World Premier International Research Center Initiative (WPI)
FY 2017 WPI Project Progress Report

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Research Center	International Institute for Carbon Neutral Energy Research	Center Director	Petros Sofronis

Common instructions:
* Unless otherwise specified, prepare this report from the timeline of 31 March 2018.
* So as to base this fiscal year's follow-up review on the "last" center project, please prepare this report from the perspective of the latest project plan.
* Use yen (¥) when writing monetary amounts in the report. If an exchange rate is used to calculate the yen amount, give the rate.
* Please prepare this report within 10-20 pages (excluding the appendices, and including Summary of State of WPI Center Project Progress (within 2 pages)).

Summary of State of WPI Center Project Progress (write within **2 pages**)

I^2CNER's grand challenge is to develop the foundations for the engineering of energy systems that will address Japan's future energy needs and contribute to the reduction of the nation's CO_2 emissions by 70% from the 1990 levels by 2050. To carry out its mission, I^2CNER's research is driven by well-defined milestones and targets that are identified in roadmaps of the underlying technologies. Our roadmaps are developed through a close collaboration between the technical divisions and the Energy Analysis Division (EAD). The impact of I^2CNER's research on CO_2 emission reductions is summarized in an I^2CNER CO_2 Report, entitled "Toward 2050: Contributing to a Low Carbon Energy Society," which outlines both the direct CO_2 reductions enabled by I^2CNER research thrusts and the industry contributions which are underpinned by these innovations. This Report specifically estimates our ongoing efforts in comparison to competing (or complementary) industries, and also factors in the technological areas in which we do not compete (nuclear energy, for example). Thus, as a result of our current accomplishments, approximately 0.42% of the total required CO_2 reductions, and as a result of our projected future achievements, approximately 5.38% of the total required reductions can be realized by I^2CNER technologies and innovations if they are applied to appropriate energy systems. Significantly, in addition to I^2CNER's direct contributions, development and implementation of I^2CNER's relevant technology efforts will account for a further 35.3% of the 2050 target, which demonstrates that I^2CNER's research efforts underpin impactful energy technologies. Lastly, the positive impact of I^2CNER's accomplishments, not only on science, engineering, and offsetting CO_2, but also on employment, the active transfer of technology to industry, influence on social and academic impacts including education and cultural exchange, and international partnerships, is described in detail by a living document entitled "Powering the Future: Economic, Environmental, and Social Impacts of I^2CNER," which was compiled by I^2CNER last March.

Conducting research of the highest world level: The relevance of the I^2CNER research efforts and objectives to enabling the green innovation initiative of the government of Japan is demonstrated by the 24 new collaborative industrial projects in FY2017 (104 in total since inception) in which its researchers are involved with industry. A total of 14 (48 in total since inception) projects resulted in technology transfer events. In FY2017, I^2CNER filed for 28 (219 in total since inception) patents and was granted 13 (59 in total since inception) patents (some of which were applied for in or before FY2016). In addition, in FY2017, I^2CNER researchers received 24 (252 in total since inception) national and international awards (including best oral, poster, and encouragement presentation awards for young researchers) from various societies and institutions around the world. As an Institute, in FY2017, we realized 5 (19 in total since inception) and made significant progress toward 2 short-term milestones and 2 targets in other projects; 4 mid-term milestones have also been realized since inception. A selection of the Institute's breakthrough results in FY2017 is as follows: a coordinated experimental and theoretical program in PI Ishihara's division which explores advanced hybrid perovskite photovoltaic device technology for hydrogen production based on novel material processing methods and supported by a multi-scale modeling technique that is being used to drive process optimization. Excellent progress has been made in PI Ogo's division on bio-mimetic catalysis of the oxidation of both H_2 and CO in one pot, which is highly relevant to our future hydrogen economy since CO is a persistent contaminant of H_2 supplies. The newly reported catalyst is based on a NiIr core, comparable in design to the active site of the iconic [NiFe]-hydrogenases and the CO-dehydrogenases (CODH), two of the most important enzymes in this area. PI Takata's

division advanced fundamental understanding of wettability and adsorption during liquid-vapor phase change by showing ultrathin water film inside open carbon nanotubes (CNTs) at high vacuum ($\sim 10^{-5}$ Pa) to be stable for the first time, and elucidated fundamental aspects governing the behavior of both short- and long-term heterogeneous nucleation on surfaces. PI Matsumoto's division reports a new electrolyte which enables high electrolyzer currents with high stability at lower temperatures, a new catalyst preparation process which yields high currents for oxygen evolution, and new detailed insights into the nature of active sites in non-precious metal oxygen reduction catalysts and the role of metal contacts for fuel cells.* PI Fujikawa's division developed membrane materials for CO_2/H_2 and CO_2/N_2 separation that set the worldwide benchmark for the highest permeance. PI Tsuji's division reported a novel continuous monitoring method to estimate spatio-temporal variation of injected CO_2 at high temporal resolution and much lower cost than existing/conventional methods. Also, the division demonstrated that the traditional view that two-phase flow in CO_2 sequestration is governed only by the capillary and viscosity ratio numbers is incomplete, and that the Reynolds number must also be considered. By employing controlled-environment experiments, PI Somerday's division demonstrated that part-per-million levels of trace gases can have profound effects on material behavior, such as friction and fracture, offering new possibilities for modifying performance of components. (* revised in the final version)

Advancing fusion of various research fields: Strengthening the collaborations with other Kyushu University (KU) units, and in particular, with the Institute of Mathematics for Industry (IMI), I^{2}CNER made significant inroads in the Applied Mathematics for Energy Initiative in FY2017. The group of PI Tsuji and Prof. Shirai (IMI) used the techniques of applied algebraic topology (known as persistence homology, a 21st century development in the field of mathematics) to quantify properties of porous materials for CO_2 sequestration. Using non-convex optimization, the group of Prof. Bose (Illinois) and Prof. Hoa (I^{2}CNER) addressed optimal production and distribution plans in uncertain situations characterized by the presence of renewable energy sources and microgeneration. The group of Profs. Murata (KU) and Hirose (IMI) deal with the patterns of energy consumption in smart grid. Prof. Murata modeled (potentially irrational) customer behavior using ideas from reinforced learning theory, and developed reverse optimization tools aimed at creating a system of incentives to shape the demand in a prescribed way. Prof. Hirose looked at statistical models to analyze the data of power consumption in order to create predictive models by clustering the energy consumers based on the patterns (time series) of their usage. Using bioinspiration, the group of Prof. Miljkovic (Illinois) is exploring the boundaries of wetting through the fusion of mechanical engineering, material science, entomology, chemistry, and biotechnology. His team was the first to show that wettability in nature is correlated with taxonomy, life cycle, and reproductive strategies, rather than habitat. In the Ogo group's *Science* publication, which fuses biochemistry with chemistry and structural biology, the crystal structure of a new form of a [NiFe]-hydrogenase enzyme in both the oxidized and reduced states was determined. The group proposed that the enzyme is able to switch geometries to either effect catalysis or to protect itself from aerobic degradation. This knowledge will be integrated into the designs of new bio-inspired catalysts.

Establishing international research environment: The international relationship between Kyushu University and Illinois continues to be strengthened. Examples include the Partnership for International Research and Education (PIRE) exchange program, which sends undergraduate students from the U.S. to Japan to conduct research at I^{2}CNER; a visit from the Dean of the KU School of Engineering, Prof. Takamatsu, to Illinois; the exchange visit of 6 KU undergraduates to Illinois for approximately 1 month; and the visits of 2 KU faculty to Illinois under the I^{2}CNER Collaborative Foreign Exchange Program, one of which was a sabbatical. Ripple effects of this productive relationship are being seen as there is now an initiative for a collaboration between the new Carle Illinois College of Medicine (CICOM) and KU's School of Medicine. In fact, this collaboration was implemented through 2 visits by KU's EVP Wakayama to Illinois, as well as a visit by the Dean of the Carle Illinois College of Medicine, Prof. King Li, to KU. Specific highlights of I^{2}CNER's globalization efforts in FY2017 include a new partnership with the University of Göttingen, led by Prof. Reiner Kirchheim and I^{2}CNER's Director, to establish an International Research Training Group that will be co-funded by the German Research Foundation (DFG) and JSPS, as well as the JSPS Core-to-Core program which provided funding for joint research carried out between I^{2}CNER, Imperial College, London, Paul Scherrer Institut, and the Massachusetts Institute of Technology. The international image of KU is also being advanced through events such as the I^{2}CNER Annual Symposium and the 12th Japan-France Workshop on Nanomaterials, which attracted 166 and 79 participants, of which 86 and 40 were from overseas, respectively. As of March 31, 2017, I^{2}CNER

has a total of 24 partner institutions in the US, Europe, and Asia. I^{2}CNER researchers hosted a grand total of 95 distinguished visitors to Kyushu University from all over the world. The Institute's researchers were responsible for organizing, co-organizing, or serving on the scientific committee for 17 international conferences, 21 international conference sessions/symposia or workshops, and 10 I^{2}CNER international workshops. In addition, in FY2017 I^{2}CNER's researchers had joint publications with researchers from 141* institutions around the world. In FY2017, I^{2}CNER placed 11 (37 in total since inception) of our researchers at various Japanese (excluding KU) and international institutions. Lastly, there were a total of 14 faculty and 3 postdoc visits from Illinois to KU in FY2017. (* revised in the final version)

Reforming the research organization: I^{2}CNER's presence at KU has precipitated the formation of the Kyushu University Platform of Inter/Transdisciplinary Energy Research (Q-PIT), which cross-pollinates a wide range of collaborations on energy research between diverse disciplines including social sciences, economics, law, and political sciences. I^{2}CNER continues to be at the center of Kyushu University's Energy Week, which is a week-long sequence of international workshops and symposia hosted by various energy research centers. I^{2}CNER has spearheaded efforts to hire female faculty and in FY2017, the following female researchers were hired: 1 Associate Professor, 1 Assistant Professor, and 3 postdocs. This brought the total number of I^{2}CNER's female researchers up to 14, which makes the percentage larger than corresponding percentages from the other sciences, math, and engineering units of KU. Among the 19 newly hired faculty and postdocs in FY2017, five were women. A huge step in reformation has been KU converting to the Academic Quarter (4-term) System in order to facilitate visiting faculty and student exchange programs from universities in the U.S., such as Illinois. Additionally, the I^{2}CNER Undergraduate Exchange Program has become such a success that a similar program is being explored for engineering graduate students between KU and Illinois.

Efforts to secure the center's future development over the mid- to long-term: On April 1, 2017, I^{2}CNER established the "Industrial Advisory Board (IAB)," whose members are prominent executives from industry, government agencies, and national laboratories who advise I^{2}CNER on opportunities for interactions with industry and technology transfer. In addition, I^{2}CNER's researchers have made every effort to secure the sustainability of the Institute beyond the WPI period by submitting proposals for external research funding. Such efforts have led to prestigious grants, such as the JSPS Core-to-Core program, as well as the creation of the Research Center for Next Generation Refrigerant Properties (NEXT-RP). These initiatives, as well as the commitment from KU on tenured faculty positions, demonstrate the permanence of I^{2}CNER and the path forward to sustainability of the Institute. As of April 1, 2018, I^{2}CNER has filled a total of 4 Associate Professor and 4 Professor Positions, with 2.75 points (approximately 3 positions) left to fill in FY2018. In addition, two tenure-track Assistant Professors were hired in the area of applied math for energy, bringing the total of tenured faculty to 10, with up to 3 more positions to be filled. To address the loss of senior PIs due to retirements, two tenured young faculty have been elevated to the PI level as of April 1, 2018.

* Please describe clearly and concisely the progress being made by the WPI center project from the viewpoints below.
- In addressing the below-listed 1-6 criteria, please place emphasis on the following:
  (1) Whether research is being carried out at a top world-level (including whether research advances are being made by fusing fields).
  (2) Whether a proactive effort continues to be made to establish itself as a "truly" world premier international research center.
  (3) Whether a steadfast effort is being made to secure the center's future development over the mid- to long-term.

1. Conducting research of the highest world level

* Regarding the criteria used when evaluating the world level of center, please note any updated results using your previous evaluation criteria and methods or any improvements you have made to those criteria and methods.

Evidence of I^{2}CNER's international stature and relevance can be seen in its 316 journal publications in FY2017, of which, 22 were published in journals with an impact factor greater than 10. In fact, the Institute's rate of productivity continues to remain high (53, 150, 263, 318, 308, 316 and 316 publications in FY2011, 12, 13, 14, 15, 16, and 17, respectively). Since its inception, 296 of the Institute's publications have been cited between 10 and 19 times, 125 have been cited 20-29 times, 48 have been cited 30-39 times, 33 have been cited 40-49 times, and 64 have been cited 50 or more times.

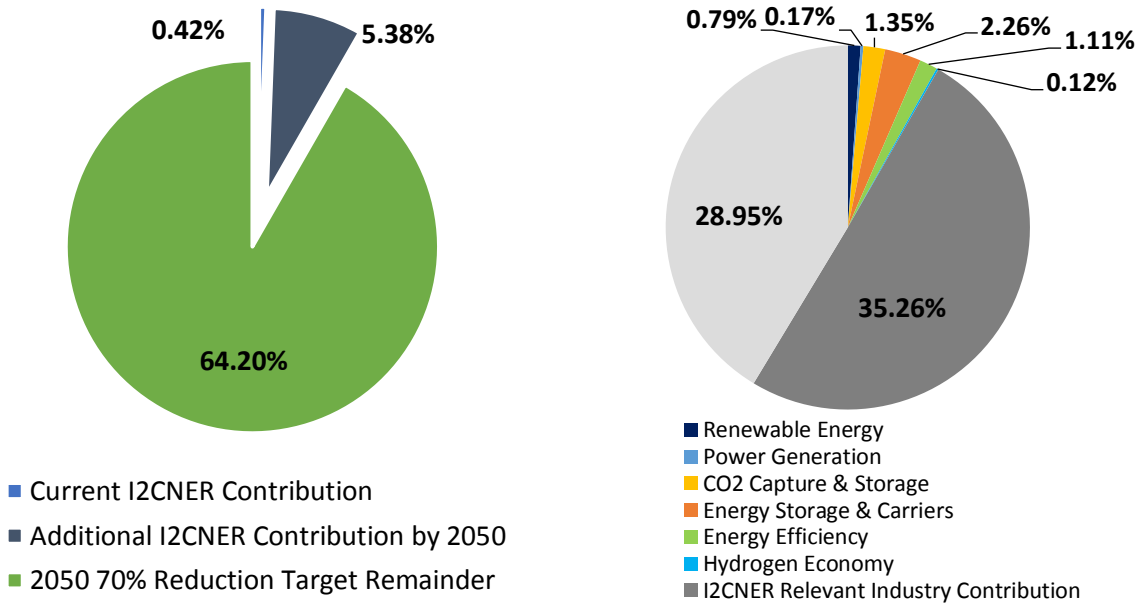
I^{2}CNER's research activities are carried out within its technical divisions in collaboration/interaction with the EAD to continuously assess techno-economic relevance and feasibility. Within the divisions,

research is organized in projects, with each project having well defined milestones on a roadmap toward a final target. According to I²CNER's scenarios, the I²CNER mission will be realized when all project targets across all divisions 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 in FY2017 are presented in relation to the advancement of the institute toward its roadmap milestones and targets.

Energy Analysis (Acting Division Leader: Prof. Itaoka)

Impact of I²CNER's Research on CO_2 Reduction

Based on our analysis of current and future achievements, approximately 0.42% of the total required CO_2 reductions via current achievements and approximately 5.38% 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 (limiting the contribution of any one technology to 50% of the resultant market). In addition to I²CNER's direct contributions, all I²CNER activities also contribute to the overall relevant industry efforts (a further 35.3% of the 2050 target, shown in dark grey in Fig. 1b) through the provision of underpinning technologies and analyses.



(a) Current and Future Contributions (b) Overall Contributions to 2050 CO_2 Reduction Target

Figure 1. I²CNER's Current and Future Contributions to CO_2 Reduction in Japan.

As shown in Fig.1b, the leading contributors to I²CNER's 2050 CO_2 reduction efforts include energy storage and carriers, encompassing electrolysis and the reversible fuel cell; CO_2 capture and storage, through novel CO_2 separation membranes and monitoring technologies; and energy efficiency, utilizing energy saving heat loop-tube technologies and friction reducing coatings. EAD continues to analyze each technology thrust within I²CNER in line with our energy system scenarios to ensure that our contribution toward CO_2 reduction and to underpinning industry efforts is maximized.

Energy Transitions in Japan

In collaboration with our University of Illinois satellite members and annual workshop participants, FY2017 has seen the significant progression of the EAD's energy transitions research. Our initial research in this area focused on an investigation of the current Japanese energy transition climate from the perspective of socio-technical regimes. This investigative and comparative work resulted in the publication of an academic paper contrasting Japan's energy transition progress and prospects with international transition leaders (Chapman and Itaoka, *Renew. Sustain. Energy Rev*. 81(2), 2019-2027, 2018). Building on these findings, a subsequent achievement within this research theme was achieved, specifically identifying householder's preferences in terms of energy choice, use and participation in the future energy market.

Utilizing the outcomes of our national survey of in excess of 4000 households across Japan, we were able to identify the impacts of energy system liberalization in terms of choice of energy retailer and reasoning (Chapman and Itaoka, *Energy Res. Soc. Sci.*, 37, 102-110, 2018). In addition, we could test several participatory scenarios incorporating demand response, energy self-sufficiency and network storage. EAD's specific knowledge of the Japanese energy market and liberalization legislation allowed for a targeted household survey to be conducted from within I^{2}CNER, reinforced by our stakeholders' participation at the annual I^{2}CNER symposia which inform future energy system modelling, cognizant of transition enablers and barriers, and stakeholder preferences.

Global Societal Penetration of Hydrogen Research

The EAD hosted international researchers from the University of Texas at Austin, Imperial College, London as well as Japanese researchers from the University of Tokyo and Kyushu University to assess the potential for hydrogen in the future energy system, with sponsorship from Toyota. This work is international and interdisciplinary in nature, taking 4 distinct case studies including a global energy model (EAD's contribution), which considers 82 global regions in order to develop a cost-minimized energy system according to fuel source, conversion, CO_2 restrictions, and cognizant of technological developments to 2050 (and beyond). Additionally, this research also considers the social welfare economics of hydrogen deployment, focusing on the social cost of carbon (The Urban Institute, Kyushu University). Further, this research considers two nation specific case studies, firstly in the U.S. utilizing hydrogen as an energy carrier for road vehicles (University of Texas at Austin), and the decarbonization of the gas grid using hydrogen in the UK (Imperial College, London). Collectively, this research identifies potential quanta of future hydrogen penetration into society in terms of feedstocks (methanol synthesis), heating (residential and industrial) and transport (predominantly through the introduction of Fuel Cell vehicles) (Chapman, *et al.*, *Environ. Res. Lett.*, under review).

I^{2}CNER's unique status as an international research institute with knowledge and prowess in terms of hydrogen research allowed for this research to flourish, and, leveraging sponsorship from Toyota was able to host a 3-day joint research seminar with our collaborators to bring together the interdisciplinary aspects of our work. EAD lead in the development of an academic research paper submitted to Environmental Research Letters, to be followed up by an in-depth global hydrogen model assessment from EAD in FY2018.

Molecular Photoconversion Devices (Lead PI: Prof. Ishihara)

Lead-free perovskite solar cells: Seminal advances in solar cells based on the hybrid perovskite materials have been made in FY2017 as reported in four publications, one of which has already been cited 19 times. The team demonstrated devices with 19% conversion efficiency and 10,000 hours half life (Qin *et al., Adv. Mater.*, 28, 466, 2016 and *Adv. Mater.*, 29, 1603808, 2017). The new process controls miscibility of precursors in solution to improve coverage of a surface. Working with Dr. Ščajev from Vilnius University, two carrier diffusion behaviors, one based on band-like and one based on delocalized diffusion were demonstrated. (Ščajev *et al.*, *J. Phys. Chem.* C 121, 21600, 2017). Which of these provides higher diffusivity depends on the carrier density. Collaborative modeling and device characterization with the University of Illinois shows mechanisms limiting the cell performance and how reduced carrier recombination in the bulk of the absorber layer was obtained through novel processing (see also below). Results of the model are shown along with simulations in Fig. 2. Defects mediating recombination were also shown to increase in some perovskites when a phase transformation occurs so materials and synthesis processes were designed to reduce this, which improved stability. The effect of additives on grain boundary properties in hybrid perovskites were also studied in collaboration with Jan Seidel of the University

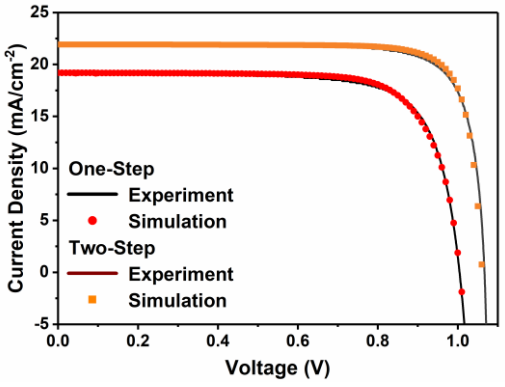


Figure 2. Experimental and simulation results for the standard and revised two-step synthesis process for hybrid perovskite solar cells showing improvement with the two-step process.

of New South Wales and using scanning Kelvin probe force microscopy. (Faraji *et al*., *J. Phys. Chem*. C, 122 (9), 4817, 2018). *This effort addresses the short-term milestone for project 1 of the Molecular Photoconversion Devices Division*.

