science, Resource engineering, Space exploration	40%	2013, June. 1st	・Leads research activities of his group ・Research Collaboration with Sugai	
Hiroshige Matsumoto	56	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr.	100%	2010, Dec. 1st	・Located at I^2CNER ・Executes duties of Associate Director ・Lead PI of Advanced Energy Conversion Systems Thrust	

Bidyut B. Saha	57	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr.	100%	2010, Dec. 1st	・Located at I^{2}CNER ・Leads research activities of his group	
Thomas Lippert	60	Prof., Department of Chemistry and Applied Biosciences, Laboratory of Inorganic Chemistry, Swiss Federal Institute of Technology Zurich, and Paul Scherrer Institut, Thin Films & Interfaces Group, Villigen-PSI, Switzerland	Dr. of Science, Physical Chemistry	25%	2016, Aug. 1st	・Primarily located at partner institution ・Leads research activities of his group ・Visited I^{2}CNER for two weeks to participate in events and work on collaborative projects ・Participates in research discussions via internet	
Tsuyohiko Fujigaya	46	Prof., Department of Applied Chemistry, Kyushu University	Ph.D. Engr., Polymer chemistry	10%	2018, Apr. 1st	・Located at I^{2}CNER ・Leads research activities of his group	
Aleksandar Staykov	44	Associate Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Ph.D., Physical and theoretical chemistry	100%	2018, Apr. 1st	・Located at I^{2}CNER ・Leads research activities of his group	
Hiroaki Watanabe	50	Prof., Department of Advanced Environmental Science and Engineering, Faculty of Engineering Sciences, Kyushu University	Ph.D. Engineering	10%	2018, Oct. 1st	・Located at I^{2}CNER ・Leads research activities of his group	
Masanobu Kubota	53	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engineering	100%	2019, Apr. 1st	・Located at I^{2}CNER ・Lead PI of the Advanced Energy Materials Thrust	Newly Added in FY2019
James Stubbins	74	Prof., Department of Nuclear, Plasma and Radiological Engineering, University of Illinois Urbana-Champaign	Ph.D., Energy Materials	20%	2020, Apr. 1st	・Primarily located at partner institution ・Leads research activities of his group on techno-economics of energy ・Participates in research discussions via internet	Newly Added in FY2020
Andrew Chapman	42	Associate Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Ph.D., Socio-Environmental Energy Science	100%	2021, Jan. 4th	・Located at I^{2}CNER ・Leads research activities of his group ・Administrative Director	Newly Added in FY2020
Koji Takahashi	58	Prof., Department of Aeronautics and Astronautics, Kyushu University	Ph.D., Thermophysical Engineering, Nanotechnology, MEMS	20%	2022, Jan. 1st	・Located at I^{2}CNER ・Leads research activities of his group	Newly Added in FY2021

*Percentage of time that the principal investigator devotes to his/her work for the Academy center vis-à-vis his/her total working hours.

Principal Investigators resigned since FY 2019

Name	Next Affiliation (Position title, department, organization)	Period of participation
Yasuyuki Takata	Research Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	2010, Dec. 1st -2022, Mar.31st
Xing Zhang	Prof., Department of Engineering Mechanics, Tsinghua University, China	2010, Dec. 1st -2022, Mar.31st
Atsushi Takahara	Research Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	2010, Dec. 1st -2020, Mar.31st
Ken Sakai	Prof., Department of Chemistry Faculty of Sciences, Kyushu University	2010, Dec. 1st -2020, Mar.31st
Kenneth T. Christensen	Prof., Assistant Dean of Faculty Development, College of Engineering, University of Notre Dame,USA	2010, Dec. 1st -2020, Mar.31st
Ian Robertson	Prof., Dean of Engineering, University of Wisconsin-Madison, USA	2010, Dec. 1st -2019, Mar.31st
Zenji Horita	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	2010, Dec. 1st -2019, Mar.31st

Appendix 3-1 Record of Center Activities (FY 2019-FY 2022)

1. Researchers and Center Staffs, Satellites, Partner Institutions

1-1. Researchers and Center Staffs Participated in the Center's Activities

- Enter the number of researchers and center staffs affiliated with the Center in the table in Appendix 3-1a.

Special mention

- Describe the Center's concrete plans for the future and already-established schedules for employing researchers, particularly principal investigators.
- As background to how the Center is working on the global circulation of world's best brains, give good examples, if any, of how career paths are being established for the Center's researchers; that is, from which top-world research institutions do researchers come to the Center and to which research institutions do the Center's researchers go, and how long are their stays at those institutions.
- In Appendix 3-1b, describe the positions that postdoctoral researchers acquire upon leaving the Center.

1-2. Satellites and Partner Institutions

- List the satellite and partner institutions, both domestic and overseas, in the table below.
- Indicate newly added and deleted institutions in the "Notes" column.

<Satellite institutions>

Institution name	Principal Investigator(s), if any	Notes
University of Illinois at Urbana-Champaign (UIUC), USA	Andrew Gewirth, James Stubbins Brian P. Somerday	

< Partner institutions>

Institution name	Principal Investigator(s), if any	Notes
Bandung Institute of Technology, Indonesia		
California Air Resources Board (CARB), USA		
Colorado School of Mines, USA		
Department of Energy (Office of Energy Efficiency and Renewable Energy), USA		
ETH Zurich		
Helmholtz-Zentrum Geesthacht		
Huazhong University of Science and Technology, China		
Imperial College London, UK	John Kilner	
Indian Institute of Technology Delhi, India		
Massachusetts Institute of Technology, USA	Harry Tuller	
Norwegian University of Science and Technology (NTNU), Norway		
RMIT (Royal Melbourne Institute of Technology) University		
Tsinghua University, China		

Universiti Teknologi Malaysia, Malaysia		
University of Bergen, Norway		
University of California, Berkeley, USA		
University of California, Irvine (National Fuel Cell Research Center), USA		
University of Göttingen, Germany	Reiner Kirchheim	
University of Edinburgh, UK		
University of New South Wales, Australia		
Illinois Institute of Technology, USA,		
University of Texas at Austin, USA		
University of Thessaly, Greece		

2. Status of Collaboration with Overseas Satellites

2-1. Coauthored Papers

- List the refereed papers published between FY 2019 and FY 2022 that were coauthored between the Center's researcher(s) in domestic institution(s) (include satellite institutions) and overseas satellite institution(s). List them by overseas satellite institution in the below blocks.
- Transcribe data in same format as in Appendix 1. Italicize the names of authors affiliated with overseas satellite institutions.

Overseas Satellite 1 University of Illinois at Urbana-Champaign (UIUC) (Total: 22 papers)

1) Harrington G.F., Kalaev D., Yildiz B., Sasaki K., *Perry N.H.,* Tuller H.L. (2019), Tailoring Nonstoichiometry and Mixed Ionic Electronic Conductivity in Pr0.1Ce0.9O2-δ/SrTiO3 Heterostructures, ACS Applied Materials and Interfaces, 11 (38), 34841-34853.
2) *Dadfarnia M.*, *Martin M.L.*, Moore D.E., Orwig S.E., Sofronis P. (2019), A model for high temperature hydrogen attack in carbon steels under constrained void growth, International Journal of Fracture, 219 (1).
3) Wang S., Nagao A., *Sofronis P.,* Robertson I.M. (2019), Assessment of the impact of hydrogen on the stress developed ahead of a fatigue crack, Acta Materialia, 174, 181-188.
4) *Bertsch K.M.,* Wang S., Nagao A., Robertson I.M. (2019), Hydrogen-induced compatibility constraints across grain boundaries drive intergranular failure of Ni, Materials Science and Engineering A, 760, 58-67.
5) Wang S., *Nygren K.E.,* Nagao A., Sofronis P., Robertson I.M. (2019), On the failure of surface damage to assess the hydrogen-enhanced deformation ahead of crack tip in a cyclically loaded austenitic stainless steel, Scripta Materialia, 166, 102-106.
6) Fujisaki T., Staykov A.T., *Jing Y.,* Leonard K., *Aluru N.R.,* Matsumoto H. (2019), Understanding the effect of Ce and Zr on chemical expansion in yttrium doped strontium cerate and zirconate by high temperature X-ray analysis and density functional theory, Solid State Ionics, 333, 1-8.
7) Chen T., Harrington G.F., Matsuda J., Sasaki K., Pham D., Corral E.L., *Perry N.H.* (2019), Modifying grain boundary ionic/electronic transport in nano-Sr- And Mg- Doped LaGAO3-δ by sintering variations, Journal of the Electrochemical Society, 166 (10).
8) Gao R., *Jain A.C.P.,* Pandya S., Dong Y., Yuan Y., Zhou H., Dedon L.R., Thoréton V., Saremi S., Xu R., Luo A., Chen T., Gopalan V., *Ertekin E.,* Kilner J., Ishihara T., *Perry N.H., Trinkle D.R.,* Martin L.W. (2020), Designing Optimal Perovskite Structure for High Ionic Conduction, Advanced Materials, 32 (1).
9) Sanders J.W., Dadfarnia M., *Sehitoglu H.*, *Stubbins J.*, Sofronis P. (2020), On the stress field ahead of a stationary crack tip during the transition from primary to secondary creep, International Journal of Solids and Structures, 193-194, 455-473.
10) *Nygren K.E.*, Nagao A., Sofronis P., Robertson I.M. (2020), The Role of Microstructure in Hydrogen-Induced Fatigue Failure of 304 Austenitic Stainless Steel, Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science, 51(11), 5704-5714.
11) *Perry N.H.*, *Skiba E.J.*, Chen T. (2020), Simultaneous electrical, electrochemical, and optical relaxation measurements of oxygen surface exchange coefficients: Sr(Ti,Fe)O3-d film crystallization case study, ACS Applied Materials and Interfaces, 12(43), 48614-48630.
12) Nan Z., Komoda R., Yamada K., Volkert C.A., Tian L., Kirchheim R., Sofronis P., *Hosseinisarani Zahra S.*, Dadfarnia M., Kubota M., Staykov A. (2020), Effect of ammonia impurity on hydrogen embrittlement of scm440 low-alloy steel in hydrogen gas, Proceedings of the International Offshore and Polar Engineering Conference, 2020-October, 3030-3035.
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2-2. Status of Researcher Exchanges

- Using the below tables, indicate the number of researcher exchanges between the Center (include domestic satellite institutions) and overseas satellite institutions during the period of FY 2019-FY 2022. Enter by institution and fiscal year.
- Write the number of principal investigator visits in the upper space and the number of other researcher visits in the lower space.

Overseas Satellite 1: University of Illinois at Urbana-Champaign (UIUC)

<To overseas satellite>

	FY 2019	FY 2020	FY 2021	FY 2022	Total
Principal investigators	0	0	0	2	2
Other researchers	3	0	0	0	3
Total	3	0	0	2	5

<From overseas satellite>

	FY 2019	FY 2020	FY 2021	FY 2022	Total
Principal investigators	1	0	0	1	2
Other researchers	4	0	0	2	6
Total	5	0	0	3	8

Overseas Satellite 2:

<To overseas satellite>

	FY 2019	FY 2020	FY 2021	FY 2022	Total
Principal investigators					

Other researchers					
Total					NA

<From overseas satellite>

	FY 2019	FY 2020	FY 2021	FY 2022	Total
Principal investigators					
Other researchers					
Total					NA

3. Holding and Participating in International Research Meetings

3-1. Holding international Research Meetings

- Indicate the number of international research conferences or symposiums held between FY 2019 and FY 2022, and give up to **five examples** of the most representative ones using the table below.

FY 2019: 8 meetings	FY 2020: 5 meetings	FY 2021: 5 meetings	FY 2022: 7 meetings

Major examples (meeting titles, places and dates held)	Number of participants
I^{2}CNER's 10th Anniversary Symposium in Tokyo, Tokyo, December 16th, 2019	From domestic institutions: 151 From overseas institutions: 9
2023 I^{2}CNER Annual Symposium, Fukuoka/ Hybrid, February 1st, 2023	From domestic institutions: 106 From overseas institutions: 23
2023 I^{2}CNER Thrust Workshop, Fukuoka/ Hybrid, February 2nd, 2023	From domestic institutions: 39 From overseas institutions: 30
HYDROGENIUS, I^{2}CNER, HYDROMATE and SINTEF Joint Research Symposium 2022, Online, January 27th and 28th, 2022	From domestic institutions: 298 From overseas institutions: 222
2022 HYDROGENIUS & I^{2}CNER Tribology symposium (HYDROGENIUS and I^{2}CNER Joint Research Symposium), Online, January 28th, 2022	From domestic institutions: 187 From overseas institutions: 35

3-2. Participating in International Research Meetings

- Give up to five examples of the most representative case in which the Center, not individual researchers, participated in international research meetings to enhance the visibility and brand of the Center or of the overall WPI Program

Meeting titles, places, dates held and number of participants	Form of participation (e.g. operating a booth)	Number of participants from the Center
E-MRS 2019 Spring Meeting, Nice, France, May 27-30, 2019, Approx. 300 participants	Operating a booth with WPI 4 centers (WPI-AIMR, iCeMS, MANA and I^{2}CNER)	1
"Mathematics Without Borders - Applied and Applicable": Kyushu University and UIUC partnership symposium, Online, March 10th and 11th 2021, 105 participants	Presentation	13
"Go Beyond Net Zero - CO_2 Capture and Utilization": Kyushu University and UIUC partnership symposium, Online, February 1st, 2021, 83 participants	Presentation	24
JAPEX-I^{2}CNER Workshop, Online, December 10th & 16th, 2020, 20 participants	Presentation	9
Sojitz-I^{2}CNER Workshop, Online, June 19th & 26th, 2020, 20 participants	Presentation	11

4. List of the Cooperative Research Agreements with Overseas Institutions

- Indicate the number of agreements concluded with overseas institutions still in effect as of the end of FY 2022 (March 31, 2023). Give five examples of the most representative agreements.

Number of effective agreements (as of March 31, 2023): 4

Examples of the most representative agreements:

1. Name of an Agreement: Agreement for academic exchange and cooperation between National Fuel Cell Research Center, University of California Irvine, U.S.A. and International Institute for Carbon-Neutral Energy Research Kyushu University, Japan
   Dates of an Agreement: January 15, 2019
   Counterpart of an Agreement: National Fuel Cell Research Center (NFCRC), University of California Irvine, USA
   Summary of an Agreement: Facilitating a sustained and enduring dialog, fundamental and practical research, and educational cooperation between the two parties.

2. Name of an Agreement: Memorandum of understanding between International Institute for Carbon-Neutral Energy Research Kyushu University and The Norwegian University of Science and Technology
   Dates of an Agreement: March 17, 2019
   Counterpart of an Agreement: The Norwegian University of Science and Technology
   Summary of an Agreement: Facilitating further cooperation in research and education.

3. Name of an Agreement: Agreement on academic cooperation between Faculty of Engineering, Graduate School of Engineering, International Institute for Carbon-Neutral Energy Research, Faculty of Engineering Sciences, Interdisciplinary Graduate School of Engineering Sciences, And School of Engineering National University Corporation Kyushu University, Japan and Indian Institute of Technology Delhi, India
   Dates of an Agreement: July 1, 2020
   Counterpart of an Agreement: Indian Institute of Technology Delhi
   Summary of an Agreement: The purpose of this Agreement is to develop scientific, academic and educational cooperation on the basis of equality and reciprocity and to promote relations between Faculty of Engineering, Graduate School of Engineering, International Institute for Carbon-Neutral Energy Research, Faculty of Engineering Sciences, Interdisciplinary Graduate School of Engineering Sciences, and School of Engineering, KYU and IITD under the mutual understanding of the Parties.

4. Name of an Agreement: Agreement on Educational And Scientific Partnership Between International Institute For Carbon Neutral Energy Research, Kyushu University, Japan and School of Environmental Science and Engineering, Huazhong University of Science and Technology, China
   Dates of an Agreement: August 1, 2021
   Counterpart of an Agreement: School of Environmental Science and Engineering, Huazhong University of Science and Technology
   Summary of an Agreement: To make efforts to promote international scientific research cooperation and talent training between I^{2}CNER and ESE to serve the society.

5. Postdoctoral Positions through Open International Solicitations

- In the columns "number of applications" and "number of selections," put the total number (upper) and the number and percentage of overseas researchers in the < > brackets (lower).
- In Appendix 3b, describe the status of employment of postdoctoral researchers.