A novel multiscale model for functionalized semiconductor electrodes: Kyushu and Illinois groups collaborated to develop an integrated multiscale model based on density functional theory (DFT) and a drift-diffusion model of charge transport in devices. The model was used to design functionalized photocathodes for high-efficiency H_2 generation (see also above). Molecular functionalization of silicon (111) photoelectrodes has been modeled to understand enhanced charge separation due to the functional group surface dipole. Our work provides a direct link between the photoelectrode functional group and the resulting device behavior. We used the model to predict which molecule would be the most effective for specific charge transport properties. The model was conceived through collaborations of post-doc (Dr. Kearney) and faculty (Profs. Staykov, Ertekin) with photoelectrode experiments carried out by a number of groups at Kyushu. (Kearney *et al*., J*. Am. Chem. Soc*. 140, 50-53, 2018 and *J. Phys. Chem*. C 121, 11312-11318, 2018). *This effort targets the short-term milestone for project 1 of the Molecular Photoconversion Devices Division*.

Catalytic Materials Transformations (Lead PI: Prof. Ogo)

One model, two enzymes: activation of hydrogen and carbon monoxide: Projects in this division made excellent progress on bio-mimetic (or bio-inspired) catalysis. The focus remains on transformations of small molecule substrates including H_2, N_2, CO_2, and H_2O, since these are central to the I^{2}CNER mission of producing clean fuels for carbon neutral power generation cycles. Following the division roadmap, research efforts of the Ogo group have made particular progress on single catalysts for transformations of multiple energy-relevant substrates. The ability to catalyze the oxidation of both H_2 and CO in one pot is highly relevant to our future hydrogen economy since CO is a persistent contaminant of H_2 supplies. The newly reported catalyst is based on a NiIr core, comparable in design to the active site of the iconic [NiFe]-hydrogenases and the CO-dehydrogenases (CODH), two of the most important enzymes in this area. The CO and H_2 bind to the Ir center, as verified by X-ray crystallography. An additional advantage of this design is its compatibility with aqueous media, which allows the operator to control product distribution by manipulating pH. The catalyst has been demonstrated in an actual fuel cell using H_2, CO, and H_2/CO as fuels for oxidation at the anode (Ogo *et al*., *Angew. Chem. Int. Ed*. 56, 9723-9726, 2017). *This effort satisfies the short-term milestone for project 1 of the Catalytic Materials Transformation Division*.

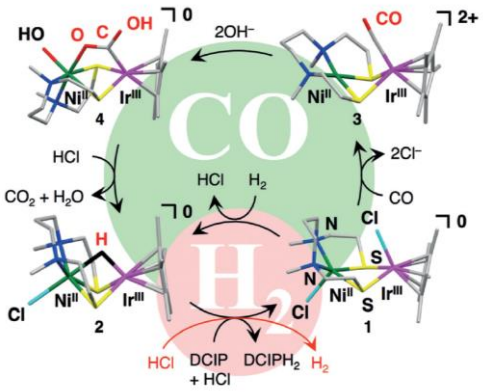


Figure 3. Scheme illustrating the activation of both H2 and CO by the new NiIr bifunctional catalyst.

Thermal Science and Engineering (Lead PI: Prof. Takata)

Super-stable ultrathin water films: Suspended ultrathin water film with thickness of 3–20 nm was shown to be stable for the first time inside open carbon nanotubes (CNTs) at high vacuum (~10^{-5} Pa) using transmission microscopy (TEM, Fig. 4). The stability of the confined water film arises due to additional molecular interactions stemming from the extended water meniscus on the hydrophilic surface. This finding enables greater fundamental understanding of wettability and adsorption effects during liquid-vapor phase change which is a *mid-term milestone of the division's projects HMT-1 and HMT-2*.

Volatile organic compound mediated nucleation: The mechanism of heterogeneous nucleation on hydrophobic surfaces remains poorly understood. We observed for the first time the formation of high surface energy nanoscale agglomerates on hydrophobic coatings after condensation/evaporation cycles in ambient conditions (Fig. 5). To investigate the deposition dynamics, we studied the nanoscale agglomerates as a function of condensation/evaporation cycles *via* optical and field emission scanning electron microscopy (FESEM), microgoniometry, nucleation statistics, and energy dispersive X-ray spectroscopy (EDS). The FESEM and EDS results indicated that the nanoscale agglomerates stem from absorption of sulfuric acid based aerosol particles inside the droplet and adsorption of volatile organic compounds during condensation, which act as preferential sites for heterogeneous nucleation after evaporation. The insights gained from this study elucidate fundamental aspects governing the behavior of both short and long term heterogeneous nucleation on surfaces, enable greater fundamental understanding of wettability and adsorption effects during liquid-vapor phase change which *is a mid-term milestone of the division's projects HMT-1 and HMT-2.*

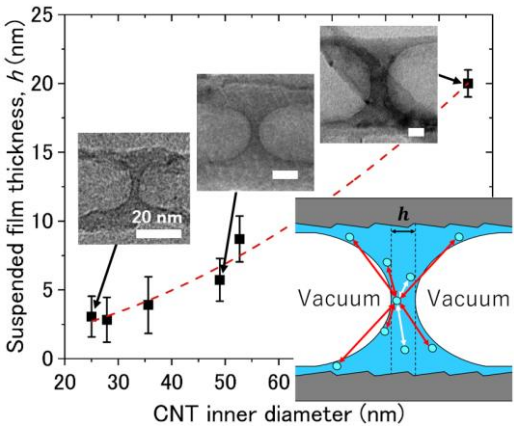


Figure 4. TEM images of suspended water film in CNT under high vacuum conditions (Tomo *et al.*, *Nano Letters*, 18(3), 1869–1874, 2018).

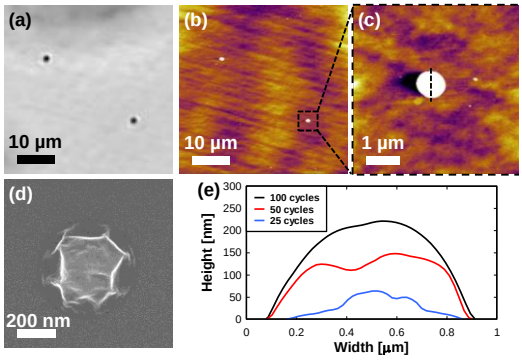


Figure 5. (a) Optical, (b)-(c) atomic force microscopy, and (d) FESEM images of agglomerates after 100 condensation/evaporation cycles, (e) Height profile of agglomerates along the dotted-line trace in (c) as a function of condensation cycles (Cha *et al.*, *Nano Letters*, 17(12), 7544-7551, 2017).

Spherical activated carbon material: We have developed a world-leading activated carbon material Spherical Activated Carbon (SAC) to enhance the adsorption capacity of heat pumps. By developing a demonstration of the system through a prototype using an SAC adsorption heat exchanger, and testing the performance in collaboration with an automotive heat pump manufacturer, we showed superior performance (Jribi *et al.*, *IJHMT*, 108, 1941-1946, 2017). *This development progresses us toward achieving the short-term and mid-term milestones of the division's project TES-1.*

Electrochemical Energy Conversion (Lead PI: Prof. Matsumoto)

Proton conductor steam electrolysis cell: A steam electrolysis voltage as low as 1.45 V was attained at current densities of 0.2 and 0.5 A cm^{-2} at temperatures of 550°C and 600°C, respectively, with current efficiency >82% using $BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{3-\delta}$ as the electrolyte (Fig. 6). The improved cell performance is due to the combination of the electrolyte with a NiO-$SrZr_{0.5}Ce_{0.4}Y_{0.1}O_{3-\delta}$ cathode substrate. From these results, the calculated amount of electricity required to produce 1 N-m^3 of hydrogen is 4.2 kWh, and is lower than the 5 kWh required for the same amount of hydrogen using ordinary water

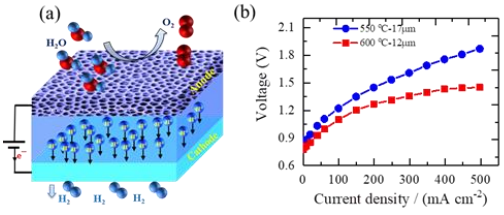


Figure 6. (a) Schematic illustration of a proton conducting solid oxide electrolysis cell, (b) I–V curves from the steam electrolysis cell measured at 550 and 600°C with a $BaZr_{0.44}Ce_{0.36}Y_{0.2}O_{3-\delta}$ electrolyte (Leonard *et al.*, *Int. J. Hyd. Ener.*, 42 (7), 3926-3937, 2017).

electrolysis. *The SOEC performance is the first step to the short-term milestone "Demonstration of SOFC and SOEC operating at 500°C in the division's Project 3-2.*

Durable Ir/MWNT based oxygen-evolving electrode for water electrolysis: A new method to prepare Ir nanoparticles (~ 1 nm diameter) on multi-walled carbon nanotubes (MWNT) was developed (Fig. 7). Due to the small size of the Ir particles coupled with the high electrical conductivity of MWNT network, the electrocatalyst (MWNT/PBI/Ir) exhibits higher mass activity (1533 Ag^{-1} @ 1.6 V in single cell) compared to previously reported electrocatalysts (<900 Ag^{-1} @ 1.6 V). In addition, due to the excellent oxidation resistance of the MWNT, the water electrolyzer utilizing the MWNT/PBI/Ir as the anode exhibited remarkable durability for over two weeks (~25,000 min) at a current density of 1.0 A cm^{-2} at 80°C. This result is the first example of a carbon-based anode for water electrolysis which exhibits both high activity and durability, and *provides an alternative solution for the short-term milestone in Project 1 "PEC: Identify theory for anode and cathode operability up to 120°C and minimized overpotential with high durability up to 10^5 potential cycles."*

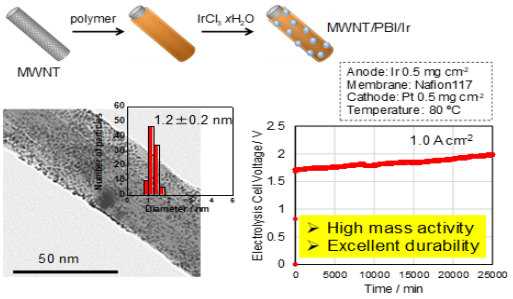


Figure 7. (top) Illustration showing preparation of MWNT/PBI/Ir catalysts along with an image of the catalyst (left) and its performance (right). (Fujigaya *et al.*, *J. Mat. Chem.* A, 5, 10584-10590, 2017).

Revealing the role of metal in non-precious-metal catalysts: By selectively removing Fe while preserving N and C species from a non-precious metal (NPM) oxygen reduction reaction catalyst it was shown that the presence of Fe in NPM catalysts contributes directly to their ability to reduce oxygen to water via a 4 e^- pathway and at lower overpotentials than catalysts featuring C and N sites alone. Catalysts without Fe, and even those containing some residual metal, reduce O_2 with larger overpotentials and favor the much less desirable 2 e^- pathway for oxygen reduction in both acidic and alkaline conditions. The work targets the *mid-term milestone of the division's Project 1* and reveals the direct involvement of the metal in the active site of non-precious metal catalysts and provide important guidance for future catalyst improvements (Varnell *et al.*, *ACS Energy Lett.*, 3, 823–828, 2018).

CO_2 Capture and Utilization (Lead PI, Prof. Fujikawa)

Membrane materials for CO_2/H_2 separation: One of the division objectives is to separate CO_2 in pre-combustion CO_2 capture, where CO_2 is separated over H_2. The required membrane performance, CO_2 permeance and selectivity, is 100 GPU (1 GPU=7.5×10^{-12} m^3 (STP)/(m^2·s·Pa)) and 30, respectively. The I^2CNER developed 2-(2-aminoethylamino)ethanol-containing polymeric membranes exhibit CO_2 permeance of 155 GPU which exceeds the target at CO_2 pressure of 1.0 MPa and 80 % relative humidity. *In comparison to the current benchmark (41 GPU, reported by Ohio State University), the I^2CNER membrane displayed the highest CO_2 permeance even under higher CO_2 pressure*. Our research has also revealed the mechanism of CO_2 permeation at the molecular level, suggesting that CO_2 migrates through the membrane in a bicarbonate ion form even under higher pressure. Currently, our efforts are focused on the development of a hollow fiber membrane module to explore the scaling-up of our membrane project to a demonstration level for technology transfer.

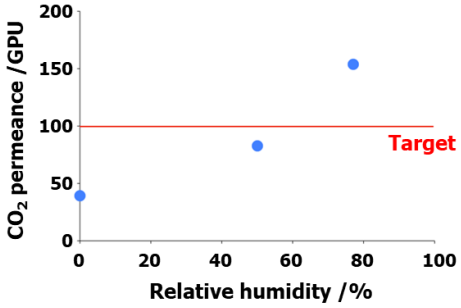


Figure 8. Effect of relative humidity on CO_2 permeance of the I^2CNER membrane.

Membrane materials for CO_2/N_2 separation: For technology applications of membranes for CO_2 separation over nitrogen, further improvement of the gas flux performance is required: CO_2 permeance should exceed 4000 GPU which is the target in our Division's roadmap. Our research has demonstrated that membrane thinning markedly improves the gas flux performance, and hence our

efforts have been directed to preparing ultimately-thinned membranes at the nanometer scale (nanomembrane) without gas leaks. We succeeded in manufacturing free-standing nanomembranes that are poly(dimethylsiloxane)-based with high CO_2 solubility. To the best of our knowledge, our developed membranes with the thickness of only 150 nm reproducibly showed preferential CO separation with world highest CO_2 permeance of about 6500 GPU. *This achievement on CO_2 permeance exceeds our roadmaps target value (4000 GPU) and the current benchmark (1000 GPU by MTR Inc., USA).* Surprisingly, our membranes captured CO_2 from CO_2/N_2 mixture with a CO_2 concentration of 1000 ppm under atmospheric pressure conditions. This finding expands the relevance of our research goals beyond the capturing of CO_2 at fire powered plants to the entirely new area of direct CO_2 capture from the air (Selyanchyn and Fujikawa, *Sci. Tech. Adv. Mater*., 18, 816-827, 2017)

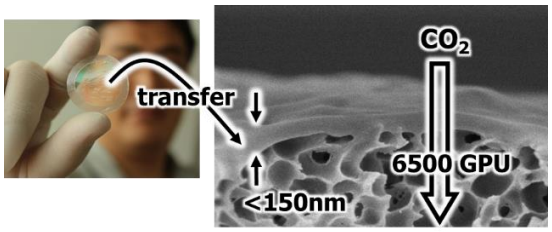


Figure 9. I²CNER free-standing nanomembrane with world record high CO_2 flux.

CO_2 Storage (Lead PI, Prof. Tsuji)

Continuous and accurate monitoring system for injected CO_2: In Carbon Capture and Storage (CCS), the monitoring of injected CO_2 is crucial for (a) predicting the risk of CO_2 leakage from reservoirs, (b) increasing the efficiency of CO_2 injection and reducing the cost, and (c) reducing the risk of injection-induced seismicity. To date time-lapse seismic surveys have been used to monitor injected CO_2 distribution. However, the interval of the time-lapse surveys is long due to their high cost and it is difficult to continuously monitor the injected CO_2. In addition, continuous monitoring of the dynamic CO_2 behavior is crucial for detecting accidental incidents, such as CO_2 leakage. To address these issues, we first developed a continuous monitoring approach to estimate spatio-temporal variation of seismic velocity using ambient noise (Nimiya *et al*., *Sci. Adv*. 3, p e1700813, 2017). Since this method constructs virtual seismic data from noise, we can extract subsurface information using only passive seismometer data. However, the disadvantage also of this monitoring system that relies on ambient noise is that the temporal variation of ambient noise would decrease the monitoring accuracy. To overcome this problem, we have developed a new novel monitoring method for injected CO_2 using a continuous and controlled seismic source. This new monitoring system generating controlled seismic signal is cost-effective, with high temporal resolution and accuracy. By deploying this system to the ongoing CCS project in Canada, we successfully identified spatial and temporal variation in the shallow subsurface (Ikeda *et al*., *J. Geophy. Res*. 122, 2859-2872, 2017). High spatial resolution of our approach makes it possible to identify leaked CO_2. Also, the system's low cost and high temporal resolution are particularly attractive for long-term monitoring of sequestered CO_2. *This effort directly addresses the short-term milestone of Project 3 of the CO_2 Storage Division (Field-scale CO_2 investigation), specifically the milestone: Develop effective monitoring system.*

Direct numerical simulation of microfluidics experiments on liquid CO_2-brine drainage: A complex interplay of capillary, viscous, buoyancy, and surface tension forces at the pore scale plays an important role in governing the macroscopic multiphase flow behavior of CO_2-brine systems. Many studies of two-phase flow in porous media demonstrate that inertial forces are negligible under realistic flow rates, so the only two dimensionless parameters of relevance are the capillary number (Ca) and viscosity ratio (M). To gain new insights into fundamental processes at the pore scale, we have compared fluid behavior derived from lattice Boltzmann simulation to microfluidics experiments of CO_2-brine at reservoir conditions for realistic rock geometry. We found that inertial effects are important for CO_2 drainage due to the low viscosity of the CO_2 phase and the localized high velocities that result during rapid pore invasion (so-called "Haines jumps"; Chen *et al*., J*. Contaminant. Hydrol*., in press). Therefore the traditional view that two-phase flow is governed only by Ca and M is incomplete, and the Reynolds number must also be considered. The research leads to new understanding of pore-scale physics which allows for more accurate prediction of large-scale behavior of injected supercritical CO_2 in industrial scale CCS projects. *This effort directly addresses the short- and mid-term milestones of Project 2 (Pore-scale CO_2 investigation), specifically the*

milestones: (1) Model injected CO_2 behavior and (2) Increase storage capacity and security by enhanced residual and solubility trapping.

Hydrogen Materials Compatibility (Lead PI: Dr. Somerday)

Effect of trace gases on friction, wear, and fracture

The following work represents progress toward milestones in Project 1 (establish validated physical descriptions of effects of gas impurities on H_2-assisted cracking) and Project 3 (establish physical description of effects of environment and surface modification of various materials in dry and lubricated contact). The common link in these research activities is identifying fundamental effects of trace gases on material behavior (friction, wear, and fracture). The motivation for the Project 3 accomplishment is recognizing that friction between metals and diamond-like carbon (DLC) coatings is sensitive to trace gases. In previous accomplishments, the effects of trace water vapor on friction for DLC/metal couples were systematically defined. Leveraging these insights, the study has been extended to examine the effects of O_2 and water vapor on friction for DLC/metal couples (Kurahashi *et al.*, Micromachines, 8, 217-231, 2017). The emerging results shown below indicate that there is an optimum O_2 concentration to maintain low friction in N_2 gas with negligible trace water. These pin-on-disk sliding experiments were complemented with Raman spectroscopy, which revealed that low friction was associated with transfer films of structured amorphous carbon on the metal counterface. The formation of these transfer films is affected by the trace gases. This approach to characterizing and optimizing DLC coatings is differentiated from similar studies by its focus on surface science to investigate the tribo-interface. The Project 1 accomplishment was inspired by previously reported achievements, in which physical descriptions and an associated model were presented for oxygen-inhibited, hydrogen-assisted cracking in steels. Advancing this study on oxygen inhibition, the effectiveness of CO in mitigating hydrogen-assisted cracking was comprehensively studied, including the effect of steel strength level (Komoda *et al.*, Proceedings ISOPE, TPC-0866, 2018). As summarized below, when H_2 gas contained 1000 vppm CO, hydrogen-assisted cracking was pronounced for the higher-strength steel (HV619), but it was almost completely suppressed (fracture toughness ~90% of the value measured in nitrogen) for the lower-strength steel (HV329). These results indicate that CO reduces hydrogen uptake into the steel but does not prevent it completely. This study has significant technological impact, since mitigating hydrogen embrittlement through CO impurities can lead to lower costs for hydrogen refueling stations, as recognized by the sponsor for this project (Air Liquide).