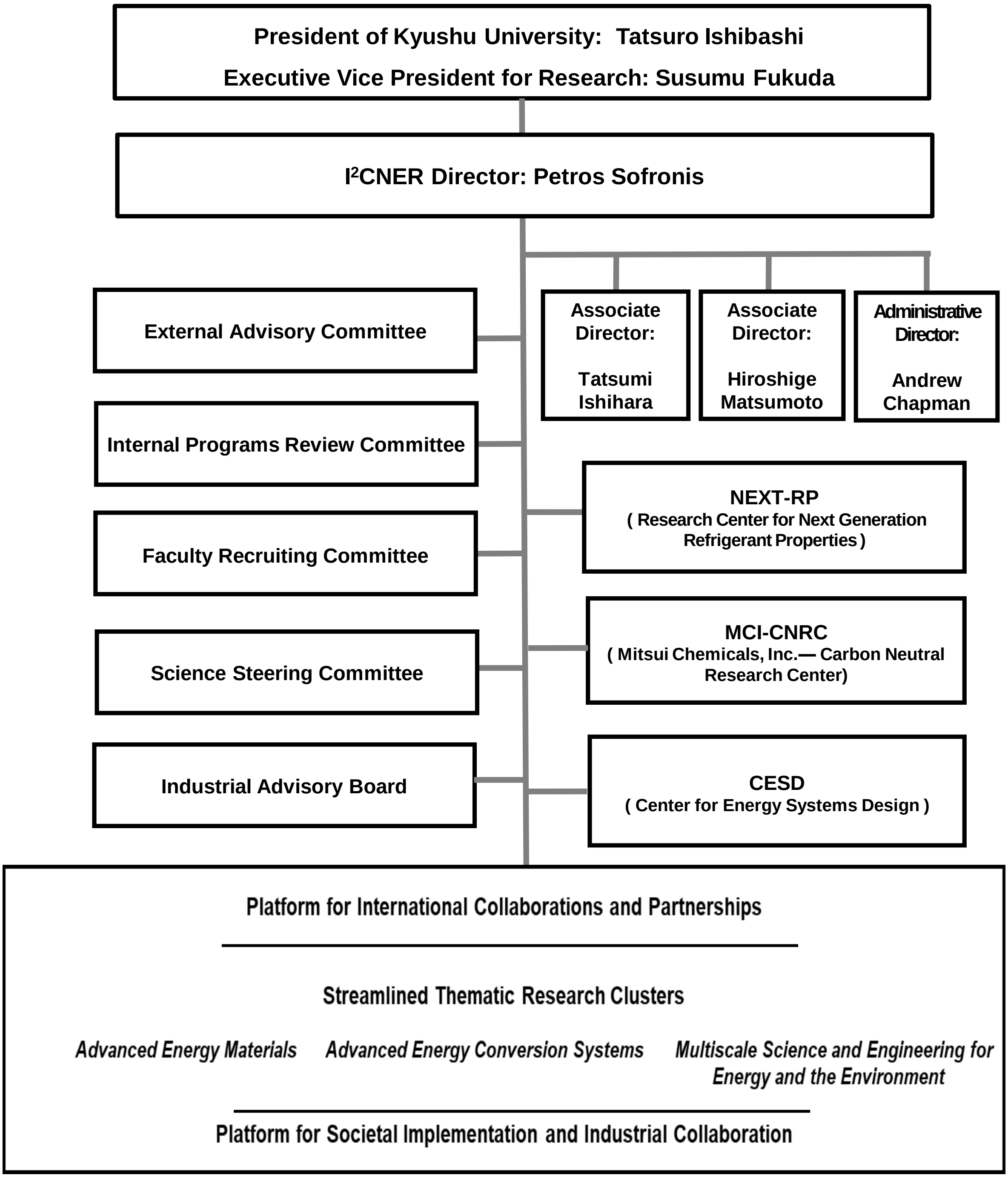
Fiscal year	Number of applications	Number of selections
FY 2019	0	0
	〈 , %〉	〈 , %〉
FY 2020	0	0
	〈 , %〉	〈 , %〉
FY 2021	13	6
	〈 9, 69.2%〉	〈 3, 50%〉
FY 2022	48	6
	〈 46, 95.8%〉	〈 4, 66.7%〉

6. Diagram of Management System

6-1.

- Diagram the Center's management system within the Center in an easily understood manner.
- If any changes have been made in the Center's management system vis-à-vis that stated in the application for WPI Academy center certification, describe them. Especially describe any important changes made in such as the center director, administrative director, head of host institution, and officer(s) in charge at the host institution (e.g., executive vice president for research).

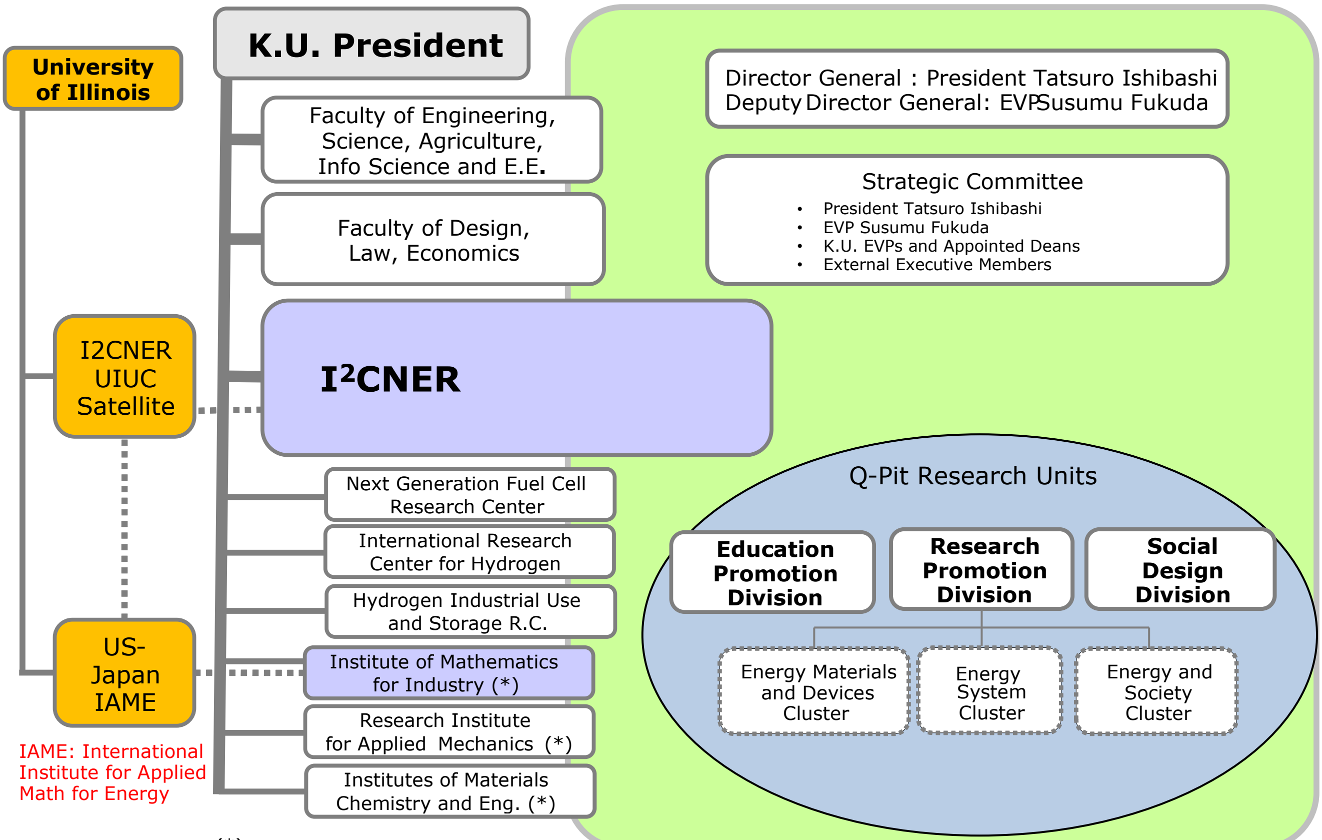
I^{2}CNER Organizational Structure



Professor Tatsuro Ishibashi has been appointed as President of Kyushu University, effective October 2022.
Professor Susumu Fukuda has been appointed as Executive Vice President (EVP) for Research, effective October 2022.
Professor Hiroshige Matsumoto has been appointed as Associate Director, effective April 2020.
Professor Andrew Chapman has been appointed as Administrative Director, effective April 2021.

6-2.

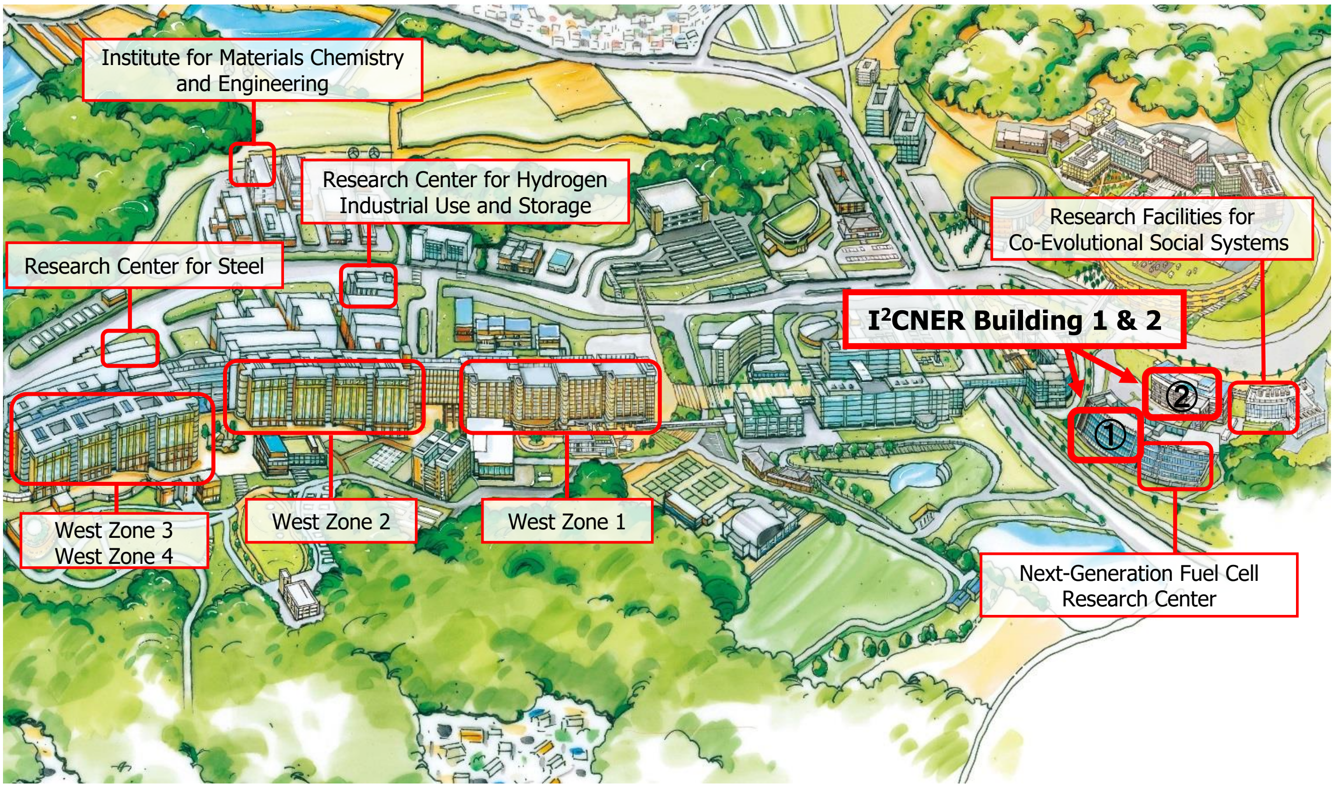
- Make a diagram of the organizational chart to show Center's position **within the host institution**.



(*) MEXT Joint Usage/Research Center

7. Campus Map

- Draw a simple map of the campus showing where the main office and principal investigator(s) are located.



Appendix3-1a Number of Center Personnel FY 2019-FY 2022

	FY 2019		FY 2020		FY 2021		FY 2022	
	Number of persons	%	Number of persons	%	Number of persons	%	Number of persons	%
Researchers	169		140		144		162	
Overseas researchers	70	41	58	41	59	41	70	43
Female researchers	20	12	13	9	15	10	21	13
Principal investigators (PIs)	26		25		24		24	
Overseas PIs	11	42	12	48	11	46	11	46
Female PIs	1	4	1	4	1	4	1	4
Other researchers	106		95		93		105	
Overseas researchers	34	32	31	33	29	31	35	33
Female researchers	14	13	10	11	9	10	13	12
Postdocs	37		20		27		33	
Overseas Postdocs	25	68	15	75	19	70	24	73
Female Postdocs	5	14	2	10	5	19	7	21
Research support staffs	59		52		62		57	
Administrative staffs	20		24		23		29	
TOTAL	248		216		229		248	

Number of persons who were/have been paid using the host institution's operating budget (excluding indirect funding) among the above persons.

	FY 2019	FY 2020	FY 2021	FY 2022
Principal investigators (PIs)	11	16	17	15
Other researchers	34	39	40	44
Postdocs	0	0	0	0
Research support staffs	0	0	0	0
Administrative staffs	7	12	10	13

※ Make consistent with the number of persons reported in Appendix 3-2.

	FY 2019		FY 2020		FY 2021		FY 2022	
	Number of persons	%	Number of persons	%	Number of persons	%	Number of persons	%
Doctoral students	50		31		22		20	
Employed	7	14.0	0	0.0	0	0.0	2	10.0

※ The number of doctoral students indicated in the lower table can also include those in the upper table of Total numbers.

Changes vis-à-vis the Center's application for academy center certification

※ If changes have been made vis-à-vis the Center's application for academy center certification, describe the main changes and the reasons for them.

Appendix 3-1b Career Path of WPI Postdocs

Enter the information below during the period from the start of the center through the end of FY 2022.

* For each person, fill in the spaces to the right. More spaces may be added.
* Leave "Position as of April 2023" blank if unknown.

Japanese Postdocs

Employment period	Position before employed at WPI center		Next position after WPI center		Position as of April 2023*	
	Position title, organization	Country where the organization is located	Position title, organization	Country where the organization is located	Position title, organization	Country where the organization is located
Apr. 1, 2011-May. 31, 2012	PhD Student, Kyoto University	Japan	Asstant Professor, Nagoya University	Japan	Research Scientist, National Institute of Advanced Industrial Science and Technology	Japan
Apr. 1, 2013-Mar. 31, 2014	Postdoc, Hokkaido University	Japan	Assistant Professor, Chuo University	Japan	Researcher, Local Independent Administrative Agency Hokkaido Research Organization	Japan
Apr. 1, 2013-Mar. 31, 2014	PhD Student, Kyushu University	Japan	Associate, The Matsushima Institute of Government and Management	Japan	Senior Researcher,Renewable Energy Institute	Japan
May 1, 2013-Mar. 31, 2014	Research Support Staff, Kyushu University	Japan	Researcher, Iwate University	Japan	NONE (unknown)	
Apr. 1, 2014-Mar. 31, 2015	Postdoc, Kyushu University	Japan	Assistant Professor, Kyushu University	Japan	Assistant Professor, Kyushu University	Japan
Apr. 1, 2014-Feb. 28, 2015	Researcher, Toyota Central R&D Labs., inc.	Japan	Researcher, National Institute of Advanced Industrial Science and Technology	Japan	Research Scientist, National Institute of Advanced Industrial Science and Technology	Japan
Apr. 1, 2014-Oct. 15, 2016	PhD Student, Kyoto University	Japan	Asstant Professor, I2CNER	Japan	Associate Professor, Kyushu University	Japan
Apr. 1, 2014-Mar. 31, 2017	Postdoc, Kyushu University	Japan	Assistant Professor, Nara Women's University	Japan	Associate Professor, Nara Women’s University	Japan
Apr. 1, 2014-Sep.30,2019	PhD Student, Kindai University	Japan	Research Assistant Professor, Hokkaido University, Japan	Japan	Research Assistant Professor, Hokkaido University	Japan
Aug. 1, 2014-Jul. 31, 2015	Researcher, Pennsylvania State University	USA	Postdoc, Kyushu University	Japan	Representative Director, DeepFlow, Inc.	Japan
Oct. 1, 2014-Sep. 30, 2016	Postdoc, Tokyo University of Science	Japan	Postdoc, Tokyo University of Science, Yamaguchi	Japan	Assistant Professor, Sanyo-Onoda City University	Japan
Oct. 1, 2014-Mar. 31, 2015	PhD Student, Kyushu University	Japan	Mitsubishi Gas Chemical Company, Inc.	Japan	Mitsubishi Gas Chemical Company, Inc	Japan
Mar. 1, 2015-Dec. 31, 2016	Researcher, Tokyo Institute of Technology	Japan	Researcher, Tohoku University	Japan	NONE (unknown)	
Apr. 1, 2015-Mar. 31, 2016	PhD Student, Kyushu University	Japan	Asstant Professor, Okayama University	Japan	Research Lecturer, Okayama University	Japan
May. 1, 2015-Mar. 31, 2018	Researcher, Asahi Intecc	Japan	Postdoc, Kyushu University	Japan	I-PEX Inc.	Japan
Apr. 1, 2016-Mar. 31, 2017	PhD Student, Kyushu University	Japan	ADECA CORPORATION	Japan	ADECA CORPORATION	Japan
Nov. 1, 2016-Mar. 31, 2018	Postdoc, Kyushu University	Japan	Tanaka Kikinzoku Kogyo K.K	Japan	Tanaka Kikinzoku Kogyo K.K	Japan