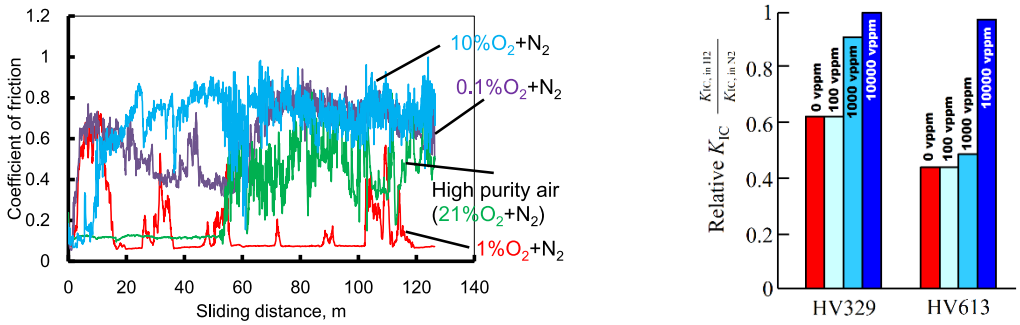


Figure 10. (left) Friction coefficient as a function of sliding distance for DLC-coated disk/iron pin in N_2 with controlled O_2 levels and water vapor <5 vppm. (right) The effect of steel hardness (strength) on the mitigation of hydrogen-assisted cracking by CO impurities (100 to 10,000 vppm) in H_2 gas.

2. Advancing fusion of various research fields

Using **bioinspiration**, Prof. Miljkovic of the Thermal Science and Engineering division is exploring the boundaries of wetting through the fusion of mechanical engineering, material science, entomology, chemistry, and biotechnology. The team was the first to show that wettability in nature is correlated with taxonomy, life cycle and reproductive strategies, rather than habitat. This work enables the development of artificial surfaces for energy and water applications such as anti-icing, self-cleaning, anti-fogging, water harvesting, and enhanced phase change heat transfer (Oh *et al.*,

ACS Applied Materials & Interfaces, 9(32), 27173−27184, 2017).

Fusing **biochemistry with chemistry and structural biology**, Prof. Ogo and his group (*Science*, 537, 928-932, 2017) determined the crystal structure of a new form of a [NiFe]-hydrogenase enzyme in both the oxidized and reduced states. In the oxidized state, the Ni center (where substrate binds) adopts an unprecedented six-coordinate geometry. The structure is potentially significant because it illustrates a probable mechanism by which the enzyme could prevent poisoning by O_2. Normally the Ni center is four- or five-coordinate, which allows H_2 to approach the Ni. The group proposed that the enzyme is able to switch geometries to either effect catalysis or to protect itself from aerobic degradation. This knowledge will be integrated into the designs of new bio-inspired catalysts.

Fostering close collaborations with other KU units and continuing the **Applied Mathematics for Energy Initiative** from FY2015 and 2016, I^{2}CNER initiated three additional projects in FY2017:

i) Prof. N. D. Hoa, "Distributed grid optimization with renewable generation," I^{2}CNER and Institute of Mathematics for Industry (IMI).

ii) Prof. H. Watanabe, "Solar power assisted hydrogen production and carbon-free high efficiently thermal power generation", Department of Mechanical Engineering.

iii) Prof. H. Matsumoto, "Carbon nanotube-based non-precious metal electrocatalysts for fuel cell, water electrolyzer and metal-air battery devices," I^{2}CNER.

The above three projects along with the 7 ongoing projects from FY2015 and FY2016 strengthen the I^{2}CNER fusion portfolio in the area of integration of renewables with the smart grid, initiate new activities in the area of power generation, and accelerate our quest for non-precious metal catalysis.

In FY2017, the Applied Mathematics thread of I^{2}CNER's research was largely focused on two broad topics: computational materials and physics and mathematics of the emerging smart grid. Also a track in biomathematics was continued. More specifically:

Two groups addressed the area of **Modeling and Characterization of Porous Materials** for CO_2 storage. The group of Prof. Triades (IMI) and PI Christensen aimed at modeling the transport dynamics of multiphase flows in porous media. The problem is complicated as it involves highly irregular, fractal boundaries of the media, and complex interactions between the components. The group used the lattice Boltzmann method (LBM) to handle complex boundaries and interfaces between multiple phases, and Lagrangian fluid particle tracking using LBM velocity fields. The models were used to investigate the key parameters of the flows in porous media, otherwise accessible only through complex and necessarily incomplete experiments. They investigated the dependence of anomalous dispersion on the pore network geometry and assumed molecular diffusivity. The group published one paper (Fakhari *et al*., *Adv. Water Resour*., 114, 119-134, 2018).

The group of PI Tsuji and Prof. Shirai (IMI) used the techniques of applied algebraic topology (known as persistence homology) to quantify properties of porous materials. Persistent homology allows one to track the properties of complex geometric structures affecting their topology (connectivity, "loopiness") across arbitrary scales. The results of the group indicate how permeability and elasticity of sandstones are reflected in their persistence diagrams. Modeling the diffusion in porous materials using random walks is another research direction. The group published one paper (Tsuji *et al*., Applications of Persistent Homology and Random Walk, In "Agriculture as a Metaphor for Creativity in All Human Endeavors," pp. 95-109, doi:10.1007/978-981-10-7811-8_11, 2018).

The **Computational Physics** track was focused on models and computations of expanding flames (combustion) for efficiency increase in power generation. The team involves Prof. Matalon (Illinois) and Prof. Matsue (I^{2}CNER & IMI). The modeling of the expanding flames, using numerical solution of systems of parabolic partial differential equations which is the key tool in the study, was tested and corroborated by comparisons with existing experimental data. The key causes of complications in the modeling are the necessity to work across several scales and the inevitability of chaotic, turbulent regimes in the solutions. Addressing several scales results in unstable solutions and the presence of turbulence prevents the standard deterministic approaches. The team looked at complementary regimes, where different techniques could be applied: Prof. Matsue attacked the problem using quasi-spectral methods; Prof. Matalon focused on weakly-nonlinear approximations. Both approaches led to stable numerical schemes that are implemented. The research will expand toward explorations of the resulting behavior, understanding the scaling laws in the models, and

interactions with experimentalists to fine-tune and adjust the models. So far, there has been one conference presentation (Matalon, Proceedings of the Seventieth Annual Meeting of the APS Division of Fluid Dynamics, Denver, CO., November 2017).

Three research groups work on **Mathematics of Smart Grid**: i) The optimization group, consisting of Prof. Bose (Illinois) and Prof. Hoa (I^2CNER & IMI). One research direction addresses game theoretic aspects of electricity markets. Networked structure of the agent interactions complicates the structure of the solutions and leads to potential losses of the efficiency. The project aims at the quantification of these losses and characterization of mechanisms to overcome it. Another research thread deals with non-convex optimization, a critical tool for finding optimal production and distribution plans in uncertain situations characterized by the presence of renewable energy sources and microgeneration. To this end, the team focused on a class of optimization algorithms, the augmented Lagrangian methods (ALM), the subgradient methods and the Mirror-Descent method. They are exploring the use of ALM with Jacobi-type updates, such that within each iteration the step is scalable with the size of the problem. The goal is to find a unified analysis framework that yields theoretical guarantees on the convergence rates of these algorithms. The group already published one conference paper (Doan *et al.*, submitted for publication to IEEE Control System Letters and for presentation at IEEE Conference on Decision and Control 2018); ii) The group of Profs. Murata (KU) and Hirose (IMI) deal with the patterns of energy consumption in smart grid. Prof. Murata addresses the important question of shaping the customer demand using a demand response programs. His group modeled the (potentially irrational) customer behavior using the ideas from the reinforced learning theory and developed reverse optimization tools aimed at creating system of incentives shaping the demand in a prescribed way. Two conference papers were published (Murakami *et al.*, Proceedings of 2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC2017), 2754-2759, 2017; Murakami *et al.*, The Papers of Joint Technical Meeting on "Systems" and "Smart Facilities", IEE Japan, 113-118, 2017). Prof. Hirose's group is looking at the statistical models to analyze the data of power consumption in order to create predictive models. To achieve that, the group is aiming to cluster the energy consumers based on the patterns (time series) of their usage, creating a few classes that can be used then for forecasting.

The research area of **Biomathematics** is represented by the group of Prof. Nishii and Mr. Koda (IMI), and Drs. Mochida and Onda (RIKEN). Their goal is to perform statistical analysis of the sequenced DNAs of Brachypodium, to understand which systems induce heterosis, a genetically driven difference in growth rates. Auto-regressive models with exogenous variables (ARX models) are deployed for the analysis. One journal paper has already been published (S. Koda, *et al.*, Frontiers in Plant Science 8, Article 2055, 2017 (DOI:10.3389/fpls.2017.02055).

3. Establishing 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 in accordance with the development stage of the center, including the following points, for example:
- Efforts being developed based on the analysis of number and state of world-leading, frontline researchers; number and state of visiting 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 young researchers from around the world (such as efforts fostering young researchers and contributing to advancing their career paths)

Globalization by the numbers

In FY2017 there was a vast amount of international activities that enhanced I^2CNER's global visibility. I^2CNER hosted 5 (37 in total since inception) international symposia; held 17 seminars in the Institute Interest Seminar Series (IISS) (120 in total since inception) with 30 speakers (212 in total since inception) of which 21 were non-Japanese (127 in total since inception); 20 seminars in the I^2CNER Seminar Series (148 in total since inception) with 21 speakers (152 in total since inception) of which 17 were non-Japanese (99 in total since inception). The Institute's researchers were responsible for organizing, co-organizing, or serving on the scientific committees for 17 (176 in total since inception) international conferences, 21 international conference sessions/symposia or workshops (212 in total since inception), and 10 I^2CNER international workshops (58 in total since inception). Our researchers have given 75 keynote, plenary and invited presentations in international conferences and fora (450 in total since inception). In addition, our researchers have joint publications with researchers from 60 new institutions (681 in total since inception) around the world

and hosted 82 (269 in total since inception) internationally recognized researchers for scientific interaction and exchange. Our researchers also hosted 95 (298 in total since inception) distinguished visitors (of which 44 were distinguished researchers) at Kyushu University from across the world. Additionally, we initiated interactions with 4 internationally recognized research centers/universities, namely, the Paul Scherrer Institut, and Laboratory of Inorganic Chemistry, ETH Zurich, Switzerland, the Helmholtz Institute Forschungszentrum Juelich, the Southwest Research Institute, and the University of Göttingen. Lastly, we hold agreements with 5 internationally recognized research centers/universities: Illinois, the National Fuel Cells Research Center (NFCRC) of the University of Irvine, ECOSTORE, a consortium based in the European Union, the University of New South Wales, SINTEF/NTNU of Norway, and the California Air Resources Board (CARB). As of March 31, 2018, I^{2}CNER has a total of 24 partner institutions in the U.S., Europe, and Asia. Lastly, in FY2017, I^{2}CNER placed 11 (37 in total since inception) of our researchers at various Japanese (excluding KU) and international institutions.

Participation of Overseas PIs and Researchers

All 9 of our overseas Principal Investigators are top-world researchers who are actively involved in I^{2}CNER's research operations. They spend between one to seven weeks at Kyushu and participate in events and exchange opinions on collaborative research projects with their Kyushu counterparts. By way of example, Prof. Kilner, an international authority in the field of ionic and mixed conducting ceramics, spent eight weeks in I^{2}CNER during FY2017. Jointly with Kyushu faculty, he won international awards and research program grants, e.g. Core-to-Core, and hosted one postdoc from I^{2}CNER at Imperial College, London for 2 months. Dr. Somerday is a leading scientist in the area of mechanical metallurgy. He visited I^{2}CNER for 2 weeks and hosted a group of researchers from I^{2}CNER at the Southwest Research Institute for the Hydrogen Materials Compatibility Division retreat. Aside from PIs, I^{2}CNER hosted world top-level researchers from overseas on a regular basis. For a brief list of distinguished visitors from abroad, please see Appendix 5.

Illinois Satellite

The Satellite Institute at the University of Illinois at Urbana-Champaign facilitates cooperative research activities and personnel exchanges. In addition to conducting Institute related research, the Satellite serves as the base for identifying and engaging key research programs and faculty at universities and institutions nationally and internationally. The ongoing relationships between the faculty of Kyushu University and the University of Illinois at Urbana-Champaign are having a transformative impact upon I^{2}CNER's overall research culture. Four of the efforts undertaken at the Satellite to promote the mission of I^{2}CNER are as follows:

Satellite Faculty Composition

The Illinois Satellite faculty members are all internationally recognized researchers in their respective areas of expertise. They were specifically invited to complement the I^{2}CNER research activities at Kyushu, and they are continually re-assessed based upon their relevance to the overall I^{2}CNER vision and roadmap. As of March 31, 2018, there are seven Illinois Faculty and one WPI Principal Investigator participating at the Illinois Satellite. One member of I^{2}CNER's External Advisory Committee (EAC), Dr. Robert Finley, is a retiree from the University of Illinois. In addition, there are former Satellite Faculty members who are still working with I^{2}CNER: Prof. Ian Robertson, Dean of the College of Engineering at the University of Wisconsin-Madison (WPI Principal Investigator); Prof. Ken Christensen, Aerospace and Mechanical Engineering Department Chair at the University of Notre Dame (WPI Principal Investigator), Prof. Angus Rockett, Metallurgical and Materials Engineering Department Head, Colorado School of Mines (WPI Professor, member of I^{2}CNER's IPRC).

Kyushu-Illinois I^{2}CNER Undergraduate Exchange Program

The "Agreement on Academic Cooperation" between KU and Illinois helps the two universities to promote mutual understanding and strengthen their relationship. A "Student Exchange Program Agreement" between KU and Illinois was signed on October 24, 2014. The numbers of KU undergraduate students who visited Illinois are 5 (FY2013), 6 (FY2014), 6 (FY2015), 6 (FY2016), and 6 (FY2017). During their monthly visit, the students observe and assist with research in Illinois laboratories under the supervision of Satellite faculty and graduate students, participate in group meetings, complete weekly "check-ins" with the Director, take tours of local engineering companies, and interact with Illinois' Center for East Asian and Pacific Studies (CEAPS) to enhance their cultural

experience of the university, including lunches and activities with Illinois undergraduate student "buddies". At the end of their stay, the KU students give presentations on their research and cultural experiences at Illinois in a mini-workshop. In FY2016, two of the students were involved in research that *resulted in a paper publication: LANGMUIR, DOI: 10.1021/acs.langmuir.7b03948*.

Partnership for International Research and Education (PIRE)
The joint PIRE award to Illinois and Kyushu, "Integrated Computational Materials Engineering for Active Materials and Interfaces in Chemical Fuel Production," is a result of I^{2}CNER's successful fusion of computational science with experiment, and was awarded beginning in FY2015 for a total of 5 years. The PIRE project brings together researchers from I^{2}CNER (both Illinois and KU), Northwestern University (NU), Imperial College, London, and the University of California, Berkeley (UCB). In FY2017, under the 2-month PIRE/x-FU(s)ION (eXchange: FUkuoka, Illinois, califOrnia, Northwestern) exchange program, 5 American students (3 from Illinois, 1 from NU, and 1 from UCB) carried out research in I^{2}CNER from June 11-August 13, 2017.

Total Graduate/Undergraduate Student Visits to KU
As of March 31, 2018, the Institute has hosted a total of 63 graduate/undergraduate students from various institutions around the world, including Illinois, since its inception. The numbers of visiting students are 1(FY2010), 9 (FY2011), 6 (FY2012), 7 (FY2013), 7 (FY2014), 6 (FY2015), 10 (FY2016), and 17 (FY2017) of which, 1, 7, 1, 3, 1, 3, 8, and 14, respectively, stayed for more than a month at KU. Of the total 63, 34 students were from Illinois and 19 of these students stayed for more than a month.

Collaborative Foreign Exchange Program
I^{2}CNER's "Collaborative Foreign Exchange Program" is in place in order to encourage young researchers to visit our overseas collaborating institutions. In FY2017, five young researchers had their proposals approved: two visited Illinois, two visited the University of Texas, Austin, and one visited the University of Edinburgh for the extended period between 1 and 5 months.

I^{2}CNER Young Researchers' Job Placement after Leaving the Center
The environment at I^{2}CNER provides a rich platform for young researchers to pursue technology impacting research in a highly international setting. To date, a large number of I^{2}CNER young researchers have leveraged their appointments at the Institute to advance their professional careers. By way of example in FY2017, an I^{2}CNER Assistant Professor, Nicola Perry, was recruited as Assistant Professor at the University of Illinois at Urbana-Champaign beginning January 1, 2018. Dr. Arnaud Macadre accepted a position as an Associate Professor at Yamaguchi University beginning April 1, 2018; Dr. Jihui Jia accepted a position as an Assistant Professor at China University of Petroleum, and Dr. Jun Yang accepted a position as a Research Professor at the Ningbo Institute of Industrial Technology, China. For more examples of how career paths are being established for our researchers, please see Appendix 3-1 (section 1-1: Special mention).

I^{2}CNER International Research Programs and Activities
I^{2}CNER is establishing several different research efforts and programs held not only at Kyushu University but also in collaboration with and at international locations. Some of the efforts undertaken by I^{2}CNER to internationalize its research portfolio and promote global visibility are as follows:

JSPS Core-to-Core Program
This is an international joint research project led by PI Matsumoto. The project provides a total 90 million JPY (15.8 million JPY in FY2017) funding for joint research carried out between I^{2}CNER, Imperial College, London, Paul Scherrer Institut (PSI, Switzerland), and the Massachusetts Institute of Technology on "Solid Oxide Interfaces for Faster Ion Transport (SOIFIT)." Three of I^{2}CNER postdocs visited the counterpart research institutions for longer than 1 month: Dr. V. Thoreton in Imperial College, London for 1 month; Dr. D. Klotz in MIT for more than 3 months; Dr. K. Ghuman Kaur in PSI for 2 months.

Partnership with the University of Göttingen
PI Reiner Kirchheim, an elected member of the United States National Academy of Engineering, and

I²CNER's Director, lead the collaboration between Kyushu University and the University of Göttingen to establish an International Research Training Group that is to be co-funded by the DFG and JSPS. On January 6, two professors from the University of Göttingen visited I²CNER. In April 2018, a two-day KU/Göttingen workshop was also organized in Göttingen so that the Kyushu and Göttingen teams identify and construct the research themes of the joint proposal. In the proposed joint Ph.D. program, Ph.D. students will visit the counterpart institute for 1 year to participate in research/educational activities.

I²CNER Annual Symposium 2018
The 2018 I²CNER Annual Symposium, which was titled "Challenges in Thermal Science and Engineering towards a Sustainable Society", was held on January 31, 2018 and was attended by 166 participants (86 from abroad.) The vision of the symposium provided a platform for discussion and debate on the science and engineering for efficiency increase in power generation, smart utilization of waste heat, nanomaterials and metal-organic frameworks for efficient heat pump cycles, next generation working fluids, and nanoscale transport and heat transfer mechanisms. The Symposium included 2 keynote lectures (i) entitled "Thermal Waste Heat Utilization for Achieving Super Smart Community" by Prof. Takao Kashiwagi (Tokyo Institute of Technology) and (ii) entitled "Different Regimes of Pool Boiling" by Prof. Gautam Biswas (Indian Institute of Technology, Guwahati).

Japan-France Workshop on Nanomaterials
The 12th Japan-France Workshop on Nanomaterials (also known as 3rd WPI Workshop on Materials Science) was held in Kyushu on May 17-19, 2017, and attended by 79 participants (40 from abroad), including the Directors of 4 WPI institutes (AIMR, MANA, iCeMS and I²CNER) and top-level researchers from 10 French Centers of Competence in Nanoscience (C'Nano).

I²CNER Seminar Series
One of the most important goals of the I²CNER Seminar Series is to engage key members of the international community from academia, national laboratories, industry, and government agencies (policy makers). In FY2017, the Institute hosted a total of 21 speakers (17 non-Japanese) in 20 I²CNER Seminars. The quality of the seminar speakers is exemplified by the credentials of the speakers listed in Appendix 5.

Administrative Support for Foreign Researchers' Transition into Japanese Society
As of March 31, 2018, the administrative office consists of 20 staff members including the Administrative Director and the Associate Administrative Director (Head of Administration), and is divided into four groups:

1. General Affairs and Human Resources (6 members)
2. Accounting and Contracting (6 members)
3. Research Support and International Affairs (3 members)
4. Public Relations (3 members)

These four groups act as a support system to the Institute's researchers and administration under the supervision of the Administrative Director and the Associate Administrative Director.