Apr. 1, 2017-Mar. 31, 2018	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan
Apr. 1, 2017-Sep. 30, 2018	Postdoc, Kyushu University	Japan	Assistant Professor, Fukuoka University	Japan	Associate Professor, Kyushu Institute of Technology	Japan
May. 1, 2017-Mar. 31, 2022	Researcher, I-Cems, Kyoto Universiy	Japan	Lecturer, Osaka Institute of Technology	Japan	Lecturer, Osaka Institute of Technology	Japan
Apr. 1, 2018-Mar. 31, 2020	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan	Mitsubishi Chemical Corporation	Japan
Jul. 16, 2018-Nov. 30, 2020	Postdoc, Kyushu University	Japan	Researcher, Toyohashi University of Technology	Japan	Research Assistant Professor, Toyohashi University of Technology	Japan
Apr. 1, 2013-Mar. 31, 2015	Kyushu University	Japan	Postdoc, Kyushu University	Japan	Assistant Professor, Kyushu University	Japan
Apr. 1, 2014-Nov. 30, 2019	PhD Student, Kyoto University	Japan	Assistant Professor, Kyushu University	Japan	Associate Professor, Kyushu University	Japan
Apr. 1, 2019-Jan. 31, 2020	Associate Professor, Dalian University of Technology	China	Research cooperator, Zurich University of Applied Sciences	Switzerland	Research cooperator, Zurich University of Applied Sciences	Switzerland
Apr. 1, 2019-Nov. 30, 2020	PhD Student, Kyushu University	Japan	Postdoc, Tohoku Univeristy	Japan	Postdoc, Tohoku Univeristy	Japan
Nov. 1, 2019-Mar. 31, 2022	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan	Assistant Professor, Kyushu University	Japan
Jan. 1, 2020-Apr. 30, 2021	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan	Research support staff, Kyushu University	Japan
Apr. 1, 2021-Mar. 31, 2022	Research Professor, Mie University	Japan	Professor, Hirosaki University	Japan	Professor, Hirosaki University	Japan
Apr. 1, 2021-Mar. 31, 2022	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan
Jun. 1, 2021-Mar. 31, 2022	Researcher, Kanazawa University	Japan	Postdoc, Kyushu University	Japan	Assistant Professor, Kyushu University	Japan
Apr. 1, 2022-Mar. 31, 2022	Ph.D, Tokyo Metropolitan University	Japan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan
Apr. 1, 2022-Mar. 31, 2023	Ph.D, Kyushu University	Japan	School of Economics, Kyushu University	Japan	Lecturer,School of Economics,KU	Japan

Overseas Postdocs

Employment period	Position before employed at WPI center		Next position after WPI center		Position as of April 2023*		Nationality
	Position title, organization	Country where the organization is located	Position title, organization	Country where the organization is located	Position title, organization	Country where the organization is located	
Jan. 16, 2012-Nov. 14, 2017	Postdoc, Imperial College London	UK	NONE (unknown)		NONE (unknown)		UK
Apr. 1, 2012-Mar. 31, 2018	Postdoc, Kyushu University	Japan	Associate Professor, Yamaguchi University	Japan	Associate Professor, Yamaguchi University	Japan	French
Sep. 1, 2012-Dec. 31, 2017	Postdoc, Northwestern University	USA	Assistant Professor, University of Illinois at Urbana-Champaign	USA	Assistant Professor, University of Illinois at Urbana-Champaign	USA	USA

Dec. 1, 2012-Jan. 30, 2015	Postdoc, Kyushu University	Japan	Associate Research Fellow, Wenzhou Institute of Biomaterials and Engineering	China	NONE (unknown)		Chinese
Dec. 1, 2012-Mar. 25, 2016	JSPS Postdoc, Tohoku Univesity	Japan	Professor, Huazhing University of Science and Technology	China	Professor, Huazhong University of Science and Technology	China	Chinese
Apr. 1, 2013-Jan. 31, 2014	PhD Student, Tokyo Institute of Technology	Japan	Postdoc, Eindhoven University of Technology	Holland	Research Associate, University of St Andrews	UK	Chinese
Apr. 1, 2013-Nov. 30, 2014	Postdoc Researcher, JST(ERATO)	Japan	Postdoc, Singapore University of Technology and Design	Singapore	Postdoc, Singapore University of Technology and Design	Singapore	Burmese
Apr. 1, 2013-Mar. 31, 2015	Postdoc, Kyushu University	Japan	Assistant Professpr, I2CNER	Japan	Associate Professpr, I2CNER	Japan	Iranian
Apr. 1, 2013-Apr. 30, 2015 Jun. 1, 2015-Jul. 17, 2015	PhD Student, Yale University	USA	Assistant Professor, North Dakota State University	USA	Assistant Prof., North Dakota State University	USA	USA
Apr. 1, 2013-Mar. 30, 2016	Postdoc, Kyushu University	Japan	Assistant Professor, Tanta University	Egypt	Professor, Tanta University	Egypt	Egyptian
Apr. 1, 2013-Mar. 31, 2016	PhD Student, Kyushu University	Japan	Assistant Professor, Yamaguchi University	Japan	Assistant Prof., Yamaguchi University	Japan	Chinese
Oct. 1, 2013-Nov. 30, 2018	PhD Student, University of Edinburgh	UK	Lecturer, University of Edinburgh	UK	Lecturer,University of Edinburgh	UK	Spanish
Oct. 1, 2013-Present	JSPS Postdoc, Kyushu University	Japan	Assistant Professor, I2CNER	Japan	Assistant Professor, I2CNER	Japan	Cameroonian
Nov. 1, 2013-Dec. 30, 2013	Lecturer, Sriwijaya University	Indonesia	Researcher, Sriwijaya University	Indonesia	Researcher, Sriwijaya University	Indonesia	Indonesian
Jan. 1, 2014-Feb. 28, 2019	Postdoc, University of Kitakyushu	Japan	Assistant Professor, I2CNER	Japan	Associate Professor ,Q-PIT, Kyushu University	Japan	Ukrainian
Feb. 1, 2014-Oct. 30, 2018	Postdoc, Kyushu University	Japan	Assistant Professor, I2CNER	Japan	Assistant Professor, University of Tsukuba	Japan	Chinese
Feb. 1, 2014-Mar. 31, 2015	Research Support Staff, Hokkaido University	Japan	Postdoc, University of Wisconsin-Madison	USA	Associate Professor, Southern University of Technology and Science	China	Chinese
Apr. 1, 2014-Apr. 15, 2015	Postdoc, Kyushu University	Japan	Chief Operating Officer/Principal Scientist, Akron Ascent Innovations	USA	Chief Operating Officer and Principal Scientist, Akron Ascent Innovation	USA	USA
May 1, 2014-Aug. 31, 2014	Postdoc, Kyushu University	Japan	Assistant Professor, Pukyung National University	Korea	Professpr, Pukyung National University	Korea	Korean
Nov. 1, 2014-Jul. 31, 2015	PhD Student, University of Edinburgh	UK	JSPS Postdoc, Kyushu University	Japan	Lecturer, University of East Anglia	UK	Greece
Mar. 16, 2015-Apr. 19, 2019	PhD Student, National University of Singapore	Singapore	Research Assistant Professor, Lulea University of Technology	Sweden	Assistant Professor, Birla Institute of Technology and Science, Pilani	India	Indian
Apr. 1, 2015-Mar. 31, 2018	PhD Student, Kyushu University	Japan	NONE (unknown)		NONE (unknown)		Vietnamese
Dec. 1, 2015-Dec. 19, 2016	JSPS Postdoc, NIMS	Japan	Researcher, Charles University in Prague	Czech	Postdoc Researcher, Charles University in Prague	Czech	Czech

Dec. 1, 2015-Mar.31.2020	PhD Student, University of Southampton	UK	Researcher, KYODO YUSHI CO., LTD.	Japan	Researcher, KYODO YUSHI CO., LTD.	Japan	Romanian
Jan. 16, 2016-Dec. 22, 2017	PhD Student, Jawaharlal Nehru Centre for Advanced Scientific Research	India	Research Fellow, University of Warwick	UK	Research Fellow, University of Warwick	UK	Indian
Mar. 1, 2016-Sep. 30, 2016	Postdoc, Kyushu University	Japan	Assistant Professor, Nanjing Tech University	China	Associate Professor, Jinan University	China	Chinese
Mar. 1, 2016-Oct. 10, 2017	Researcher, Sebelas Maret Univesity	Indonnesia	Assistant Professor, Sebelas Maret University	Indonesia	Assistant Professor, Sebelas Maret University	Indonesia	Indonesian
Apr. 1, 2016-May. 31, 2017	PhD Student, Kyoto Institute of Technology,	Japan	Analyst, Bangchak Corporation Public Company Limited	Thailand	Analyst, Bangchak Corporation Public Company Limited	Thailand	Thai
May 1, 2016-Jul. 14, 2017	Postdoc, Kyushu University	Japan	Research Professor, Ningbo Institute of Industrial Technology,	China	Research Professor, Ningbo Institute of Industrial Technology	China	Chinese
May 16, 2016-Oct. 11, 2017	PhD Student, Indian Institute of Science, Bangalore	India	Postdoc, Indian Institute of Technology Kharagpur	India	Assistant Professor, Indian Institute of Technology Kharagpur	India	Indian
May 16, 2016-Nov. 8, 2018	PhD Student, Imperial College London	UK	Postdoc, University of Bath	UK	NONE (unknown)		Chinese
Jun. 1, 2016-Aug. 31, 2017	Postdoc, Kyushu University	Japan	Assistant Professor, China University of Petroleum	China	Assistant Professor, China University of Petroleum	China	Chinese
Sep. 1, 2016-Nov. 30, 2018	Assistant Professor, Jagannath University	Bangladesh	Associate Professor, Jagannath University	Bangladesh	Professor Jagannath University	Bangladesh	Bangladeshi
Oct. 1, 2016-Mar. 31, 2018	Research Assistant Professor, Hangyang University	Korea	Assistant Professor, Hokkaido University	Japan	Assistant Professor, Hokkaido University	Japan	Chinese
Nov. 1, 2016-Mar. 31, 2018	Postdoc, Kyushu University	Japan	Yanmar Co. Ltd., Japan	Japan	Yanmar Co. Ltd.	Japan	German
Nov. 16, 2016-Mar. 31, 2019	Postdoc, Norweigian University of Science and Technology	Norway	Invited researcher, University of Oslo	Norway	Invited researcher, University of Oslo	Norway	French
Dec. 1, 2016-Aug. 9, 2018	Postdoc, Kyushu University	Japan	Lecturer, University of East Anglia in Norwich	UK	Lecturer, University of East Anglia	UK	Greece
Dec. 1, 2016-Sep. 30, 2018	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan	NONE (unknown)	Japan	Bulgarian
Jan. 1, 2017-Aug.30.2019	Researcher, University of Toronto	Canada	Assistant Professor, University of Quebec, Canada	Japan	Assistant Professor, Institut national de la recherche scientifique	Canada	Indian
Jan. 1, 2017-Nov.20. 2019	PhD Student, University of Girona	Spain	Researcher, Universitat de Girona	Spain	Researcher, Universitat de Girona	Spain	Spanish
Apr. 1, 2017-Mar. 31, 2021	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan	NONE (unknown)	Japan	Thai
May. 1, 2017-Mar. 31, 2018	Researcher, National Central University	Taiwan	Postdoc, Academia Sinica	Taiwan	Postdoc, Academia Sinica	Taiwan	Taiwanese
Jun. 1, 2017-Mar.31.2021	PhD Student, Huazhong University of Science and Technology	China	Researcher, Waseda University	Japan	Researcher, Waseda University	Japan	Chinese

Jun. 1, 2017-Jan.31.2022	Postdoc, Karlsruhe Institute of Technology	Germany	Application Scientist, Zurich Instruments, Zurich, Switzerland	Japan	Application Scientist, Zurich Instruments	Switzerland	German
Oct. 1, 2017-Jul.12,2019	Research Support Staff, I2CNER	Japan	Senior Research Engineer,Hansol Chemical	South Korea	Senior Research Engineer,Hansol Chemical	South Korea	Korean
Oct. 1, 2017-May 31.2021	PhD Student, Daegu Gyeongbuk Institute of Science and Technology	South Korea	Assistant Professor, Vellore Institute of Technology	India	Assistant Professor, Vellore Institute of Technology	India	Indian
Dec. 1, 2017-Mar. 31, 2018	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan	Manager Strategic Projects / Assistant to the CTO, Freudenberg Group	Germany	Swiss
Dec. 1, 2017-Dec. 31, 2018	Postdoc, Kyushu University	Japan	Research associate, Imperial college	London	Postdoctoral Fellow, Universite de Bordeaux	France	Chinese
Dec. 16, 2017-Mar.31, 2020	PhD Student, Tulane University	USA	Research Associate, Leipzig University	Germany	Research Associate, Leipzig University	Germany	Chinese
Dec. 16, 2017-Jan. 31, 2019	Postdoc, Sungkyunkwan University	Korea	SAMSUNG Electronics	South Korea	Research Associate, Imperial College London	UK	Korean
Mar. 1, 2018-Sep.30, 2019	Research Associate, Akita University	Japan	Researcher, Research Institute for Humanity and Nature	Japan	Researcher, Research Institute for Humanity and Nature	Japan	Iranian
Apr. 1, 2018-Mar. 31, 2020	Postdoc, University of Tokyo	Japan	Postdoc, Kyushu Institute of Technology, Japan	Japan	Assistant Professor, Kyushu University	Japan	Chinese
May. 16, 2018-Present	Postdoc,National Taiwan University	Taiwan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Indian
Jun. 16, 2018-Mar. 31, 2020	Lecturer and Researcher, Institute of Technology Bandung	Indonesia	Assistant Professor, Bandung Institute of Technology	Japan	Assistant Professor, Bandung Institute of Technology	Indonesia	Indonesian
Oct. 1, 2012-Mar. 31, 2016	Postdoc, Kyushu University	Japan	NONE (unknown)		NONE (unknown)		Korean
Apr. 16, 2013-Nov. 30, 2015	Postdoc, CNRS	France	NONE (unknown)		NONE (unknown)		Iranian
Apr. 1, 2019-Mar. 31, 2020	Postdoc, Kyushu University	Japan	Researcher, Kyushu Institute of Technology	Japan	Researcher, Kyushu Institute of Technology	Japan	Chinese
Jun. 16, 2019-Nov. 14, 2019	PhD Student, Kyushu University	Japan	Lecturer, University of Dhaka	Bangladesh	Assistant Professor, University of Dhaka	Bangladesh	Bangladeshi
Oct. 16, 2019-Mar. 31, 2020	PhD Student, Kyushu University, Japan	Japan	Postdoc, Kyushu University, Japan	Japan	Postdoc, Kyushu University	Japan	Chinese
Oct. 16, 2019-Mar. 31, 2020	PhD Student, Kyushu University, Japan	Japan	Senior Lecturer, University of Sri Jayewardenepura	Sri Lanka	Senior Lecturer, University of Sri Jayewardenepura	Sri Lanka	Sri Lankan
Nov. 1, 2019-Nov. 30, 2019	Technical staff, The National Institute of Advanced Industrial Science and Technology	Japan	Researcher, Tokyo Institute of Technology	Japan	Researcher, Shokubai Wang Institute	Japan	Chinese
Dec. 1, 2019-Mar. 31, 2020	Postdoc, Kyushu University	Japan	Postdoc, Kyushu University	Japan	Postdoc, Korea Institute of Industrial Technology	South Korea	Korean
Mar. 1, 2020-Mar. 31, 2022	Postdoc, Massachusetts Institute of Technology (MIT)	USA	Postdoc, Kyushu Univeristy	Japan	Postdoc, Kyushu Univeristy	Japan	Korean

Oct. 1, 2020-Jul.31, 2021	Postdoc, Kyushu University	Japan	NONE (unknown)		NONE (unknown)		Chinese
Oct. 1, 2020-	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Taiwanese
Nov. 1, 2020-	Postdoctoral Reseacher, Institute for Chemical Research, Kyoto University	Japan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Taiwanese
Feb. 1, 2021-Mar. 31, 2021	Postdoc, I2CNER	Japan	Lecturert, Institut Teknologi Bandung	Indonesia	Lecturert, Institut Teknologi Bandung	Indonesia	Indonesian
Apr. 1, 2021-Sep. 30, 2022	Postdoc, Kyushu University	Japan	Designated Associate prof., Nagoya University	Japan	Designated Associate prof., Nagoya University	Japan	Czech
Apr. 1, 2021-Oct. 31, 2021	Postdoc, Kyushu University	Japan	Research associate, University of Cambridge	UK	Research associate, University of Cambridge	UK	Mongolian
Jan. 1, 2022-	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Bangladeshi
Feb. 1, 2022-	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Indian
Feb. 1, 2022-	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Bangladeshi
Feb. 1, 2022-	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Vietnamese
Apr. 1, 2022-	Postdoc, Utsunomiya University, Tochigi	Japan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Bangladeshi
Jun. 1, 2022-	Asst. Manager,Energon Labs Private Limited, Hyderabad	India	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Indian
Sep. 16, 2022-	Postdoc, National Yunlin University of Science and Technology	Taiwan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Vietnamese
Sep. 16, 2022-	Postdoc, Anna University	India	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Indian
Oct. 1, 2022-Mar. 31, 2023	Postdoc, I2CNER	Japan	Assistant Professor, Nagaoka University of Technology	Japan	Assistant Professor, Nagaoka University of Technology	Japan	Chinese
Oct. 1, 2022-Mar. 31, 2023	Postdoc, I2CNER	Japan	NONE (unknown)		NONE (unknown)		Sri Lankan
Nov. 1, 2022-	Device Engineer,KOALA Tech. Inc	Japan	Postdoc, I2CNER	Japan	Postdoc, I2CNER	Japan	Sri Lankan