The I²CNER Administrative Office is in close communication with the existing KU International Student and Researchers Support Center, and offers full-time support to overseas researchers in the invitation procedures, including visa application processing and accommodations on campus. 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 I²CNER researcher are required to complete prior to conducting experiments in the laboratory. Additionally, the Administrative Office provides extensive living assistance with medical checkups, off-campus accommodations, travel arrangements for family members, and introduction to the Japanese social insurance system.
For invited international researchers, university accommodation facilities are available, or arrangements are made for fully furnished private apartments with easy access to Kyushu University. "Ito Guest House," an on-campus housing accommodation for short-stay researchers from overseas, was built and opened on April 6, 2012 in the Center Zone of Ito campus, where I²CNER is located.

Director as a Fukuoka City Ambassador
On February 1, 2018, Director Sofronis was reappointed by the Mayor of the City of Fukuoka as a city Ambassador for two additional years. His duties include the advancement of the international image of Fukuoka and the organization of international conferences in the city. In fact, Director Sofronis is currently in the process of putting together a committee to submit a proposal to hold the 2024 World Hydrogen Energy Conference (WHEC) in Fukuoka. This would be a joint proposal from the city of Fukuoka and Kyushu University and if successful, it would attract approximately 1,800 attendees.

4. Reforming the research organization

* If innovated system reforms generated by the center have had a ripple effect on other departments of the host institutions or on other research institutions, clearly describe in what ways.
* Please describe the center's operation and the host institution's commitment to the system reforms.

Kyushu University Platform of Inter/Transdisciplinary Energy Research (Q-PIT)
In order to promote the concept of I^{2}CNER as the model project for internationalization of research and education in the University, and integrate research efforts and education on energy across its various units, KU established the "Kyushu University Platform of Inter/Transdisciplinary Energy Research (Q-PIT)". I^{2}CNER plays a key role in this organization by helping to cross-pollinate a wide range of collaborations on energy research between KU research units of diverse disciplines including social sciences, economics, law, and political sciences. This will allow I^{2}CNER to capitalize on opportunities to broaden and enrich its energy portfolio while also helping Q-PIT advance its mission to catalyze interactions between disparate disciplines and units.

As of March 31, 2018, Kyushu University has allotted 5 tenured faculty positions to Q-PIT. To date, 3 tenured Professor positions have been filled, and a total of 14 faculty members are engaged in energy research as Q-PIT Faculty. Director Sofronis is a member of the Q-PIT strategic and faculty recruiting committees.

KU Energy Week in Support of Q-PIT
"Kyushu University Energy Week" is a week-long sequence of international workshops and symposia hosted by various energy research centers of Kyushu University. KU has held Energy Week during the last week of January since 2016 in order to support Q-PIT becoming an international hub for "future energy" research and education. Energy week is centered around I^{2}CNER's Annual Symposium and International Workshops organized by I^{2}CNER's divisions. The 2018 KU Energy Week was held from January 29 through February 2 with a theme of "Energy Intelligence without Borders for Protection of our Future." The 5-day event welcomed a total of over 1,800 participants from academia, industry, and government, both locally and overseas.

Switching to Academic Quarter (4-term) System
In FY2017, KU made a noteworthy academic change by implementing the Academic Quarter (4-term) System in order to facilitate student exchange programs from universities in the U.S., such as Illinois. The system also enables cross-appointed faculty from overseas to teach courses more easily at KU and makes it possible for KU faculty to participate in research/teaching activities at overseas partner institutions, vice versa.

Efforts to Hire Female Researchers
It is a priority within the Institute to hire and retain excellent female researchers. The Director specifically reviews applications by every woman applicant for any postdoc or faculty position. As a result, the number of female researchers in I^{2}CNER has been 4 (FY2010), 7 (FY2011), 9 (FY2012), 12 (FY2013), 11 (FY2014), 11 (FY2015), 10 (FY2016), and 14 (FY2017). These numbers, although not at the desired level, are certainly larger than corresponding totals in the other sciences, math, and engineering units of KU. The fact that there are now 14 women researchers in I^{2}CNER is a direct result of the Director's concentrated efforts to make the I^{2}CNER environment more attractive to women applicants. Among the 19 newly hired faculty and postdocs in FY2017, five were women: 1 was an Associate Professor, 1 was an Assistant Professor, and 3 were postdocs. As of March 31, 2018, I^{2}CNER has a total of 27 women researchers: 14 at KU, 9 at Illinois, and 4 at other

international/domestic institutions.

New Initiative on Tenure-Track Hires
I^{2}CNER and the Institute of Mathematics-for-Industry (IMI) jointly hired 2 tenure-track assistant professors, Drs. K. Matsue and N. D. Hoa, in Fall 2016 after submitting a joint proposal to KU's newly initiated tenure-track faculty program. These two faculty work to foster the I^{2}CNER applied math for energy research initiative and strengthen the ties and interaction between I^{2}CNER and IMI. In FY2017, the two faculty visited Illinois respectively for 1 month and for 5 months under the framework of the I^{2}CNER Collaborative Foreign Exchange Program. The visits advanced the collaborations reported in Section 2.

Super Research Assistant Program
I^{2}CNER instituted the "Super Research Assistants (SRA)" Program in order to recruit and support excellent graduate students to carry out their PhD thesis work under the supervision of our faculty within the various divisions of the Institute. These SRAs, who are supported by the WPI fund, are carefully selected from a large pool of KU graduates and are supervised by young faculty. This helps I^{2}CNER young faculty develop educational and research supervision skills. In FY2017, I^{2}CNER employed a total of 10 SRAs.

Plans for Graduate Student Exchange
The I^{2}CNER Undergraduate Exchange Program has become such a success that a similar program is being explored for graduate students between KU and Illinois. In order to explore this possibility, Prof. Takamatsu, Dean of the KU School of Engineering, visited the Illinois College of Engineering in November, 2017. During his visit, Dean Takamatsu met with the leadership team of the Illinois College of Engineering, including the Dean, and discussed how to establish an institutionalized exchange program for graduate students between the KU Graduate School of Engineering and the Illinois College of Engineering.

I^{2}CNER Faculty Involvement with Teaching
I^{2}CNER continues its tradition of collaborating with KU's School of Engineering, Graduate School of Engineering, and Graduate School of Integrated Frontier Sciences because it brings faculty into the classroom who have international experiences with cutting-edge research.

Additionally, KU is seeking the involvement of I^{2}CNER in KU's new School of Interdisciplinary Science and Innovation, which has now opened in April 2018. A new international energy course will be developed, in which I^{2}CNER faculty are expected to be involved with teaching, with the purpose being to contribute to the international education of Japanese students.

I^{2}CNER will play a crucial role in the KU "Excellent" Graduate School initiative that will establish an "Excellent" Graduate School in KU with Q-PIT at its core. A number of the admitted students to this "Excellent" Graduate School will be advised/supervised by I^{2}CNER faculty. KU envisions that I^{2}CNER's faculty involvement in this innovative and attractive graduate education program will advance the research/educational capabilities of KU and foster the international graduate education culture throughout KU.

Cross-Appointment Employment System
In view of the successful model of Director Sofronis' cross-appointment case, the KU Administration institutionalized a cross-appointment employment system in March 2015. In FY2017, plans for the cross-appoint of Prof. Baryshnikov as a Director of the US-Japan Institute for Applied Math for Energy (US-Japan IAME) are in place, and discussions have begun on how to process the appointment through the system. The US-Japan IAME involves mathematicians, engineers, and theorists from Illinois, KU, and other research institutions such as the University of Hawaii at Manoa.

Intra-University Faculty Transfer System
By virtue of Kyushu's "Intra-University Faculty Transfer System," which enables flexibility in allocating faculty within the University, in FY2017, 8 senior-level faculty were transferred to I^{2}CNER and served as the core Kyushu-based PIs of I^{2}CNER.

I^{2}CNER's Merit-based Salary System/ KU's New Merit-based Annual Salary System

In view of the effectiveness of the I^{2}CNER's Merit-based Salary System, Kyushu University adopted and introduced this system across all units. As of April 1, 2017, 339 Kyushu University faculty (16.4%) are paid within this system. Kyushu University's long-term goal is to pay approximately 20% of its faculty within this system.

5. Efforts to secure the center's future development over the mid- to long-term

* Please address the following items, which are essential to mid- to long-term center development:
- Future Prospects with regard to the research plan, research organization and PI composition; prospects for the fostering and securing of next-generation researchers
- Prospects for securing resources such as permanent positions and revenues; plan and/or implementation for defining the center's role and/or positioning the center within the host institution's institutional structure
- Measures to sustain the center as a world premier international research center after program funding ends
- Host institution's organizational reforms carried out for the Center's autonomous administration simultaneously with the creation of the Center.

Research Plan Organization and PI Composition

I^{2}CNER's grand challenge is to contribute to the creation of a carbon-neutral society (CNS) through basic research underlying energy technology which, when deployed, leads to a large reduction of greenhouse gas (GHG) emissions (70-80% by 2050 from 1990 levels). Executing this vision, I^{2}CNER plans to advocate for carbon-neutral energy solutions to the public and become a technology solution resource for government agencies on energy policy and investment. Such carbon energy neutrality is vital for Japan as the future energy mix must account for uncertainty regarding nuclear energy deployment, CO_2 management, and the fact that the world energy demand and resource availability are highly dynamic.

On the technical side, I^{2}CNER will continue pursuing electrochemical energy conversion, conversion of molecular photoenergy, thermal science and engineering, molecular catalysis, materials in aggressive environments, and CO_2 capture and storage technology or the conversion of CO_2 to a useful product. To address the loss of senior PIs due to retirements, two tenured young faculty have been elevated to the PI level as of April 1, 2018: Prof. Staykov for the advancement of our computational capabilities across division boundaries and Prof. Fujigaya, who has already discovered and developed electrocatalyst systems for fuel cells that set the benchmark of durability, to lead the efforts in low temperature fuel cells. The plan is also to elevate Prof. Kubota to the PI level to lead I^{2}CNER's expansion into materials for aggressive thermal and chemical environments. In FY2018, I^{2}CNER will also address research division reorganization in order to improve interactions among various research groups and teams.

I^{2}CNER will continue to diversify its expertise and research portfolio to include the integration of renewable energy with the grid, the interaction of the energy networks with the environment, and social and economic dynamics. Toward this goal, collaborations are already in place through the "Competitive Funding Initiative." By way of example, Prof. Hirose uses machine learning to analyze data and discover customer behaviors that affect the power grid. Prof. Managi, who specializes in economics, investigates "welfare" models of energy, work, leisure, health, and finances to rank social and economic systems. Prof. Murata applies optimization theory to model residential energy consumption and accounts for customer behavior. Prof. Shirai uses Persistent Homology to understand porous materials for CO_2 storage. Prof. Baryshnikov (Illinois) works with IMI at KU to establish the US-Japan IAME in collaboration with EVP Wakayama. His area is in stochastic networks, their geometry, topology, and applications; topological data analysis; and nonlinear control systems.

The two tenure-track assistant professors who have been hired jointly with the Institute of Mathematics of Industry (IMI) lead specific math efforts directed to effective power generation (Matsue) and on scalable grid optimization (Hoa), both work jointly with faculty at the University of Illinois. I^{2}CNER will continue to interact with, and assist with the mission of the Platform for Inter/Transdisciplinary Energy Research (Q-PIT) to identify the linkages between technology and society for future research and technology goals. In this framework, I^{2}CNER plans to hire a tenured faculty in the area of energy transitions and socioeconomics of energy. Through such hires in mathematics and social sciences and partnering with IMI, I^{2}CNER helps KU to collaborate in diverse fields/domains, such as natural science, mathematics, humanities, and social sciences.

Our large number of international research programs such as the PIRE Program, the Core-to-Core Program, and the planned International Research Training Group with the University of Göttingen

provide ideal platforms for the fostering and development of young researchers through visit exchanges that include extended overseas stays of Japanese researchers. I^{2}CNER's promotion and tenure system offers its young faculty and postdocs the opportunity to advance their careers in a way that is internationally visible, and which has obvious implications for their career development beyond I^{2}CNER. I^{2}CNER young faculty have the opportunity to take long-term sabbaticals based on the Agreement on Academic Cooperation between KU and Illinois (signed in FY2014). By way of example, Prof. Hoa's fall 2017 visit to Illinois was a sabbatical visit.

I^{2}CNER's Permanent Position within Kyushu University

Effective April 1, 2013, with the revision of the "Regulations of Kyushu University," I^{2}CNER's position is clearly defined as a permanent Research Institute of Kyushu University without regard to the length of the WPI Program.

Through a change in KU internal policy, KU will accommodate I^{2}CNER in "I^{2}CNER Building 1" with reduced rental fees, freeing ~100 M JPY for new investments in research and technology initiatives. Even after the WPI Program ends, KU will continue to provide space for the program in parts of I^{2}CNER Buildings 1 and 2. This key resource is provided as "President's Discretionary Space" in an effort to support the world-class research conducted at I^{2}CNER. To expand I^{2}CNER fusion initiatives, some Q-PIT faculty from the humanities, social sciences, and economic sciences carrying out energy research will be accommodated in the two I^{2}CNER buildings in the coming years.

President Kubo's Vision Regarding Tenured Faculty and PIs

President Kubo envisions that by 2020, I^{2}CNER will employ 20-25 PIs, including 10 tenured PIs organically in the Institute (3 to 4 of which will be non-Japanese). Following this vision, Kyushu University has allotted a total of more than 10 tenured faculty positions (Professor and Associate Professor level) to I^{2}CNER. With regard to the 10-15 PI positions which are not "tenured and organic in I^{2}CNER," they will be filled through either: i) the Intra-University Transfer System (i.e., faculty transfer from other units of KU), ii) cross-appointments between I^{2}CNER and other units of KU (e.g. economics, sciences, mathematics, life sciences, etc.), or iii) cross-appointments between I^{2}CNER and its international partner institutes and industry.

Academic units of KU can obtain points for faculty hires through an annual internal competition under the framework of the University Reform Revitalization Program, and I^{2}CNER has been successful at winning and filling positions. As of April 1, 2018, I^{2}CNER has filled a total of 4 Associate Professor and 4 Professor positions, with 2.75 points (approximately 3 positions) left to fill in FY2018. In addition, two tenure-track Assistant Professors were hired in the area of applied math for energy, bringing the total of tenured faculty to 10, with up to 3 more positions to be filled. The KU administration has stipulated that at least 2 positions must be occupied by foreign PIs (1 was filled in FY2015).

Industrial Research Unit and Industrial Advisory Board

On April 1, 2017, I^{2}CNER established the "Industrial Advisory Board (IAB)," whose members are prominent executives from industry, government agencies, and national laboratories that advise I^{2}CNER on opportunities for interactions with industry and technology transfer. The first IAB meeting was held on February 1, 2018 and attended by 9 out of 10 IAB members. The meeting provided invaluable inputs to I^{2}CNER researchers in regards to research areas that industries would have interest for promoting the development of new technologies.

Additional resources are being secured through projects sponsored by industrial partners within the newly established "Industrial Research Unit." This Unit was established in FY2017 with its purpose being to advance technology transfer with corporations and pursue stronger relationships with industry and government programs. This new "Unit" comprises of several industry-sponsored research projects, wherein a team of I^{2}CNER researchers and embedded-industry-affiliates work on a particular research area of mutual interest. Through this new unit, I^{2}CNER will expand its outreach to promote the deployment of its technology to industries that will fund I^{2}CNER projects in the future. The first such project is "Mobile Energy Storage for Low-Carbon Society" sponsored by Mazda Motor Corporation for 71 million JPY with a duration of three years beginning in FY2017. Additionally, the IHI Corporation has sponsored 5 million JPY on the "Study of High-temperature Co-electrolysis of CO_2 and H_2O."

Strategy and action plan for acquiring external funding
The Director's vision is that I^{2}CNER can remain strong and agile by developing cores of embedded centers funded by external agencies (both industrial and governmental) and securing industrial projects that will last beyond the WPI funding period.

Drawing from the experience gained from the establishment of the NEXT-RP Center, I^{2}CNER will intensify its efforts to establish similar internal research centers in response to national initiatives by government agencies such as NEDO, METI, Riken, JSPS, and JST. Riken, for example, currently does not have a location in the Western part of Japan, making Kyushu University a strong option for a potential future center. With regard to establishing internal research centers, I^{2}CNER will i) be active on implanting future research themes in government agencies for new national agency research initiatives, ii) rely on the input from the Industrial Advisory Board to create new ideas that will attract funding from industry, government, and national and international foundations (e.g. Gates Foundation, Simons Foundation), and iii) utilize the new Industrial Research Division to attract industrial projects for collaborative efforts in the form of open innovation.

An example of attracting industrial funding is the workshops that were organized jointly with Toshiba Corporation to explore the possibilities of joint research on topics of mutual interest. The first workshop targeting chemistry applications was held at I^{2}CNER on October 31, 2017 and the second workshop targeting materials for adverse environments was held at Toshiba on March 6, 2018. As a result of these workshops, there is an ongoing discussing between I^{2}CNER and Toshiba on the funding of these initiatives.

Ongoing Funded Research Programs
I^{2}CNER researchers leverage the established infrastructure, research culture, and international visibility of the Institute to aggressively pursue funding. By way of example, some major I^{2}CNER research programs are: i) The JST-CREST Grant awarded to Profs. M. Yamauchi and N. Nakashima at a level of ~ 180 million JPY from FY15 to FY19; ii) the Research Center for Next Generation Refrigerant Properties (NEXT-RP) awarded to Profs. Y. Takata and S. Koyama at a level of 58 million JPY/year from FY16 to FY17; iii) the joint PIRE program awarded by the U.S. NSF and JSPS to researchers at Illinois and Kyushu at a level of ~ 495 million JPY from FY15 to FY19 (4.5 million USD at an exchange rate of 110 JPY); iv) the Kakenhi Grant-in-Aid awarded to Profs. Ishihara and Sakai at a level of ~385 million JPY from FY15 to FY19; v) the JSPS Core-to-Core Grant for an advanced research network to Prof. Matsumoto and collaborators at a level of 90 million JPY from FY17 to FY21; vi) The Center for Small Molecule Energy (CSME) awarded to Prof. Ogo at a level of 99 million JPY from FY14 to FY18; vii) the "International Research Center of Giant Straining for Advanced Materials (IRC-GSAM) awarded to Prof. Horita from FY15 to FY20 with funding so far at the level of ~ 3 million JPY; and viii) the JSPS Grant-in-Aid for Specially Promoted Research awarded to Prof. Ogo from FY2014 to FY2018 at a level of ~440 million JPY.

Director's Authority
Kyushu University regulations and rules give the authority for the I^{2}CNER operations to the Institute Director, and the appointment/dismissal of the Institute Director is authorized by the President of the host institution. The Director is assisted by two Associate Directors. The Institute Director, Prof. Sofronis, has direct access to the Office of the President and the Office of the Executive Vice President (EVP) in charge of Research and Industry Collaboration. Regular meetings are held between the Director and the EVP in charge of Research and Industry Collaboration. 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 making decisions regarding the planning and conduct of the research activities, the formation and composition of the research program areas or divisions, potential division reorganization and redirection of research efforts in response to the 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.

Administrative Director

Since April 1, 2015, Mr. Shunichi Masuda has been the I^{2}CNER Administrative Director, which includes responsibility for the oversight of the Administrative Office and other duties as assigned by the Director, e.g. interactions with other KU units, government agencies, and corporations. Mr. Masuda has extensive experience working in industry, both in the U.S. and Japan.

6. Others

* In addition to the above 1-5 evaluation items, only if there is anything else that deserves mention regarding the center project's progress, please note it.

CICOM (Carle Illinois College of Medicine)

Another example of KU-Illinois synergy outside of I^{2}CNER is the initiative for the collaboration between the Carle Illinois College of Medicine and KU's School of Medicine. CICOM was established in May of 2017 and is the first such college of medicine in the U.S. in which medicine and engineering are fused together. The discussions for establishing a partnership between the two colleges have been carried out through the following mutual visits: May 1, 2017: EVP Wakayama and his delegation at Illinois; August 22, 2017: Prof. King Li, Dean of CICOM, and his delegation at KU; February 5, 2018: EVP Wakayama and Prof. Yusaku Nakabeppu, Director of the Medical Institute of Bioregulation at Illinois. Finalized discussions toward establishing this collaboration are projected to be complete in FY2018.

NEXT-RP (Research Center for Next Generation Refrigerant Properties)

NEXT-RP was awarded to Profs. Y. Takata and S. Koyama at a level of 58 million JPY/year from FY2016 to FY2017 by the New Energy and Industrial Technology Development Organization (NEDO). This is a unique center throughout the world because it is a focused effort on behalf of NEDO to help coordinate the efforts of the international community toward the development of next generation refrigerants. More specifically, the objectives of the Center are: accurate evaluation of thermophysical properties and fundamental performance of heat exchange and air conditioning and refrigeration (ACR) cycles for zero-ODP (ozone depletion potential) and low-GWP (global warming potential) refrigerants; organize the R&D national research group led by Kyushu University; development of base knowledge and technology for thermophysical properties, performance of heat exchange, and the fundamentals of the ACR cycle; technology transfer and assistance to ACR industrial sectors; and contributions to Japanese ACR industries to make them more competitive in the global market. Other I^{2}CNER researchers involved in the project are PI B.B. Saha and WPI Professor M. Kohno. The amount to be funded (by NEDO) to NEXT-RP in FY2018 will be at the level of 10 million JPY.