Project Expenditures FY2020

（Thousand yens）

	Amount	Details	Operational subsidies to National University Corporations/Incorporated Administrative Agency		Funding by WPI Academy		Government Subsidies except Funding from WPI Academy		Donations		Indirect funding		Joint research projects		Competitive funding		Others	
			Total costs	Details (no. of persons)	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details
Personnel	384,836	Operational subsidies to National University Corporations/Incorporated Administrative Agency	9,000	Center director 1							15,157						35,902	
	29,241	Funding by WPI Academy		Administrative director														
	-	Government Subsidies except Funding from WPI Academy	149,709	Principal investigators 16	-	Principal investigators 0	-	0	-	0	-	0	-	0	-	0	-	0
	-	Donations	45,872	・Full-time／Japanese 4		・Full-time／Japanese												
	15,157	Indirect funding	73,580	・Concurrent／Japanese 9		・Concurrent／Japanese												
	-	Joint research projects	30,257	・Full-time／Overseas 3		・Full-time／Overseas												
	-	Competitive funding		・Concurrent／Overseas		・Concurrent／Overseas												
	35,902	Others	155,076	Other researchers 39	21,065	Other researchers 4	-	0	-	0	-	0	-	0	-	0	-	0
			35,033	・Professor 9		・Professor												
			84,902	・Associate professor 17		・Associate professor												
			35,141	・Others 13	21,065	・Others 4												
				Postdocs		Postdocs												
				Research support staffs		Research support staffs		Research support staffs										
			71,051	Administrative staffs 12	8,176	Administrative staffs 3		Administrative staffs										
Subtotal	465,136		384,836	68	29,241	7	-	0	-	0	15,157	0	-	0	-	0	35,902	0
Project activities	11	Operational subsidies to National University Corporations/Incorporated Administrative Agency	11		360	Honorarium					64,846						29,861	
	12,664	Funding by WPI Academy			1,738	Interdisciplinary Research Fund												
	-	Government Subsidies except Funding from WPI Academy			7,924	Outreach expenses												
	-	Donations			274	Consumables costs												
	64,846	Indirect funding			2,368	Others												
	-	Joint research projects																
	-	Competitive funding																
	29,861	Others																
Subtotal	107,382		11		12,664		-		-		64,846		-		-		29,861	
Travel	3,085	Operational subsidies to National University Corporations/Incorporated Administrative Agency	3,085								238						373	
	-	Funding by WPI Academy																
	-	Government Subsidies except Funding from WPI Academy																
	-	Donations																
	238	Indirect funding																
	-	Joint research projects																
	-	Competitive funding																
	373	Others																
Subtotal	3,696		3,085		-		-		-		238		-		-		373	
Equipment	-	Operational subsidies to National University Corporations/Incorporated Administrative Agency			313	75 inch 4K Display					13,006						2,490	
	2,415	Funding by WPI Academy			2,102	Interdisciplinary Research Fund												
	-	Government Subsidies except Funding from WPI Academy																
	-	Donations																
	13,006	Indirect funding																
	-	Joint research projects																
	-	Competitive funding																
	2,490	Others																
Subtotal	17,911		-		2,415		-		-		13,006		-		-		2,490	
Research projects	-	Operational subsidies to National University Corporations/Incorporated Administrative Agency							15,175				129,851		178,164	Grants-in-Aid for Scientific Researc	864,091	
	-	Funding by WPI Academy													1,792	R&D promotion project for national issues		
	-	Government Subsidies except Funding from WPI Academy													2,783	SICORP		
	15,175	Donations													85,579	Strategic Basic Research Programs		
	-	Indirect funding													4,543	MIRAI Program		
	129,851	Joint research projects													90	Strategic basic technology advancement support project		
	272,951	Competitive funding																
	864,091	Others																
Subtotal	1,282,068		-		-		-		15,175		-		129,851		272,951		864,091	
Others	-	Operational subsidies to National University Corporations/Incorporated Administrative Agency																
	-	Funding by WPI Academy																
	-	Government Subsidies except Funding from WPI Academy																
	-	Donations																
	-	Indirect funding																
	-	Joint research projects																
	-	Competitive funding																
	-	Others																
Subtotal	-		-		-		-		-		-		-		-		-	
Total	1,876,193		387,932		44,320		-		15,175		93,247		129,851		272,951		932,717	

Operational subsidies to National University Corporations/Incorporated Administrative Agency	運営費交付金
Funding by WPI Academy	WPIアカデミー国際頭脳循環の加速・拡大事業
Government Subsidies except Funding from WPI Academy	機関補助金（WPIアカデミー国際頭脳循環の加速・拡大事業を除く）
Donations	寄付金
Indirect funding	間接経費
Joint research projects	共同研究費
Competitive funding	競争的資金
Others	その他

Project Expenditures FY2021

(Thousand yens)

	Amount	Details	Operational subsidies to National University Corporations/Incorporated Administrative Agency			Funding by WPI Academy			Government Subsidies except Funding from WPI Academy		Donations		Indirect funding		Joint research projects		Competitive funding		Others	
			Total costs	Details (no. of persons)		Total costs	Details		Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details
Personnel	400,753	Operational subsidies to National University Corporations/Incorporated Administrative Agency	12,000	Center director	1								39,455						957	
	31,011	Funding by WPI Academy		Administrative director																
	-	Government Subsidies except Funding from WPI Academy	153,897	Principal investigators	17	-	Principal investigators	0	-	0	-	0	-	0	-	0	-	0	-	0
	-	Donations	48,104	・Full-time／Japanese	4		・Full-time／Japanese													
	39,455	Indirect funding	74,538	・Concurrent／Japanese	10		・Concurrent／Japanese													
	-	Joint research projects	31,255	・Full-time／Overseas	3		・Full-time／Overseas													
	-	Competitive funding		・Concurrent／Overseas			・Concurrent／Overseas													
	957	Others	161,204	Other researchers	40	19,728	Other researchers	3	-	0	-	0	-	0	-	0	-	0	-	0
			31,682	・Professor	8		・Professor													
			93,821	・Associate professor	19		・Associate professor													
			35,701	・Others	13	19,728	・Others	3												
				Postdocs			Postdocs													
				Research support staffs			Research support staffs			Research support staffs										
			73,652	Administrative staffs	10	11,283	Administrative staffs	4		Administrative staffs										
Subtotal	472,176		400,753		68	31,011		7	-	0	-	0	39,455	0	-	0	-	0	957	0
Project activities	18,710	Operational subsidies to National University Corporations/Incorporated Administrative Agency	18,710			330	Honorarium						72,090						31,263	
	19,336	Funding by WPI Academy				14,766	Interdisciplinary Research Fund													
	-	Government Subsidies except Funding from WPI Academy				1,748	Outreach expenses													
	-	Donations					Consumables costs													
	72,090	Indirect funding				2,492	Others													
	-	Joint research projects																		
	-	Competitive funding																		
	31,263	Others																		
Subtotal	141,399		18,710			19,336			-		-		72,090		-		-		31,263	
Travel	-	Operational subsidies to National University Corporations/Incorporated Administrative Agency											1,706						353	
	-	Funding by WPI Academy																		
	-	Government Subsidies except Funding from WPI Academy																		
	-	Donations																		
	1,706	Indirect funding																		
	-	Joint research projects																		
	-	Competitive funding																		
	353	Others																		
Subtotal	2,059		-			-			-		-		1,706		-		-		353	
Equipment	44,882	Operational subsidies to National University Corporations/Incorporated Administrative Agency	44,882			7,153	Interdisciplinary Research Fund						23,557						13,006	
	7,153	Funding by WPI Academy																		
	-	Government Subsidies except Funding from WPI Academy																		
	-	Donations																		
	23,557	Indirect funding																		
	-	Joint research projects																		
	-	Competitive funding																		
	13,006	Others																		
Subtotal	88,598		44,882			7,153			-		-		23,557		-		-		13,006	
Research projects	-	Operational subsidies to National University Corporations/Incorporated Administrative Agency									12,882				185,488		141,753	Grants-in-Aid for Scientific Researc	774,992	
	-	Funding by WPI Academy															1,815	R&D promotion project for national issues		
	-	Government Subsidies except Funding from WPI Academy															3,716	SICORP		
	12,882	Donations															41,599	Strategic Basic Research Programs		
	-	Indirect funding															32,743	MIRAI Program		
	185,488	Joint research projects															6,743	Strategic basic technology advancement support project		
	230,669	Competitive funding															2,300	A-STEP		
	774,992	Others																		
Subtotal	1,204,031		-			-			-		12,882		-		185,488		230,669		774,992	
Others	-	Operational subsidies to National University Corporations/Incorporated Administrative Agency																		
	-	Funding by WPI Academy																		
	-	Government Subsidies except Funding from WPI Academy																		
	-	Donations																		
	-	Indirect funding																		
	-	Joint research projects																		
	-	Competitive funding																		
	-	Others																		
Subtotal	-		-			-			-		-		-		-		-		-	
Total	1,908,263		464,345			57,500			-		12,882		136,808		185,488		230,669		820,571	