7. Center's response to the follow up results in last year

* Transcribe the item from the "Advice/ recommendations" section in the site visit report and "Actions required and recommendations" in the Follow-up report, then note how the center has responded to them.
* For the center launched in FY 2017, please describe the status of response to the pointed items in "Major points that need to be improved" of "The screening result for WPI centers launched in FY 2017."
* However, if you have already provided this information, please indicate where in the report.

"Advice/recommendations" from the Site Visit Report: The I^{2}CNER Scenarios and Roadmap documents are vital to defining the future vision of I^{2}CNER. Although I^{2}CNER tends to emphasize recent achievements in specific fields of scientific interest, it is more important to stress the importance or impact of this research on the development of future energy systems. These analyses should be based on the relationship of the research to various CO_2 reduction scenarios, the background, status and level of the work in comparison to that of other institutes, references to competing technologies, and commercialization potential. At present, there are many ongoing energy-related projects in Japan supported by governmental agencies such as NEDO, JST and government ministries. It is crucial to facilitate discussions between the Institute and the various ministries or funding agencies associated with energy research.

Building on the scenarios and the division roadmaps, which provide a clear comparison of the current I^{2}CNER research accomplishments to technology targets and benchmarks worldwide, I^{2}CNER's research portfolio is continuously updated with regard to the impact of its relevant technologies on CO_2 emission reductions. In particular, the continuously updated I^{2}CNER CO_2 Report entitled "Toward

2050: Contributing to a Low Carbon Energy Society" outlines the direct CO_2 reductions enabled by I^{2}CNER research thrusts and the industry contributions which are underpinned by these innovations. In addition, the energy transitions research within the Energy Analysis Division specifically addresses the technological advances in renewable and low-carbon initiatives to the development of energy system scenarios for Japan. The I^{2}CNER CO_2 Report specifically estimates our ongoing efforts in comparison to competing (or complementary) industries, and also factors in the technological areas in which we do not compete (nuclear energy, for example).

In general, I^{2}CNER is an enabler for *advanced materials*, *energy technologies*, and the *future of Japan's energy*. In the area of advanced materials, we are developing steels for adverse chemo-mechanical environments, efficient catalysts, and promising semiconductors. In the area of energy technologies, we are developing durable hybrid Perovskite solar cells, low and high temperature fuel cells, fuel storage systems, and positively impacting the implementation of the hydrogen economy in Japan. Lastly, with regard to the future of Japan's energy, our research informs policy and planning as well as promoting a cleaner environment through capture, utilization, or sequestration of CO_2. By way of example, our productive collaboration with Toyota Motor Corporation on the distribution of hydrogen fueling stations throughout Japan and the submission of the relevant report to the Ministry of Economy Trade and Industry demonstrates the commitment of I^{2}CNER to execute its mission through an active partnership with industry and government agencies. The multi-million yen awards from both national and international agencies such JST, METI, NEDO, and U.S. NSF also show that I^{2}CNER makes and will continue to make a serious effort to keep its research portfolio in line with and simultaneously competitive in the international energy landscape. Most importantly, the vision of Kyushu University is for I^{2}CNER to become a resource that will inform these agencies on the current state-of-the-art in energy research. Lastly, the establishment of the Industrial Research Unit within I^{2}CNER is helping to advance open innovation with industries such as Mazda Corporation and IHI Corporation while the Industrial Advisory Board is informing and facilitating the returning of our research results to society as technological innovations.

"Actions required and recommendations" from the Follow-up Report: I^{2}CNER has certainly achieved "World Premier Status", especially in the areas of institutional reform, internationalization, relationship with industry, and transfer of research results to society. Maintaining the level of research in these areas in the future will be a considerable challenge. Accordingly, it will be essential to continue providing the center support from the entirety of Kyushu University, especially from the president. Regarding I^{2}CNER's research, it would be better to develop a clear vision concerning the development of truly innovative and path-breaking energy devices and processes with demonstrative impacts on the primary goal of achieving a carbon neutral society.

Effective April 1, 2013, with the revision of the "Regulations of Kyushu University," I^{2}CNER's position is clearly defined as a permanent Research Institute of Kyushu University without regard to the length of the WPI Program. I^{2}CNER enjoys the full support of President Kubo, and as described in Section 5 under "President Kubo's Vision Regarding Tenured Faculty and PIs", I^{2}CNER's future regarding the required tenured faculty and PI numbers for a smooth transition into the post WPI-Program period is secure. As of October 1, 2016, and drawing from its international research experiences and approaches, I^{2}CNER plays a central role in the *Kyushu University Platform for Inter/Transdisciplinary Energy Research (Q-PIT)* by helping to promote and advance a wide range of collaborations on energy research with other KU units. This allows the Institute to capitalize on opportunities to broaden and enrich its energy portfolio by identifying the linkages between technology and society for future research and technology goals while also helping Q-PIT advance its mission to catalyze interactions between diverse and disparate disciplines and units. Regarding the laboratory infrastructure, through a change in KU's internal policy, KU will accommodate I^{2}CNER in "I^{2}CNER Building 1" with reduced rental fees, freeing ~100 M JPY for new investments in research and technology initiatives. After the WPI Program, KU will provide space in parts of I^{2}CNER Buildings 1 and 2, which are located at the heart of the Center Zone at the Ito Campus.

In terms of a systematic approach toward the development of a future vision, with particular focus on technology, economy, environment and a carbon-neutral society, I^{2}CNER has also developed a second living document entitled "Powering the Future: Economic, Environmental, and Social Impacts of I^{2}CNER". This document addresses many of the key "World Premier Institute" criteria, demonstrating not only the energy and technology thrusts under investigation but also the active transfer of technology to industry (34 events as of Aug. 2017, 48 in total since inception), the flow-

on impacts for employment, brain circulation and international partnerships, and our contribution to offsetting CO_2. This living document provides a strong evidence base for the future support of the institute, demonstrating I^2CNER's positive impact on science and technology, the economy, energy security, the environment, interaction with industry, and our influence on social and academic impacts including education and cultural exchange. All of these impacts are underpinned by our basic science, engineering, and energy analysis research achievements.

Appendix 1 FY2017 List of Center's Research Results and Main Awards

1. Refereed Papers

- List only the Center's papers published in 2017. (Note: The list should be for the calendar year, not the fiscal year.)

(1) Divide the papers into two categories, A and B.

A. WPI papers
List papers whose author(s) can be identified as affiliated with the WPI program (e.g., that state the name of his/her WPI center). (Not including papers in which the names of persons affiliated with the WPI program are contained only in acknowledgements.)

B. WPI-related papers
List papers related to the WPI program but whose authors are not noted in the institutional affiliations as WPI affiliated. (Including papers whose acknowledgements contain the names of researchers affiliated with the WPI program.)

Note: On 14 December 2011, the Basic Research Promotion Division in MEXT's Research Promotion Bureau circulated an instruction requiring paper authors to include the name or abbreviation of their WPI center among their institutional affiliations. As some WPI-affiliated authors of papers published up to 2011 may not be aware of this requirement, their papers are treated as "WPI-related papers." From 2012, however, the authors' affiliations must be clearly noted and only category A papers will be basically listed.

(2) Method of listing paper

- List only referred papers. Divide them into categories (e.g., original articles, reviews, proceedings).
- For each, write the author name(s); year of publication; journal name, volume, page(s), and article title. Any listing order may be used as long as format is the same. (The names of the center researchers do not need to be underlined.)
- If a paper has many authors (say, more than 20), all of their names do not need to be listed.
- If the papers are written in languages other than English, divide them into paper's categories when listing them.
- Assign a serial number to each paper to be used to identify it throughout the system.
- Order of Listing

A. WPI papers
1. Original articles
2. Review articles
3. Proceedings
4. Other English articles
5. Articles written in other than English

B. WPI-related papers
1. Original articles
2. Review articles
3. Proceedings
4. Other English articles
5. Articles written in other than English

(3) Submission of electronic data

- In addition to the above, provide a .csv file output from the Web of Science (e.g.) or other database giving the paper's raw data including Document ID. (Note: the Document ID is assigned by paper database.)
- These files do not need to be divided into paper categories.

(4) Use in assessments

- The lists of papers will be used in assessing the state of WPI project's progress in FY 2017.
- They will be used as reference in analyzing the trends and whole states of research in the said WPI center, not to evaluate individual researcher performance.
- The special characteristics of each research domain will be considered when conducting assessments.

(5) Additional documents

- After all documents, including these paper listings, showing the state of research progress have been submitted, additional documents may be requested.

Note: This list includes the refereed papers published in the calendar year 2017 either online or in-print whichever comes first.

No.	Description
	A.1. Original Articles
1	Chouwatat, P., Higaki, Y., Hirai, T. and Takahara, A. (2017), Aqueous Lubrication of Poly(ether ether ketone) Surface via Surface-initiated Polymerization of Electrolyte Monomers, Polymer, 116 (5), 549-555.
2	Watanabe, M., Honda, Y., Hagiwara, H. and Ishihara, T. (2017), [FeFe]-Hydrogenase and its organic molecule mimics-Artificial and bioengineering application for hydrogenproduction, JOURNAL OF PHOTOCHEMISTRY AND PHOTOBIOLOGY C-PHOTOCHEMISTRY REVIEWS, 33, 1-26.
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	A.2. Review Articles
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318	Hagiwara, H., Watanabe, M., Ida, S. and Isumara, T. (2017), Overall Water Splitting on Dye-modified Inorganic Semiconductor Photocatalysts, Journal of the Japan Petroleum Institute, 60 (1), 10-18.
319	Shao, HY., He, LQ., Lin, HJ. and Li, HW. (2017), Progress and Trends in Magnesium-Based Materials for Energy-Storage Research: A Review, ENERGY TECHNOLOGY, 6 (3), 445-458.
	A.3. Proceedings

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322	Ishihara, T., Bahrain, A.M.K. and Wu, K.T. (2017), Anodic performance of $La_{0.5}Sr_{0.5}Mn_{0.9}Al_{0.1}O_3$ perovskite oxide for solid oxide fuel cells using dry C3H8 fuel, ECS Transactions, 78 (1), 2511-2518.
323	Chen, Y.-M., Lin, T.-N., Liao, M.-W., Kuo, H.-Y., Yeh, C.-Y., Kao, W.-X., Yang, S.-F., Wu, K.-T. and Ishihara, T. (2017), Applications of the glycine nitrate combustion method for powder synthesis on the LSGM-based electrolyte-supported solid oxide fuel cells, ECS Transactions, 78 (1), 773-781.
324	Ito, K., Terabaru, K., Li, H., Inada, A. and Nakajima, H. (2017), Challenging of Reducing Electrolysis Voltage by Superimposing Boiling on PEMWE-A Thermodynamic Coupling-, ECS Transactions, 80 (8), 1117-1125.
325	Van Pham, T., Nguyen, D.H. and Banjerdpongchai, D. (2017), Decentralized iterative learning control of building temperature control system, Proceedings of 2017 SICE International Symposium on Control Systems, ISCS 2017, 1-7.
326	Kikuchi Y., Matsuda J., Tachikawa Y., Shiratori Y., Taniguchi S. and Sasaki K. (2017), Degradation of SOFCs by various impurities: Impedance spectroscopy and microstructural analysis, ECS Transactions, 78 (1), 2497-2504.
327	Van Pham T., Nguyen D.H. and Banjerdpongchai D. (2017), Design of iterative learning control via alternating direction method of multipliers for building temperature control system, ECTI-CON 2017 - 2017 14th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, (8096363), 814-817.
328	Komoday, R., Morita, N., Nakashima, F., Kubota, M. and Sawada, R. (2017), Development of New Measurement Method Applying MEMS Techonology for Relative Slip Range During Fretting Fatigue Test in Hydrogen, International Hydrogen Conference (IHC2016): Materials Perfomance in Hydrogen Environments, (2017), 454-461.
329	Matsumoto, S., Nagamine,M., Noda, Z., Matsuda, J., Hayashi, A. and Sasaki, K. (2017), Development of PEFC Alloy Electrocatalysts Supported on SnO2, ECS Transactions, 80 (8), 907-918.
330	Yamauchi, M., Watanabe, R., Hata, S., Kitano, S., Sadakiyo, M. and Takeguchi, T. (2017), Direct power charge and discharge using the glycolic acid/oxalic acid redox couple toward carbon-neutral energy circulation, ECS Transactions, 75 (43), 17-21.
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332	Uda, K., Noda, Z., Sasaki, K. and Hayashi, A. (2017), Electrochemical Characterization of MEAs with Different Pt-loading for the Efficient Use of Pt, ECS Transactions, 80 (8), 789-799.
333	Jige, D., Inoue, N. and Koyama, S. (2017), EVAPORATION HEAT TRANSFER AND PRESSURE DROP OF R32 IN A HORIZONTAL MULTIPORT TUBE WITH MICROFINS, The 5th IIR International Conference on Thermophysical Properties and Transfer Processes of Refrigerants, 1-8.
334	Pambudi, NA., Pristiandaru, DL., Basori; Wijayanto, DS., Bugis, H., Wahyudi, BD., Sudibyo, C., Karno, MW., Rahman, N., Sriwardani, N. and Subagsono. (2017), Experimental Investigation of Wind Turbine Using Nozzle-lens at Low Wind Speed Condition, Energy Procedia, 105, 1063-1069.
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337	Pambudi, N.A., Itaoka, K., Yamakawa, N. and Kurosawa, A. (2017), Future Japan Power Generation Sector by Introducing Hydrogen plant with 80% CO_2 emission reduction target : A preliminary analysis, IEEE The 4th International Conference on Sustainable Energy Engineering and Application (ICSEEA 2016), 7873569, 66-69.
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340	Pambudi, N.A., Itaoka, K., Chapman, A., Kurosawa, A. and Kato, E. (2017), Industrial Carbon Capture Storage (CSS) Model Using Times-Japan Framework, Energy Procedia, 142, 2525-2533.
341	Singh S., Jiang F. and Tsuji T. (2017), Influence of Slip Flow at Fluid-solid Interface upon Permeability of Natural Rock, Energy Procedia, 114, 3572-3577.
342	Ochiai, T., Nakajima, H., Karimata, T., Kitahara, T., Ito, K. and Ogura, Y. (2017), In-situ analysis of the in-plane current distribution difference between electrolyte-supported and anode-supported planar solid oxide fuel cells by segmented electrodes, ECS Transactions, 78 (1), 2203-2209.
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349	Dadfarnia, M., Nagao, A., Somerday, B.P., Shembri, P.E., Foulk III, J.W., Nibur, K.A., Balch, D.K., Ritchie, R.O. and Sofronis, P. (2017), Modeling hydrogen-induced fracture and crack propagation in high strength steels, International Hydrogen Conference (IHC 2016): Materials Perfomance in Hydrogen Environments, 572-580.
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359	Ishihara, T. (2017), Solid Oxide Reversible Cells (SORCs) Using LaGaO3-Based Oxide Electrolyte and Oxide Fuel Electrode, AIP Conference Proceedings, 1877, 02001-1-020001-6.
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364	Kubota, M., Komoda, R. and Furtado, Jader. (2017), The Effects of Oxygen Impurities on Fretting Fatigue of Austenitic Stainless Steel I Hydrogen Gas, International Hydrogen Conference (IHC 2016): Materials Perfomance in Hydrogen Environments, 62-69.
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367	Matsue, K., & Tomoeda, K. (2017), Toward a mathematical analysis for a model of suspension flowing down an inclined plane, Proceedings Of Equadiff 2017 Conference, 349-358.
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369	Li, Q. -Y., Takahashi, K. and Zhang, X. (2017), Comment on "divergent and ultrahigh thermal conductivity in millimeter-long nanotubes", Physical Review Letters, 119, 179601.
370	Takahara, A. and Higaki, Y. (2017), Design and Physicochemical Characterization of Novel Organic-Inorganic Hybrids from Natural Aluminosilicate Nanotubes, FUNCTIONAL POLYMER COMPOSITES WITH NANOCLAYS, 2017-January (22), 131-156.
371	Saha, B.B. and Thu, K. (2017), Editorial, Evergreen, 4 (1), ii-iii.

372	Weisensee P.B., Wang Y., Hongliang Q., Schultz D., King W.P. and Miljkovic N. (2017), Erratum: “Condensate droplet size distribution on lubricant-infused surfaces” (International Journal of Heat and Mass Transfer (2017) 109 (187–199) (S0017931016334925) (10.1016/j.ijheatmasstransfer.2017.01.119)), International Journal of Heat and Mass Transfer, 112, 366.
	A.5. Articles Written in other than English (In Japanese)
373	Masuda T. and Horita Z. (2017), Development of ultra high strength (1GPa) aluminum alloy using severe plastic deformation under high pressure, Keikinzoku/Journal of Japan Institute of Light Metals, 67 (10), 519-520.
374	Araki, S., Fujii, K., Akama, D., Tsuchiyama, T., Takaki, S., Ohmura, T. and Takahashi, J. (2017), Effect of low temperature aging on hall-petch coefficient in ferritic steels containing a small amount of carbon and nitrogen, Tetsu-to-Hagané, 103 (8), 491-497.
375	Hashimoto, S., Tsuchiyama, T. and Takaki, S. (2017), Effect of morphology of dual-phase structure on inhomogeneous plastic deformation and ductile fracture in Ti-4%Cr Alloy, Tetsu-To-Hagane/Journal of the Iron and Steel Institute of Japan, 103 (11), 636-645.
376	Akama, D., Tsuchiyama, T. and Takaki, S. (2017), Effect of Ni on the dislocation strengthening in ferritic iron, Tetsu-To-Hagane/Journal of the Iron and Steel Institute of Japan, 103 (5), 230-235.
377	Hashimoto, S., Komata, H. and Matsunaga, H. (2017), Effect of small defect on the flaking strength of rolling bearings (Part 2: Evaluation of the flaking strength of rolling bearing having a small drilled hole based on stress intensity factor), Transactions of the JSME, 83 (852), 16-00584.
378	Akama, D., Tsuchiyama, T. and Takaki, S. (2017), Evaluation of Dislocation Density in Cold-Worked Iron as Measured Via X-Ray Diffractometry, Zairyo/Journal of the Society of Materials Science, 66 (7), 522-528.
379	Masuda, T. and Horita, Z. (2017), Fabrication of high-strength and high-ductility laminated A2024 aluminum alloy/aluminum composite by severe plastic deformation under high pressure, Keikinzoku/Journal of Japan Institute of Light Metals, 67 (5), 179-185.
380	Nakajima, K., Ito, M., Liang, X. and Matsue, K. (2017), Present and Future of Nanomechanics by Atomic Force Microscope, Hyomen Kagaku, 38 (10), 520-525.
381	Takaki, S. and Tsuchiyama, T. (2018), Theoretical discussion of dislocation strengthening in cold rolled iron, Tetsu-To-Hagane/Journal of the Iron and Steel Institute of Japan, 104 (2), 117-120.

2. Invited Lectures, Plenary Addresses (etc.) at International Conferences and International Research Meetings

- List up to 10 main presentations during FY2017 in order from most recent.
- For each, write the lecturer/presenter's name, presentation title, conference name and date(s)

1) Takeshi Tsuji, CO_2 behavior characterization from digital rock physics and innovative monitoring system, International CCS/CCUS Seminar, Jakarta, Indonesia, Feb. 7, 2018 (Invited).
2) Yasuyuki Takata, Effect of Wettability and Dissolved Air on Early Onset of Boiling, 3rd International Symposium of Fluids and Thermal Engineering, Ningbo, China, Dec. 17-19, 2017 (Keynote).
3) Elif Ertekin, Towards a Framework for Modeling Ionic Diffusivity in Disordered Alloys: Application to Mixed Conducting Perovskites, Symposium on Design, Control and Advanced Characterization of Functional Defects in Materials — Theory and Experiment, Materials Research Society Fall Meeting, Boston, USA, Nov. 26-Dec. 1, 2017 (Invited).
4) Paul Kenis, Electrochemical CO_2 Conversion: Status and Remaining Challenges, US National Academy of Sciences / UK Royal Society Sackler Forum: "Dealing with Carbon Dioxide at Scale", Buckinghamshire, UK, Oct. 17-18, 2017 (Invited).
5) Nguyen Dinh Hoa, A novel optimization model for integrating carbon constraint with demand response and real-time pricing, Forum Math for Industry 2017 (FMfI 2017), Hawaii, USA, Oct. 1 (Invited).
6) Joichi Sugimura, Tribology and Materials for Hydrogen Energy Society, 6th World Tribology Congress, Beijing, China, Sep. 21, 2017 (Plenary).
7) Nenad Miljkovic, Towards Durable Hydrophobicity and Omniphobicity, ASME International Conference on Nanochannels, Microchannels and Minichannels, Cambridge, USA, Aug. 27-31, 2017 (Keynote).
8) Benny D. Freeman, "Ion Sorption, Diffusion and Transport in Charged Polymer Membranes", EMS Giulio C. Sarti Honorary Session, 2017 International Congress on Membranes and Membrane Processes (ICOM 2017), San Francisco, USA, Aug. 1, 2017 (Invited).
9) Miho Yamauchi, Oxide catalysts for electro-reduction of carboxylic acid toward efficient power storage, International Symposium on Pure & Applied Chemistry (ISPAC 2017), Ho Chi Minh, Vietnam, Jun. 8, 2017 (Invited).
10) John Kilner, Ionic and Mixed Conduction Phenomena in Oxides and Their Applications in Devices, ICE 2017 8th International Conference on Electroceramics, Nagoya, Japan, May 28-31, 2017 (Plenary).

3. Major Awards

- List up to 10 main awards received during FY2017 in order from the most recent.
- For each, write the recipient's name, name of award, and year issued.
- In case of multiple recipients, underline those affiliated with the center.

1) Kaveh Edalati, Scientist Medal for Advanced Energy Materials and Technology, International Association of Advanced Materials, 2018.
2) Chhun, Chanmaly, Jia, Jihui, Arata, Kioka, Tsuji, Takeshi, The Best Oral Presentation Award, 137th The Society of Exploration Geophysicists of Japan conference, 2017.
3) Nicola H. Perry, Award for Encouragement of Research, International Union of Materials Research Societies (IUMRS), 2017.
4) John Kilner, Imperial College Medal, Imperial College London, 2017.
5) Kathryn Huff, The 2017 Mary Jane Oestmann Professional Women's Achievement Award, The American Nuclear Society, 2017.
6) Tomoyasu Hirai, Young Scientist Award of the Society of Polymer Science, The Society of Polymer Science, Japan, 2017

7) Arnaud Macadre, Award for Promising Researchers, The Society of Materials Science, Japan, 2017.
8) Tomohiro Shiraki, CSJ Presentation Award 2017 for Industries, The Chemical Society of Japan (CSJ), 2017.
9) Nenad Miljkovic, Distinguished Visiting Fellow, United Kingdom Royal Society of Engineering, 2017.
10) Ken T. Christensen, Fellow, American Association for the Advancement of Science (AAAS), 2017.

Appendix 2　FY 2017 List of Principal Investigators

NOTE:
・Underline names of principal investigators who belong to an overseas research institution. Place an asterisk (*) by names of investigators considered to be ranked among world's top researchers.
・In case of researchers not listed in the latest report, attach "Biographical Sketch of a New Principal Investigator".

<Results at the end of FY2017> **Principal Investigators Total: 25**

Name	Age	Affiliation (Position title, department, organization)	Academic degree specialty	Effort (%)*	Starting date of project participation	Status of project participation (Describe in concrete terms)	Contributions by PIs from overseas research institutions
Center director Petros Sofronis*	60	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	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 (49.6% time) ・Promotes I^2CNER's interests worldwide to various universities, government agencies, laboratories, and industries on a daily basis ・Intensive trans-Pacific electronic communication via e-mail, Skype, videoconferencing, etc.	Manages and directs I^2CNER's operations
Tatsumi Ishihara*	56	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr., Catalyst and solid state electrochemistry	100%	2010, Dec. 1st	・Located at I^2CNER ・Executes duties of Associate Director ・Lead PI of Molecular Photoconversion Devices Division	
Chihaya Adachi*	54	Prof., Department of Applied Chemistry, Kyushu University	Dr. of Engr., Materials science and device physics	80%	2010, Dec. 1st	・Located at I^2CNER ・Leads research activities of his team	

Atsushi Takahara*	62	Prof., Institute for Materials Chemistry and Engineering, Kyushu University	Dr. of Engr., Surface and Interface Characterization	80%	2010, Dec. 1st	・Located at I^2CNER ・Leads research activities of his team	
Seiji Ogo*	54	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Science, Green Chemistry	100%	2010, Dec. 1st	・Located at I^2CNER ・Lead PI of Catalytic Materials Transformations Division	
Zenji Horita*	64	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Ph.D., Dr. of Engr., Materials Science	100%	2010, Dec. 1st	・Located at I^2CNER ・Leads research activities of his team	
Kazunari Sasaki* (for engineering next generation fuel cells)	53	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Science and technology, Fuel cell materials, Inorganic materials	100%	2010, Dec. 1st	・Located at I^2CNER ・Leads research activities of his team	
Harry L. Tuller*	72	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 team ・Visited I^2CNER for two weeks to participate in events and work on collaborative research projects ・Participates in research discussions via internet	Hosted Assistant Professor Nicola Perry and Dr. Dino Klotz from I^2CNER at MIT for multiple months

John A. Kilner*	71	Prof., 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 team ・Visited I^2CNER for eight weeks to participate in events and work on collaborative projects ・Participates in research discussions via internet	Hosted Dr. Vincent Thoreton from I^2CNER at the Imperial College London twice in FY2017: once for 2 weeks and another for three weeks
Joichi Sugimura*	60	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 team	
Yasuyuki Takata*	61	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr., Thermal Engineering	100%	2010, Dec. 1st	・Located at I^2CNER ・Executes duties of Associate Director ・Lead PI of Thermal Sciences and Engineering Division	
Xing Zhang*	56	Prof., Department of Engineering Mechanics, Tsinghua University, China	Ph.D., Thermal Science	20%	2010, Dec. 1st	・Primarily located at partner institution ・Leads research activities of his team ・Visited I^2CNER for four weeks to participate in events and work on collaborative projects ・Participates in research discussions via internet	
Brian P. Somerday*	49	Dr., Southwest Research Institute, USA	Ph.D., Materials Science and Engineering	20%	2010, Dec. 1st	・Primarily located at partner institution ・Lead PI of Hydrogen Materials Compatibility Division ・Visited I^2CNER for two weeks to participate in events and work on collaborative projects ・Participates in meetings/events via internet and videoconferences	Hosted a group of researchers from I^2CNER at the Southwest Research Institute for the Hydrogen Materials Compatibility Division retreat

Setsuo Takaki*	65	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr.	100%	2011, Apr. 1st	・Located at I^2CNER ・Leads research activities of his team	
Reiner Kirchheim*	74	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 team ・Visited I^2CNER for one week to participate in events and work on collaborative projects ・Participates in research discussions via internet	
Miho Yamauchi*	44	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Science, Chemistry	100%	2012, Jan. 1st	・Located at I^2CNER ・Leads research activities of her team	
Ken Sakai*	56	Prof., Department of Chemistry Faculty of Sciences, Kyushu University	Dr. of Science, Inorganic Chemistry	90%	2012, Jan. 16th	・Located at I^2CNER ・Leads research activities of his team	
Ian Robertson*	60	Prof., Dean of Engineering, University of Wisconsin-Madison, USA	Ph.D., Metallurgy	15%	2012, April. 1st	・Primarily located at partner institution ・Participates in research/events as Chief Science Advisor to the Director ・Participates in research discussions via internet	

Andrew A. Gewirth*	58	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 team ・Serves as a member of the Illinois Satellite Advisory Committee and IPRC ・Visited I^2CNER for two weeks to participate in events and work on collaborative projects ・Participates in research discussions via internet	
Kenneth T. Christensen*	44	Prof., Department Chair, Aerospace and Mechanical Engineering, University of Notre Dame, USA	Ph.D., Theoretical and Applied Mechanics specializing in experimental fluid mechanics	25%	2012, April. 1st	・Primarily located at partner institution ・Leads research activities of his team ・Serves as a member of the Illinois Satellite Advisory Committee and IPRC ・Participates in research discussions via internet	
Shigenori Fujikawa (Associate Professor)	47	Associate 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 CO_2 Capture and Utilization Division	
Takeshi Tsuji*	38	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Science, Earth and Planetary Science, Resource engineering, Space exploration	100%	2013, June. 1st	・Located at I^2CNER ・Lead PI of CO_2 Storage Division	

Hiroshige Matsumoto*	51	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr.	100%	2010, Dec. 1st	・Located at I^2CNER ・Lead PI of Electrochemical Energy Conversion Division	
Bidyut B. Saha*	52	Prof., International Institute for Carbon-Neutral Energy Research, Kyushu University	Dr. of Engr.	100%** (**revised in the final version)	2010, Dec. 1st	・Located at I^2CNER ・Leads research activities of his team	
Thomas Lippert*	55	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 team ・Visited I^2CNER for three weeks to participate in events and work on collaborative projects ・Participates in research discussions via internet	Hosted Dr. Kulbir Ghuman from I^2CNER at PSI for multiple months

*Percentage of time that the principal Investigator will devote to his/her work for the center vis-à-vis his/her total working hours (total time for whole working activities including education, medical services, and others as well as research).

Researchers unable to participate in project in FY 2017

Name	Affiliation (Position title, department, organization)	Starting date of project participation	Reasons	Measures taken
Naotoshi Nakashima	Research Professor, International Institute for Carbon-Neutral Energy Research, Kyushu University	2010, Dec. 1st	Retirement from the PI position as of March 31, 2017	Appointment changed to WPI Professor
Etsuo Akiba	Research Professor, International Research Center for Hydrogen Energy, Kyushu University	2010, Dec. 1st	Retirement from the PI position as of March 31, 2017	Appointment changed to WPI Professor

Appendix 3-1 FY 2017 Records of Center Activities

1. Researchers and center staffs, satellites, partner institutions

1-1. Number of researchers in the "core" established within the host institution

- Regarding the number of researchers at the Center, please fill in the table in Appendix 3-1a.

Special mention

- Enter matters warranting special mention, such as concrete plans for achieving the Center's goals, established schedules for employing main 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.

<FY2017 (April 1, 2017~March 31, 2018)>

Researcher (Nationality)	Position at I²CNER	Affiliated with I²CNER for:	Affiliation before I²CNER	Affiliation after I²CNER
Stephen Lyth (British)	Asst. Prof. (until March 31, 2015), Assoc. Prof.	6 years and 4 months	Tokyo Institute of Technology, Japan	Associate Professor, Kyushu University, Japan (since October 1, 2017)
Arnaud Macadre (French)	Postdoc	6 years	Kyushu University, Japan	Associate Professor, Yamaguchi University, Japan (beginning April 1, 2018)
Nicola Perry (British/USA)	Postdoc (until August 15, 2014) Asst. Prof.	5 years and 4 months	Northwestern University, USA	Assistant Professor, University of Illinois at Urbana-Champaign, USA (since January 1, 2018)
Nga Thi Thanh Nguyen (Vietnamese)	Postdoc	3 years	Kyushu University, Japan (Ph.D. Student)	TBD *(Appointment not renewed after March 31, 2018)*
Yuki Terayama (Japanese)	Postdoc	2 years and 11 months	Asahi Intecc Co., Japan	Postdoc, Kyushu University, Japan (beginning April 1, 2018)
Shiwani Singh (Indian)	Postdoc	1 year and 11 months	Jawaharlal Nehru Centre for Advanced Scientific Research, India	Research Fellow, University of Warwick, UK (since January 1, 2018)
Pambudi Nugroho Agung (Indonesian)	Postdoc	1 year and 7 months	Sebelas Maret University, Indonesia	Assistant Professor, Sebelas Maret University, Indonesia (since November 1, 2017)
Yu Sun (Chinese)	Postdoc	1 year and 6 months	Hangyang University, South Korea	Assistant Professor, Hokkaido University, Japan (beginning April 1, 2018)
Tomohiro Tsugawa (Japanese)	Postdoc	1 year and 5 months	Kyushu University, Japan	Tanaka Kikinzoku Kogyo K.K, Japan (beginning April 1, 2018)
Sourav Mitra (Indian)	Postdoc	1 year and 4 months	Indian Institute of Science Bangalore, India (Ph.D. Student)	Postdoc, Indian Institute of Technology Kharagpur, India (since November 1, 2017)
Jihui Jia (Chinese)	Postdoc	1 year and 3 months	Kyushu University, Japan	Assistant Professor, China University of Petroleum, China (since September 1, 2017)
Thomas Bayer (German)	Postdoc	1 year and 2 months	Kyushu University, Japan	Yanmar CO. Ltd., Japan (since February 1, 2018)

Patcharida Chauwatat (Thai)	Postdoc	1 year and 2 months	Kyoto University, Japan (Ph.D. Student)	TBD *(Resigned from I²CNER as of May 31, 2017)*
Jun Yang (Chinese)	Postdoc	1 year and 2 months	Kyushu University, Japan	Research Professor, Ningbo Institute of Industrial Technology, China (since August 1, 2017)
Fumiyuki Toshimitsu (Japanese)	Postdoc	1 year	Kyushu University, Japan	Postdoc, Kyushu University, Japan (beginning April 1, 2018)
Kosem Nuttavut (Thai)	Postdoc	1 year	Kyushu University, Japan	(Currently at I²CNER)
Ryosuke Komoda (Japanese)	Postdoc	1 year	Kyushu University, Japan (Ph.D. Student)	(Currently at I²CNER)
Yi-Hsuan Lee (Taiwanese)	Postdoc	11 months	National Central University, Taiwan	Postdoc, Academia Sinica, Taiwan (beginning April 1, 2018)
Takashi Fukushima (Japanese)	Postdoc	11 months	iCeMs, Kyoto University, Japan	(Currently at I²CNER)
Junfang Cheng (Chinese)	Postdoc	10 months	Huazhong University of Science and Technology, China (Ph.D. Student)	(Currently at I²CNER)
Dino Klotz (German)	Postdoc	10 months	Karlsruhe Institute of Technology, Germany	(Currently at I²CNER)
Hackho Kim (South Korean)	Assoc. Prof.	7 months	Kyushu University, Japan	(Currently at I²CNER)
Wei Ma (Chinese)	Postdoc	6 months	Kyushu University, Japan	(Currently at I²CNER)
Youngsung Lee (Chinese)	Postdoc	6 months	Kyushu University, Japan	(Currently at I²CNER)
Ganesan Pandian (Indian)	Postdoc	6 months	Daegu Gyeongbuk Institute of Science and Technology, South Korea	(Currently at I²CNER)
Yukina Takahashi (Japanese)	Assoc. Prof.	6 months	Kyushu University, Japan	(Currently at I²CNER)
Aline Fluri (Swiss)	Postdoc	4 months	Kyushu University, Japan	Postdoc, Kyushu University, Japan (beginning April 1, 2018)
Zonghao Shen (Chinese)	Postdoc	3 months	Kyushu University, Japan	Postdoc, Kyushu University, Japan (since March 1, 2018)
Sijun Luo (Chinese)	Postdoc	3 months	Tulane University, USA (Ph.D. Student)	(Currently at I²CNER)
Gabseok Seo (South Korean)	Postdoc	3 months	Sungkyunkwan University, South Korea	(Currently at I²CNER)
Miho Isegawa (Japanese)	Asst. Prof.	2 months	Fukui Institute for Fundamental Chemistry, Japan	(Currently at I²CNER)
Minkyu Son (South Korean)	Asst. Prof.	1 month	Swiss Federal Laboratories for Materials Science and Technology (EMPA), Switzerland	(Currently at I²CNER)
Hadi Farabi Asl (Iranian)	Postdoc	1 month	Akita University, Japan	(Currently at I²CNER)

1-2. Satellites and partner institutions

- List the satellite and partner institutions in the table below.
- Indicate newly added and deleted institutions in the "Notes" column.
- If satellite institutions have been established, describe by satellite the Center's achievements in coauthored papers and researcher exchanges in Appendix 4.

<Satellite institution: 1 institution>

Institution name	Principal Investigator(s), if any	Notes
University of Illinois at Urbana-Champaign (UIUC), USA	Andrew Gewirth	

<Partner institutions: 23 institutions>

Institution name	Principal Investigator(s), if any	Notes
Banding 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		
Helmholtz Institute Forschungszentrum Juelich, Germany		
Imperial College London, UK	John Kilner	
Massachusetts Institute of Technology, USA	Harry Tuller	
Norwegian University of Science and Technology (NTNU), Norway		
Paul Scherrer Institute (PSI), Switzerland	Thomas Lippert	
Southwest Research Institute, USA	Brian Somerday	
Tsinghua University, China	Xing Zhang	
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		
University of Notre Dame, USA,	Kenneth Christensen	
University of Oxford, UK		
University of Texas at Austin, USA		
University of Thessaly, Greece		
University of Wisconsin-Madison, USA	Ian Robertson	

2. Securing external research funding*

External research funding secured in FY2017

Total: 1,772,850,451 yen

- Describe external funding warranting special mention. Include the name and total amount of each grant.
* External research funding includes "Grant-in-Aid for Scientific Research," funding for "commissioned research projects," and for "joint research projects" as listed under "Research projects" in Appendix 3-2, Project Expenditures.

COMPETITIVE FUND			
RECIPIENT	NAME OF GRANT	FUNDED BY:	FY2017 TOTAL JPY
Joichi Sugimura	R&D Project (Useful Technology of Hydrogen)	NEDO	318,331,440
Chihaya Adachi	Exploratory Research for Advanced Technology (ERATO)	JST	274,106,000
Tatsumi Ishihara	KAKENHI (Specially Promoted Research)	JSPS	117,800,000
Kazunari Sasaki	Demonstration Research on a Hydrogen-based Society through Collaboration among Industry, University, Government and Local Community	MEXT	103,274,000

COMPETITIVE FUND

RECIPIENT	NAME OF GRANT	FUNDED BY	PERIOD	TOTAL JPY
Miho Yamauchi	CREST	JST	FY2015-18 (FY2017)	120,055,000 (36,530,000)
Development of Highly Selective Nanoalloy Catalysts for the Realization of Carbon-neutral Energy Cycles				
Hiroshige Matsumoto	SIP	JST	FY2014-18 (FY2017)	48,750,000 (11,212,500)
Novel Steam Electrolysis				
Naotoshi Nakashima	KAKENHI (Scientific Research A)	JSPS	FY 2016-20 (FY 2017)	41,600,000 (8,970,000)
Nanocarbon-based Advanced Materials Design for the Construction of Ecological Energy and Environmental Society				
Ikuo Taniguchi	ALCA	JST	FY2014-18 (FY2017)	31,980,000 (9,100,000)
Development of CO_2 Separation Membrane Comprised of Nano-gels with Controlled Phase Transition by pKa and the Effective Separation Process				
Motonori Watanabe	KAKENHI (Young Scientists A)	JSPS	FY 2017-19 (FY2017)	24,440,000 (10,530,000)
Development of Noble Metal-free Photocatalyst System Using Iron-based Organometalic Complex as Co-catalyst				
Edalati Kaveh	KAKENHI (Scientific Research B)	JSPS	FY 2016-19 (FY2017)	18,460,000 (1,300,000)
Development of New Mg-Based Hydrogen Storage Materials by Binding-Energy Engineering				

Masanobu Kubota	KAKENHI (Scientific Research B)	JSPS	FY 2016-18 (FY2017)	18,070,000 (1,690,000)

Elucidation of Material Degradation Phenomena in High-temperature Hydrogen Environment for Ensuring Safety of Next-generation Hydrogen Utilization Technologies

Xing Zhang	KAKENHI (Scientific Research B)	JSPS	FY 2016-18 (FY2017)	17,680,000 (4,030,000)

Laser-flash Raman Spectroscopy Method and Heat Transfer Performance of Novel Low-dimensional Materials

Toshinori Matsushima	KAKENHI (Scientific Research B)	JSPS	FY 2016-18 (FY2017)	17,290,000 (1,950,000)

Organic-inorganic Perovskite Field-effect Transistors

Masaaki Sadakiyo	KAKENHI (Young Scientists A)	JSPS	FY 2017-18 (FY2017)	16,250000 (6,110,000)

Control of Catalytic Property Using the Interface between Metal and Metal-Organic Framework

Yukina Takahashi	KAKENHI (Young Scientists A)	JSPS	FY2017-19 (FY2017)	11,310,000 (4,940,000)

Formation of Highly-efficient Photoenergy Conversion Fields by Controlling Configuration and Orientation of Anisotropic Metal Nanoparticles

Miho Yamauchi	KAKENHI Challenging Research (Exploratory)	JSPS	FY2017-18 (FY2017)	6,370,000 (4,030,000)

Creation of High Density Hydrogen Storage Metal Nano-capsules

Motonori Watanabe	KAKENHI Challenging Research (Exploratory)	JSPS	FY2017-18 (FY2017)	6,370,000 (3,510,000)