Operational subsidies to National University Corporations/Incorporated Administrative Agency	運営費交付金
Funding by WPI Academy	WPIアカデミー国際頭脳循環の加速・拡大事業
Government Subsidies except Funding from WPI Academy	機関補助金（WPIアカデミー国際頭脳循環の加速・拡大事業を除く）
Donations	寄付金
Indirect funding	間接経費
Joint research projects	共同研究費
Competitive funding	競争的資金
Others	その他

Project Expenditures FY2022

（Thousand yens）

	Amount	Details	Operational subsidies to National University Corporations/Incorporated Administrative Agency		Funding by WPI Academy		Government Subsidies except Funding from WPI Academy		Donations		Indirect funding		Joint research projects		Competitive funding		Others	
			Total costs	Details (no. of persons)	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details	Total costs	Details
Personnel	400,221	Operational subsidies to National University Corporations/Incorporated Administrative Agency	12,000	Center director 1							35,243						11,066	
	16,276	Funding by WPI Academy		Administrative director														
	-	Government Subsidies except Funding from WPI Academy	133,026	Principal investigator 15	-	Principal investigator 0	-	0	-	0	-	0	-	0	-	0	-	0
	-	Donations	36,178	・Full-time／Japane 3		・Full-time／Japanese												
	35,243	Indirect funding	64,819	・Concurrent／Japa 9		・Concurrent／Japanese												
	-	Joint research projects	32,029	・Full-time／Overse 3		・Full-time／Overseas												
	-	Competitive funding		・Concurrent／Overseas		・Concurrent／Overseas												
	11,066	Others	164,827	Other researchers 44	13,630	Other researchers 2	-	0	-	0	-	0	-	0	-	0	-	0
			34,398	・Professor 9		・Associate professor /Assistant professor												
			95,110	・Associate professor 22		・Associate professor /Assistant professor												
			35,319	・Others 13	13,630	・Others 2												
				Postdocs		Postdocs												
				Research support staffs		Research support staffs		Research support staffs										
			90,368	Administrative staffs 13	2,646	Administrative staffs 1		Administrative staffs										
Subtotal	462,806		400,221	73	16,276	3	-	0	-	0	35,243	0	-	0	-	0	11,066	0
Project activities	25,109	Operational subsidies to National University Corporations/Incorporated Administrative Agency	25,109		366	Honorarium					51,882						28,405	
	12,284	Funding by WPI Academy			2,749	Interdisciplinary Research Fund												
	-	Government Subsidies except Funding from WPI Academy			1,970	Outreach expenses												
	-	Donations			7,199	Others												
	51,882	Indirect funding																
	-	Joint research projects																
	-	Competitive funding																
	28,405	Others																
Subtotal	117,680		25,109		12,284		-		-		51,882		-		-		28,405	
Travel	3,043	Operational subsidies to National University Corporations/Incorporated Administrative Agency	3,043		16,560						5,407						2,448	
	16,560	Funding by WPI Academy																
	-	Government Subsidies except Funding from WPI Academy																
	-	Donations																
	5,407	Indirect funding																
	-	Joint research projects																
	-	Competitive funding																
	2,448	Others																
Subtotal	27,458		3,043		16,560		-		-		5,407		-		-		2,448	
Equipment	1,495	Operational subsidies to National University Corporations/Incorporated Administrative Agency	1,495		682	magnetron-sputter					8,650						433	
	1,243	Funding by WPI Academy			561	Interdisciplinary Research Fund												
	-	Government Subsidies except Funding from WPI Academy																
	-	Donations																
	8,650	Indirect funding																
	-	Joint research projects																
	-	Competitive funding																
	433	Others																
Subtotal	11,821		1,495		1,243		-		-		8,650		-		-		433	
Research projects	-	Operational subsidies to National University Corporations/Incorporated Administrative Agency							8,055				352,164		137,250	Grants-in-Aid for Scientific Research	1,046,120	
	-	Funding by WPI Academy													6,224	R&D promotion project for national issues		
	-	Government Subsidies except Funding from WPI Academy													3,125	SICORP		
	8,055	Donations													38,781	Strategic Basic Research Programs		
	-	Indirect funding													87	Fusion Oriented Research for disruptive Science and Technology		
	352,164	Joint research projects													1,800	MIRAI Program		
	187,267	Competitive funding																
	1,046,120	Others																
Subtotal	1,593,606		-		-		-		8,055		-		352,164		187,267		1,046,120	
Others	-	Operational subsidies to National University Corporations/Incorporated Administrative Agency																
	-	Funding by WPI Academy																
	-	Government Subsidies except Funding from WPI Academy																
	-	Donations																
	-	Indirect funding																
	-	Joint research projects																
	-	Competitive funding																
	-	Others																
Subtotal	-		-		-		-		-		-		-		-		-	
Total	2,213,371		429,868		46,363		-		8,055		101,182		352,164		187,267		1,088,472	

Operational subsidies to National University Corporations/Incorporated Administrative Agency	運営費交付金
Funding by WPI Academy	WPIアカデミー国際頭脳循環の加速・拡大事業
Government Subsidies except Funding from WPI Academy	機関補助金（WPIアカデミー国際頭脳循環の加速・拡大事業を除く
Donations	寄付金
Indirect funding	間接経費
Joint research projects	共同研究費
Competitive funding	競争的資金
Others	その他

Appendix 4 Outreach Activities and Their Results

List up to three of the Center's outreach activities carried out during the period between FY 2019 and 2022 that have contributed to enhancing the brand or recognition of your Center and/or the brand of the overall WPI program, and describe its concrete contents and effect in narrative style. (Where possible, indicate the results in concrete numbers.)

Examples:
- As a result of using a new OO press-release method, a OO% increase in media coverage was obtained over the previous year.
- By holding seminars for the public that include people from industry, requests for joint research were received from companies.
- We changed our public relations media. As a resulting of using OO to disseminate information, a OO% increase in inquiries from researchers was obtained over the previous year.
- As a result of vigorously carrying out OO outreach activity, ¥OO in external funding was acquired.

Enter a list of your outreach activities in Attachment 4a.

Example 1: 2019 E-MRS Spring Meeting *(May 27-31, 2019)*

(Description)

WPI was represented by four WPI centers, including I^{2}CNER, at the European Materials Research Society (E-MRS) 2019 Spring Meeting in Nice, France. Founded in 1983, the E-MRS now has more than 4,000 members. I^{2}CNER, along with AIMR, iCeMS and MANA, ran a WPI booth throughout the event, and outreach staff from the four WPI centers answered questions and described the centers' unique research environments and significant achievements. The booth attracted researchers from a diverse range of fields and countries, including both senior scientists, many of whom had collaborated with Japanese researchers or had stayed in Japan, and young researchers who were interested in exploring opportunities for advancing their careers at institutions in Japan.

Example 2: A series of press releases regarding "Direct Air Capture of CO_2" *(October 2020-February2022)*

(Description)

As a result of a series of the press releases regarding the "Direct Air Capture: Membranes for capturing carbon dioxide from the air", the project has been introduced on NHK's "Science Zero" , NHK World's "Science View", Nikkei Shimbun and Nikkan Kogyo Shimbun, which has contributed to improving the visibility of the WPI-I^{2}CNER.

Example 3: Kyushu University Energy Week 2023 *(January 30-February 3, 2023)*

(Description)

Kyushu University Energy Week 2023 was held January 30 to February 3, 2023, featuring symposia concerning energy on the theme of "Energy Intelligence beyond Borders: Opening the Path to Future Energy and Energy Security with Integrative Knowledge." At this symposium, energy-related organizations inside and outside the university collaborated to hold international workshops, industry-academia-government collaboration workshops, etc., and played a role as a place for interaction that functions as an international hub for energy researchers. The I^{2}CNER Annual Symposium, I^{2}CNER Thrust Workshop, I^{2}CNER-HYDROGENIUS Joint Research Symposium and I^{2}CNER-IMI joint international workshop, were all held during Energy Week. This time, the 7th time, it was mostly held in a hybrid format including researchers who are active in Japan and overseas, as well as researchers, students, industry, and others who are engaged in a wide range of energy-related research. A total of approximately 2,000 people attended the event.

Appendix 4a State of Outreach Activities from FY 2019 to FY 2022

* For each activity, enter the number of times that the activity was held each fiscal year.

Activities	FY 2019 (number of activities, times held)	FY 2020 (number of activities, times held)	FY 2021 (number of activities, times held)	FY 2022 (number of activities, times held)
PR brochure, pamphlet	3	3	1	3
Lectures, seminars for general public	11	6	10	13
Teaching, experiments, training for elementary, secondary and high school students	13	6	7	8
Science café	1	0	1	1
Open house	1	1	1	1
Participating, exhibiting in events	1	3	3	1
Press releases	17	16	15	15
Others (I^{2}CNER Special Lecture)	0	0	0	2

*If there are activities that the center hasn't implemented, delete those lines. If you have other activities, list them in the space between parentheses after "Others" and state the number of times they were held in the spaces on the right. Another line under "Others" can be added, if needed.

<Notes>