An Attempt to Synthesize Cyclacene Using Decarbonyl Aromatic Ring Reaction

Ikuo Taniguchi	KAKENHI (Scientific Research C)	JSPS	FY 2017-19 (FY2017)	4,940,000 (2,080,000)

Elucidation of CO_2 Transport Mechanism of Piperazine-containing CO_2 Separation Membranes

Ki Suk Yoon	KAKENHI (Scientific Research C)	JSPS	FY 2015-17 (FY2017)	4,940,000 (1,040,000)

Elucidating Electron Transfer Mechanism of New [NiFe]hydrogenase Surpassing Platinum Catalyst

Kenshi Itaoka	KAKENHI (Scientific Research C)	JSPS	FY 2017-19 (FY2017)	4,940,000 (650,000)

Estimation of Utility Function and Construction of Cost Benefit Model Considering Altruistic Benefits of Climate Policy

Aleksandar Staykov	KAKENHI (Young Scientists B)	JSPS	FY2016-17 (FY2017)	4,290,000 (1,300,000)

Molecular Spin-switch for Effective Electron-hole Separation at Hybrid Interfaces for Application in Photocatalysis

John Druce	KAKENHI (Young Scientists B)	JSPS	FY2016-17 (FY2017)	4,160,000 (1,950,000)

Effects of Feed Gas Composition on Surface Reactivity and Degradation of Solid Oxide Electrodes

(Prof. Druce resigned from I²CNER as of November 14, 2017)

Daniel Orejon	KAKENHI (Young Scientists B)	JSPS	FY2016-17 (FY2017)	4,160,000 (1,430,000)

Effect of Micro-/Nano-patterned Wettability on the Fundamentals of Condensation Heat Transfer

Yukina Takahashi	KAKENHI (Challenging Exploratory Research)	JSPS	FY2016-17 (FY2017)	3,640,000 (650,000)

Development of Plasmon-induced Charge Separation Systems at the Interface between a Metal Nanoparticle and a p-type Semiconductor

Thomas Bayer	KAKENHI (Young Scientists B)	JSPS	FY2017-18 (FY2017)	3,250,000 (2,210,000)

Study of Nanocellulose as a New Proton Conducting Material for Fuel Cells and Electrolysers

(Dr. Bayer resigned from I²CNER as of January 31, 2018)

Arnaud Macadre	KAKENHI (Young Scientists B)	JSPS	FY2016-17 (FY2017)	3,120,000 (1,170,000)

Ultra-grain Refinement as Prevention against Hydrogen-assisted Crack Propagation

Sivasankaran Harish	KAKENHI Research Activity start-up	JSPS	FY2016-17 (FY2017)	2,990,000 (1,430,000)

Liquid-vapour Phase Change Phenomena of Droplet Impacting on a Super-heated Nano-engineered Surfaces

Ryosuke Komoda	KAKENHI Research Activity start-up	JSPS	FY2017-18 (FY2017)	2,990,000 (1,430,000)

Elucidation of Inhibitory Effect of Gas Impurities on Hydrogen-induced Fracture and Effects of Various Factors

Tatsunori Ikeda	KAKENHI (Young Scientists B)	JSPS	FY2016-17 (FY2017)	2,340,000 (910,000)

Development of Monitoring Techniques in CO_2 capture and Storage Using Temporal Change in Seismic Velocity and Attenuation

COMMISSIONED RESEARCH

RECIPIENT	FUNDED BY	PERIOD	TOTAL JPY
Hiroshige Matsumoto	JSPS (Core-to-Core Program)	FY2017-21 (FY2017)	90,000,000 (15,840,000)

Solid Oxide Interfaces for Faster Ion Transport (SOIFIT)

Tatsumi Ishihara	JSPS (PIRE Program)	FY2015-20 (FY2017)	49,500,000 (9,900,000)

Integrated Computational Materials Engineering for Active Materials and Interfaces in Chemical Fuel Production

Tatsumi Ishihara	METI	FY2017	19,999,980

Research in the Field of Proton Conducting Ceramic Materials (PCCM) and Membranes, Oxygen Transport Membranes, Low Temperature Solid Oxide Fuel Cells and Electrolysers

Ikuo Taniguchi	Tokyo Boeki Mechanics	FY2017-19 (FY2017)	19,698,235 (4,420,235)

Development of Carbon-free Hydrogen Production System with High Performance CO_2 Separation Membranes

Kenshi Itaoka	Toyota	FY2017	16,849,898
Study on Domestic Infrastructure for Hydrogen Use and Economic Impact of Hydrogen Energy Introduction in the World			
Kenshi Itaoka	Meiji University	FY2017-18 (FY2017)	6,400,000 (3,200,000)
Creation of Environmental and Economic Evaluation Model on CCS			
Yukihiro Higashi	METI	FY2017	2,373,357
Research of Thermophysical Properties for the Binary R1123 + R1234yf Refrigerant Mixture			
Kenshi Itaoka	Mizuho Information & Research Institute	FY2017	2,042,330
Study on Measures to Expedite Implementation of CCS in Japan			
Keigo Kitamura	Geothermal Energy Research & Development	FY2017	1,409,206
Experimental Study for Electrical Impedance Measurement of High-temperature Rock			

JOINT RESEARCH

RECIPIENT	FUNDED BY	PERIOD	TOTAL JPY
Industrial Research Unit (Mazda Project)	Mazda Motor Corporation	FY2017-19 (FY2017)	71,248,000 (31,308,000)
Mobile Energy Storage for Low-carbon Society			
Masanobu Kubota	Air Liquid Laboratories	FY2014-17 (FY2017)	51,468,000 (9,480,000)
Effect of Gas Impurities on Inhibition of Hydrogen Embrittlement of Steels			
Yukihiro Higashi	Daikin	FY2017-18 (FY2017)	19,960,182 (19,960,182)
Accurate Measurements of Thermodynamic Properties for Next Generation Refrigerants			
Petros Sofronis	IHI	FY2017	4,992,000
Study on High-temperature Co-electrolysis of CO_2 and H_2O			
Naotoshi Nakashima	Zeon	FY2017	4,800,000
Study on the Development of a Nanocarbon-based New Reduction Catalyst			
Naotoshi Nakashima	Itoh Kouki	FY2017	3,600,000
Study on Durability Testing of Fuel Cell Catalyst			
Masanobu Kubota	Nippon Steel & Sumitomo Metal Corporation	FY2017-18 (FY2017)	1,944,000 (1,944,000)
Development of Fatigue Strength Evaluation Method-based on Fretting Fatigue and Small Crack Growth Properties			
Ikuo Taniguchi	Tosoh	FY2017	1,500,000
Natural Gas Purification by Membrane Separation with Novel Amines			

Shigenori Fujikawa	Tokyo Ohka Kogyo	FY2016-17 (FY2017)	1,500,000 (1,000,000)
Surface Functionalization by Ultrathin Polymer Coating and Elucidation its Functional Origin			
Bidyut Baran Saha	Tokyo Boeki Engineering	FY2017	1,200,000
Performance Improvement of Adsorption Chiller and its Validity			
Yukihiro Higashi	Kobe Steel	FY2017	720,000
Fundamental Study of the Heat Transfer Medium for Heat Exchangers			
Naotoshi Nakashima	ADEKA	FY2017	60,0000
Study on Graphene-based fuel Cell Catalyst			

3. International research conferences or symposiums held to bring world's leading researchers together

- Indicate the number of international research conferences or symposiums held in FY2017 and give up to three examples of the most representative ones using the table below.

FY 2017: 5 meetings

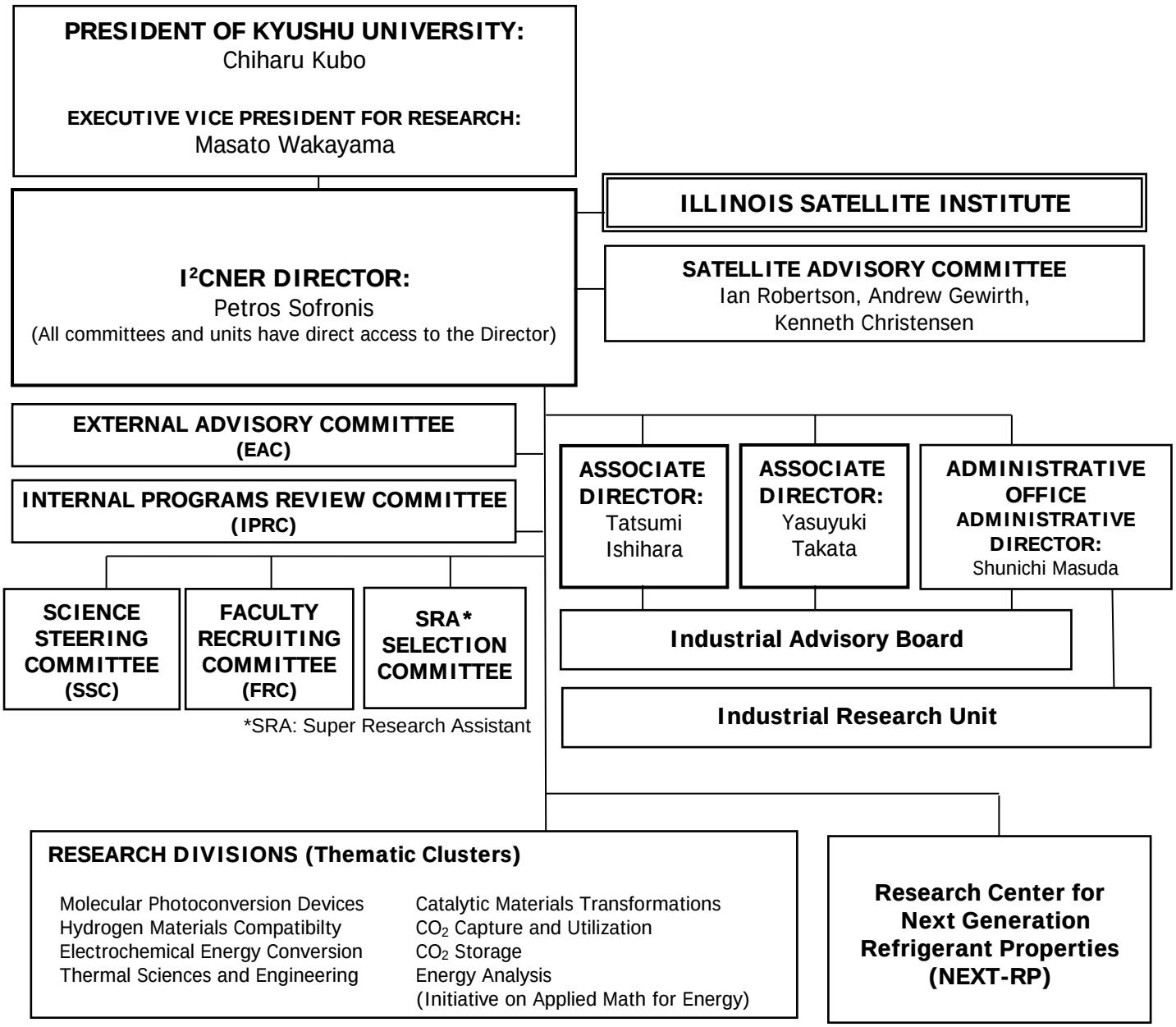
Major examples (meeting titles and places held)	Number of participants
2018 I^{2}CNER Annual Symposium, I^{2}CNER Hall, Ito Campus, Kyushu University, Fukuoka January 31, 2018	From domestic institutions: 80 From overseas institutions: 86
2018 I^{2}CNER International Workshops, Ito Campus, Kyushu University, Fukuoka February 2, 2018	From domestic institutions: 282 From overseas institutions: 114
The 10th International Conference on Boiling and Condensation Heat Transfer (ICBCHT 2018), Nagasaki Brick Hall, Nagasaki March 12-15, 2018	From domestic institutions: 150 From overseas institutions: 60

4. Center's management system

- Please diagram management system in an easily understood manner.
- If any changes have been made in the management system from that in the latest "center project," please describe them. Please 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).

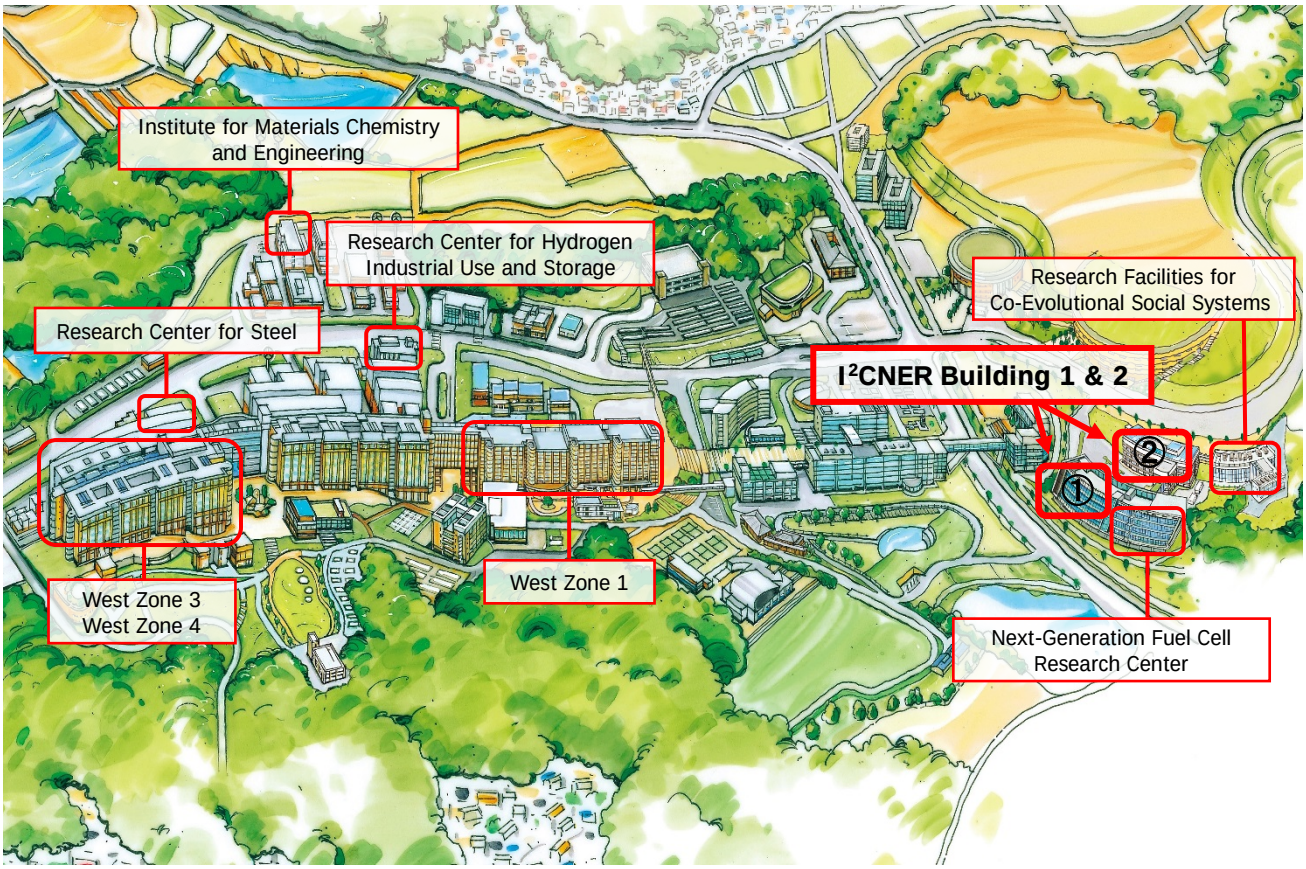
I²CNER ORGANIZATIONAL STRUCTURE

(As of March 31, 2018)



5. Campus Map

- Please draw a simple map of the campus showing where the main office and principle investigator(s) are located.



Appendix 3-1a FY 2017 Records of Center Activities

1-1. Number of researchers and other center staffs

* Please fill in the number of researchers and other center staffs in the table blow.
* Please describe the final goals for achieving these numbers and dates when they will be achieved.

a) Principal Investigators（full professors, associate professors or other researchers of comparable standing)

(persons)

	At beginning of project	At end of FY 2017	Final goal (Date: March, 2020)
Researchers from within the host institution	16	16	18
Foreign researchers invited from abroad	11	9	8
Researchers invited from other Japanese institutions	3	0	0
Total principal investigators	30	25	26

b) Total members

	At beginning of project		At end of FY2017		Final goal (Date: March, 2020)	
	Number of persons	%	Number of persons	%	Number of persons	%
Researchers	71		182		173	
Overseas researchers	21	30%	89	49%	80	46%
Female researchers	4	6%	27	15%*	29	17%
Principal investigators	30		25		26	
Overseas PIs	11	37%	11	44%	8	31%
Female PIs	1	3%	1	4%	1	4%
Other researchers	41		157		147	
Overseas researchers	10	24%	78	50%	72	49%
Female researchers	3	7%	26	17%	28	19%
Research support staffs	32		67		70	
Administrative staffs	23		20		21	
Total number of people who form the "core" of the research center	126		269		264	

(* revised in the final version)

Appendix 3-2 Project Expenditures

1) Overall project funding

* In the “Total Cost” column, enter the total amount of funding required to implement the project, without dividing it into funding sources.
* In the “Amount covered by WPI funding” column, enter the amount covered by WPI within the total amount.
* In the “Personnel,” “Project activities,” “Travel,” and “Equipment” blocks, the items and details may be changed to coincide with the project’s actual content.

(Million yens)

Cost Items	Details (For Personnel - Equipment please fill in the breakdown of fiscal expenditure, and the income breakdown for Research projects.)	Total Costs	Amount covered by WPI funding
Personnel	Center director and Administrative director	22	22
	Principal investigators (no. of persons):15	212	172
	Other researchers (no. of persons):80	371	274
	Research support staffs (no. of persons):27	61	61
	Administrative staffs (no. of persons):23	102	52
	Subtotal	768	581
Project activities	Gratuities and honoraria paid to invited principal investigators (no. of persons):71	6	6
	Cost of dispatching scientists (no. of persons):0	0	0
	Research startup cost (no. of persons):24	52	21
	Cost of satellite organizations (no. of satellite organizations):1	189	189
	Cost of international symposiums (no. of symposiums):1	5	5
	Rental fees for facilities	242	242
	Cost of consumables	18	18
	Cost of utilities	34	6
	Other costs	45	23
	Subtotal	591	510
Travel	Domestic travel costs	16	14
	Overseas travel costs	47	44
	Travel and accommodations cost for invited scientists (no. of domestic scientists):57 (no. of overseas scientists):60	20	19
	Travel cost for scientists on secondment (no. of domestic scientists):2 (no. of overseas scientists):60	3	3
	Subtotal	86	80
Equipment	Depreciation of buildings	81	1
	Depreciation of equipment	854	208
	Subtotal	935	209
Research projects (Detail items must be fixed)	Projects supported by other government subsidies, etc. *1	120	
	Grants-in-Aid for Scientific Research, etc.	213	
	Commissioned research projects, etc.	913	
	Joint research projects	144	
	Ohers (donations, etc.)	5	
	Subtotal	1,395	0
Total		3,775	1,380

Costs (Million yens)

WPI grant in FY 2017	1320
Costs of establishing and maintaining facilities	2
Establishing new facilities (Number of facilities: , 0m²)	0
Repairing facilities (Building 2) (Number of facilities:5,000m²)	2
Others	0
Cost of equipment procured	534
Hall Voltage Measuring System (Number of units:1)	15
Ultra high resolution scanning electron micrograph (Number of units:1)	52
Others	467

*1. Funding sources that include government subsidies (including Enhancements promotion expenses (機能強化促進経費), National university reform reinforcement promotion subsidy (国立大学改革強化推進補助金) etc.), indirect funding, and allocations from the university’s own resources.
*2 When personnel, travel, equipment (etc.) expenses are covered by Grants-in-Aid or under commissioned research projects or joint research projects, the amounts should be entered in the “Research projects” block.

2) Costs of Satellites and Partner institutions

(Million yens)

Cost Items	Details	Total Costs	Amount covered by WPI funding
Personnel	Principal investigators (no. of persons):2		
	Other researchers (no. of persons):6		
	Research support staffs (no. of persons):20		
	Administrative staffs		
	Subtotal	118	118
Project activities	Subtotal	49	49
Travel	Subtotal	19	19
Equipment	Subtotal	3	3
Research projects	Subtotal	0	0
Total		189	189

Appendix 4 FY 2017 Status of Collaboration with Overseas Satellites

1. Coauthored Papers

- List the refereed papers published in FY 2017 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.
- For reference write the Appendix 1 item number in parentheses after the item number in the blocks below. Let it free, if the paper is published in between Jan.-Mar. 2018 and not described in Appendix 1.

Overseas Satellite 1 University of Illinois at Urbana-Champaign (Total: 18 papers)

No	Description
(8)	Martin, M.L., *Dadfarnia, M.*, Orwig, S., Moore, D. and Sofronis, P. (2017), A microstructure-based mechanism of cracking in high temperature hydrogen attack, Acta Materialia, 140, 300-304.
(27)	Ma, S., Liu, J., Sasaski, K., Lyth, S.M. and *Kenis, P.* (2017), Carbon foam decorated with silver nanoparticles for electrochemical CO_2 conversion, Energy Technology, 5 (6), 861-863.
(70)	*Kearney, K.*, Iyer, A., *Rockett, A.*, Staykov, A. and *Ertekin, E.* (2017), Effect of Surface Coverage and Composition on the Stability and Interfacial Dipole of Functionalized Silicon, Journal of Physical Chemistry C, 121 (21), 11312-11318.
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(365)	Nygren, K., Nagao, A., Sofronis, P. and *Robertson I.M.* (2017), The influence of high internal hydrogen content on the evolved microstructure during fatigue-crack growth in 316L stainless steel, International Hydrogen Conference (IHC 2016): Materials Perfomance in Hydrogen Environments, 270-276.
(-)	Nagao, A., *Dadfarnia, M.*, Somerday, B.P., Sofronis, P. and O. Ritchie, R.O. (2018), Hydrogen-enhanced-plasticity mediated decohesion for hydrogen-induced intergranular and “quasi-cleavage” fracture of lath martensitic steels, Journal of the Mechanics and Physics of Solids, 112, 403-430.

2. Status of Researcher Exchanges

- Using the below tables, indicate the number and length of researcher exchanges in FY 2017. Enter by institution and length of exchange.
- Write the number of principal investigator visits in the top of each space and the number of other researchers in the bottom.

Overseas Satellite 1: University of Illinois at Urbana-Champaign

<To satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2017	0	0	0	0	0
	2	1	0	1	4

<From satellite>

	Under 1 week	From 1 week to 1 month	From 1 month to 3 months	3 months or longer	Total
FY2017	1	1	0	0	2
	5	9	1	0	15

Appendix 5　FY 2017 Visit Records of World Top World-level Researchers from Abroad

* If top world-level researchers have visited/ stayed at the Center, please provide information on them in the below table.
* To determine whether the researcher is a "top world-level researcher," please see the standard stipulated in the Application Guideline.

Total: 44

	Name	Age	Affiliation (Position title, department, organization)	Academic degree, specialty	Record of research activities (Awards record, etc.)	Time, duration	Summary of activities during stay at center (e.g., participation as principal investigator; short-term stay for joint research; participation in symposium)
1	George Shimizu		Prof., Department of Chemistry, University of Calgary, Canada	Ph.D., Inorganic Chemistry	・Strem/Canadian Society for Chemistry Award for Pure or Applied Inorganic Chemistry ・Petro-Canada Young Innovator Award	April 21, 2017	I^2CNER Seminar Series Presentation
2	Denis Morineau		Senior Scientist, Department of Materials and Nanoscience Institute of Physics of Rennes, University of Rennes 1, France	Ph.D., Physical-Chemistry	・Head of the Department of Materials and Nanosciences, IPR, Rennes (2012-2016) ・Member of the executive board of the Competence Center in Nanoscience, C'Nano (2005-)	May 17, 2017- May 19, 2017	Participation in NanoMat 2017
3	Emmanuel Fort		Prof., École Supérieure de Physique et de Chimie Industrielles of Paris (ESPCI ParisTech), France	Ph.D., Wave-matter Interactions	・Prix Jerphagnon (2012) ・Diderot Innovation Award (2009) ・The founder of the start-up company Abbelight	May 17, 2017- May 19, 2017	Participation in NanoMat 2017
4	Thierry Epicier		Research Director, French National Centre for Scientific Research (CNRS) at INSA-LYON (National Intsitute for Applied Sciences), University of Lyon, France	Ph.D., Chemistry of Materials	・Vice Director of the national 'TEM and Atom Probe' network METSA (FR CNRS 3507) (2016-) ・A member of the executive board of the European Microscopy Society (EMS) (2012-) ・Director, Consortium Lyon - St-Etienne de Microscopie (CLYM) (2007-2015)	May 17, 2017- May 19, 2017	Participation in NanoMat 2017

5	Xavier Bouju	51	Research Director, French National Centre for Scientific Research (CNRS) at Centre d'é laboration des matériaux et d'études structurales (CEMES), France	Ph.D., Physics	· Deputy-Director of the Labex NEXT (2016-) · President of Midi-Pyrénées section of SFP (2015-) · Evaluator-expert for the National Research Agency (ANR), Program Nano (P3N and P2N) and General Great Challenges (Défi7) (2009-) · Evaluator-expert for the NMP-FP7 program and M-era.Net program (2011-2016) · Expert at the Observatory for Micro and Nanotechnologies – OMNT (2006) · Expert at Evaluator-expert for NCN, FNRS, MI-CNRS, C'Nano IdF, University Montpellier, CR Franche-Comté, University Catholic Louvain, Ohio University (2005)	May 17, 2017- May 19, 2017	Participation in NanoMat 2017
6	Reiko Oda		Research Director, French National Centre for Scientific Research (CNRS) at Institute of Chemistry & Biology of Membranes & Nano objects (UMR5248 CBMN), Universite Bordeaux, France	Ph.D., Physics	· Director of Laboratoire International Associé –CNRS (LIA, Mix laboratory) between Bordeaux University, Kumamoto University and Kyoto University for Chiral Nanomaterials for Photonic Applications (2015-) · Invited Professor, Kumamoto University (2016-)	May 17, 2017- May 19, 2017	Participation in NanoMat 2017
7	Vincent Fournee		Research Director, French National Centre for Scientific Research (CNRS) at the Institut Jean Lamour, France	Ph.D., Physical-Chemistry	· P.I or Co P.I. of nine different projects (funding agencies: ANR, ADEME, MESR, CNRS or industrial partners) (2010-)	May 17, 2017- May 19, 2017	Participation in NanoMat 2017
8	Galina Besstremyannaya		Lead Research Fellow, The Center for Economic and Financial Research at New Economic School, Russia	Ph.D. in Math Methods, Ph.D. in Economics	· Listed among Russian specialists on Japan according to bio-bibliographical dictionary Miliband S. D. (2008) · Russian orientalists of the 20th and Early 21st Centuries. Moscow. ISBNº 978-5-02-036364-9	May 22, 2017	I^2CNER Seminar Series Presentation

9	John A. Kilner	71	Prof., Department of Materials, Imperial College, London, UK	Ph.D., Materials for solid oxide fuel cells and electrolysers	・Daiwa Adrian Prize (2016) ・Imperial College Medal (2016) ・Christian Friedrich Schonbein Contribution to Science Medal (2014) ☐Platinum Medal, Institute of Materials Minerals and Mining (2012) ☐Somiya Award, International Union of Materials Research Societies (2012) ☐Fellow, City and Guilds Institute of London (2007) ☐Royal Society Armourers and Brasiers' Company Prize, Royal Society (2005) ☐Verulam Medal, Institute of Materials, Minerals and Mining (2005) ☐Schoenbein Medal, European Solid Oxide Forum (2004) ☐Excellence in Teaching, Imperial College (1997)	(1) May 23-26, 2017 & June 1-7, 2017 (2) June 25, 2017-July 5, 2017 (3) November 27, 2017-December 4, 2017 (4) January 28, 2018- February 15, 2018	(1) Joint Research (2) Joint Research and Participation in Site Visit as Principal Investigator (3) Joint Research (4) Joint Research and Participation in I^2CNER Annual Symposium and International Workshops as Principal Investigator
10	Stephen Cheng		Prof., Department of Polymer Science, The University of Akron, USA	Ph.D., Polymer Chemistry	・The Polymer Physics Prize of The American Physical Society (2013) ・The Cooperative Research Award of the Division of Polymer Materials Science and Engineering, American Chemical Society (2005) ・The Distinguished Corporate Inventors Award, American Society of Patent Holders, The National Inventors Hall of Fame (1995 and 1998) ・The Presidential Young Investigator Award(1991)	May 26, 2017	I^2CNER Seminar Series Presentation
11	James Stubbins		Prof., Department Head of Nuclear, Plasma, and Radiological Engineering, University of Illinois, USA	Ph.D., Materials Science	・Donald Biggar Willett Professor (2013) ・Outstanding Achievement Award, Materials Science and Technology Division (2012) ・Media Relations Award - Award for Communications & Marketing Excellence 2011 ・Engineering Council Award for Excellence in Advising (2011) ・Glenn Murphy Award (2010) ・International Scientist of the Year (2004) ・American Men and Women of Science (1994)	(1) June 23, 2017-July 1, 2017 (2) January 27, 2018- February 3, 2018	(1) Joint Research, Participation in Site Visit as Satellite Faculty (2) Joint Research, Participation in I^2CNER Annual Symposium and International Workshops as Satellite Faculty
12	Andrew A. Gewirth	58	Prof., Department of Chemistry, University of Illinois at Urbana Champaign, USA	Ph.D., Chemistry	☐University of Illinois Scholar (1995) ☐Alfred P. Sloan Fellowship (1993) ☐DOE Outstanding Accomplishment in Materials Science (1993) ☐Fellow, UIUC Center for Advanced Study (1991) ☐Presidential Young Investigator Award (1990)	(1) June 25, 2017-June 29, 2017 (2) January 28, 2018- February 3, 2018	(1) Joint Research, Participation in Site Visit as Principal Investigator (2) Joint Research, Participation in I^2CNER Annual Symposium and International Workshops as Principal Investigator

13	Thomas Lippert	55	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	☐President of the Senate of the European-Materials Research Society (E-MRS) (from 1/2016 to 2/2017) ☐President of the European-Materials Research Society (E-MRS) (from 1/2014 to 12/2015) ・ Dr. honoris causa, University of Bucharest, Romani (2014) ☐Vice-President of the European-Materials Research Society (E-MRS) (from 6/2011 to 12/2013) ☐Member of the E-MRS Executive Committee (from 2008)	(1) June 26, 2017-June 30, 2017 (2) January 29, 2018-February 9, 2018	(1) Joint Research and Participation in Site Visit as Principal Investigator (2) Joint Research and Participation in I^2CNER Annual Symposium and International Workshops as Principal Investigator
14	Paul Kenis		Prof., Department Head of Chemical and Biomolecular Engineering, University of Illinois, USA	Ph.D., Chemistry	・ University Scholar, University of Illinois, UC (2011) ・ Beckman Fellow, Center for Advanced Study (2007-2008) ・ Helen Corley Petit Scholar, College of Liberal Arts and Sciences, University of Illinois, UC (2007-2008) ・ CAREER Award, National Science Foundation (2006) ・ Xerox Award for Faculty Research, College of Engineering, University of Illinois, UC (2006) ・ Excellence in Teaching Award, School of Chemical Sciences, University of Illinois, UC (2006) ・ Accenture Award for Excellence in Advising, College of Engineering, University of Illinois, UC (2003) ・ Excellence in Advising Award, College of Engineering, University of Illinois, UC (2002, 2003, 2008) ・ Young Faculty Award, 3M (2001-2005) ・ Collins Scholar, Academy of Excellence in Engineering Education (2001) ・ TALENT Postdoctoral Fellowship, Dutch Science Foundation (1997-1998)	June 26, 2017-July 1, 2017	Joint Research, Participation in Site Visit as Satellite Faculty
15	Brian P. Somerday	49	Dr., South West Research Institute, USA	Ph.D., Materials Science and Engineering	☐DOE Hydrogen and Fuel Cell Program Achievement Award (2014) ☐Best Poster Award, ASME 12th Fuel Cell Science, Engineering, and Technology Conference (2014)	(1) June 26, 2017-July 1, 2017 (2) January 29, 2018-February 3, 2018	(1) Joint Research and Participation in Site Visit as Principal Investigator (2) Joint Research and Participation in I^2CNER Annual Symposium and International Workshops as Principal Investigator

16	Xiuling Li		Prof., Department of Electrical and Computer Engineering, University of Illinois, USA	Ph.D., Chemistry	□IEEE Fellow (2017) □Campus Excellent Teacher ranked by students, UIUC (2015) □Faculty Entrepreneurial Fellow, Inaugural, College of Engineering, UIUC (2015-2016) ・Distinguished Lecturer, IEEE Nanotechnology Council (2014-2016) □Board of governors, IEEE Photonics Society (2014-2016) □A. T. Yang Research Award, ECE, UIUC (2013) ・Dean's Award for Excellence in Research, College of Engineering, UIUC (2012) □ONR Young Investigator Program Award (2011-14) □DARPA Young Faculty Award (2009-2011) □NSF CAREER Award (2008-2013) □Fellow, Center for Advanced Study (2010-2011) □Finalist, ECE Pratt Teaching award (2010) □IEEE Senior Member (2008)	June 27, 2017- July 1, 2017	Joint Research, Participation in Site Visit as Satellite Faculty
17	Juliy Baryshnikov	56	Prof., Department of Electrical and Computer Engineering, Department of Mathematics, University of Illinois, USA	Ph.D., Applied Mathematics, Nonlinear Dynamics and Control, Applied Topology, Stochastic Processes	・Member of Faculty Senate (2015-2017) ・AMS Committee on Mathematical Research Communities (Chair) ・Lady Davis Professorship, Technion (2003) ・Alexander von Humboldt Fellow (1992)	June 27, 2017- July 2, 2017	Joint Research, Participation in Site Visit
18	Xing Zhang	56	Prof., Department of Engineering Mechanics, Tsinghua University, China	Ph.D., Thermal Science	□Significant Contribution Awards from the 10th Asian Thermophysical Properties Conference (2013) □National Nature Science Award (Second Class) from the State Council of the People's Republic of China (2011) □Best Paper Award from the Heat Transfer Society of Japan (2008)	July 16, 2017- August 11, 2017	Joint Research
19	Rigoberto C. Advincula		Prof., Department of Macromolecular Science and Engineering, Case Western Reserve University, USA	Ph.D., Chemistry	・Chair, Polymer Chemistry Division, American Chemical Society (ACS) 2015 ・Herman Mark Scholar Award, Poly. Chem. Div., American Chemical Society, 2013 ・Fellow, American Chemical Society (ACS) 2010	July 24, 2017	I^2CNER Seminar Series Presentation

20	Sahel Ashhab		Senior Scientist, Qatar Environment and Energy Research Institute, Qatar	Ph.D., Condensed Matter Physics	・F. Yoshihara, T. Fuse, S. Ashhab, K. Kakuyanagi, S. Saito, and K. Semba Superconducting qubit-oscillator circuit beyond the ultrastrong coupling regime, Nature Phys. 13, 44 (2017).	August 21, 2017	I^{2}CNER Seminar Series Presentation
21	Jeffrey S. Moore		Director, The Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign, USA	Ph.D., Materials Science	・Member, National Academy of Sciences (2017) ・Edward Leete Award (2015) ・Professor, Howard Hughes Medical Institute ・Fellow, American Chemical Society ・Fellow, Polymeric Materials Science and Engineering (PMSE) ・Fellow, American Academy of Arts and Sciences ・UIUC Campus Award for Excellence in Undergraduate Teaching ・LAS Dean's Award for Excellence in Undergraduate Teaching	August 22, 2017	Participation in I^{2}CNER laboratory tour
22	Martin D. Burke		Prof., Department of Chemistry, University of Illinois at Urbana-Champaign, USA	Ph.D., Chemistry, Medical Doctor	・American Chemical Society Nobel Laureate Award for Graduate Education (2017) ・Hirata Memorial Lectureship Award, Japan (2014) ・Thieme-IUPAC Prize in Synthetic Organic Chemistry (2014) ・International Organic Chemistry Foundation Lectureship Award, Japan (2014) ・Elias J. Corey Award for Outstanding Contribution in Organic Synthesis by a Young Investigator, American Chemical Society (2013) ・Arthur C. Cope Scholar Award, American Chemical Society (2011) ・Bristol-Myers Squibb Lectureship at Harvard University (2010) ・Frontiers in Chemistry Lectureship at The Scripps Research Institute (2010) ・Novartis Lectureship at The University of California Berkeley (2010)	August 22, 2017	Participation in I^{2}CNER laboratory tour
23	King Li		Dean, Carle Illinois College of Medicine, University of Illinois at Urbana-Champaign, USA	Ph.D., Medical Doctor	・Holding 16 patents ・Co-author of more than 150 articles ・Wells Fargo Faculty Scholar at Wake Forest	August 22, 2017	Participation in I^{2}CNER laboratory tour

24	Reiner Kirchheim	74	Prof., The Institut für Metallphysik, University of Göttingen, Germany	Ph.D., Hydrogen in Metals, Thermodynamics of alloys, Interstitial solution and diffusion in glasses	・Foreign Affiliate of the United States National Academy of Engineering (2017) ☐Leibniz-Medaille of the IFW Dresden (2013) ☐Hydrogen & Energy Award, H&E-Symposium (2010) ☐Lee Hsun Lecture Award, IMR Shenyang, Chinese Academy of Sciences (2007) ☐International Award of Materials Engineering for Recourses, Akita, Japan (2005) ☐Heyn-Denkmünze (highest award of the German Materials Society, DGM) (2004) ☐Honda Memorial Award, Tohoku University (2003) ☐Highly Cited Author in Materials Science (1980-2000) ☐Carl Wagner Prize (1990) ☐Scripta Metallurgica Outstanding Paper Award (1987)	September 6, 2017- September 13, 2017	Joint Research
25	Eduardo Ruiz Hitzky		Senior Research Prof., Materials Science Institute of Madrid (ICMM), Spanish National Research Council (CSIC), Spain	Ph.D., Chemistry	・The National Academy of Sciences Award (Cuba, 2017) ・The GUILLAUME BUDÉ Medal (Collège de France, Paris, 2011) ・The Josep Leal Medal (Salón Internacional de la Quimica. Expoquimia, Barcelona 2011)	September 22, 2017	I^2CNER Seminar Series Presentation
26	Min Soo Kim		Prof., Department of Mechanical Engineering, Multiscale Mechanics Design, Seoul National University, South Korea	Ph.D., Thermal Engineering	・70 Excellent PhDs of College of Engineering, Seoul National University(2016) ・Best Industry-University Cooperation Award, College of Engineering, Seoul National University(2015) ・Han-Song Award, Society of Air-conditioning and Refrigerating Engineers of Korea(2014)	September 29, 2017	I^2CNER Seminar Series Presentation
27	Yong Tae Kang		Prof., Department of Mechanical Engineering, Korea University, South Korea	Ph.D., Engineering Physics	・The Korean Society of Mechanical Engineers, Nam-Heon Academic Award(2012) ・Ministry of Land, Transport and Maritime Affairs, Minister Award(2012)	September 29, 2017	I^2CNER Seminar Series Presentation

28	Moshe Matalon		Caterpillar Distinguished Professor, Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, USA	Ph.D., Mechanical and Aerospace Engineering	・Numa Manson Medal of the Institute for the Dynamics of Explosions and Reacting Systems (IDERS)(2017) ・AIAA Fluid Dynamics award (2016) ・Fellow of the American Physical Society, Institute of Physics and American institute of Aeronautics and Astronautics (AIAA) ・AIAA Pendray Aerospace Literature Award (2010)	October 31, 2017	I^{2}CNER Seminar Series Presentation
29	Leif Hammarstrom		Prof., Department of Chemistry, Uppsala University, Sweden	Ph.D., Physical Chemistry	・Elected Member of the Royal Society of Sciences (May 2013) ・Nominated as No 1 and offered two open Chair Professorships: Chemical Physics (Uppsala Univ) and Molecular Electronics (Royal Inst. Techno., Stockholm) (May 2004) ・The Thuréus prize by the Royal Society of Sciences (Uppsala) (2003)	November 13, 2017	I^{2}CNER Seminar Series Presentation
30	Cynthia Volkert		Prof., Institute of Materials Physics, University of Göttingen Germany	Ph.D., Physics	・Member of the National Academy of Sciences Leopoldina (Since 2011) 104 Research items 4,444 Reads 4,375 Citations	January 9, 2018	I^{2}CNER Seminar Series Presentation
31	Christian Jooss		Prof., Institute of Materials Physics, University of Göttingen Germany	Ph.D., Physics	・Memberships: German Physical Society; Materials Research Society, USA; Scientific committee of the Open University; Founder member of the Institute of research and education (IFB); Göttingen Member in the Society of Scientists for Peace in Gö ttingen, e. V. 49 Research items 1,582 Reads 228 Citations	January 9, 2018	I^{2}CNER Seminar Series Presentation
32	Yang Li		Prof., Peking University, China]	Ph.D., Inorganic Chemistry	・Chang Jiang Scholar by Chinese Ministry of Education(2014) ・National Outstanding Youth Fund of China(2011)	January 19, 2018	I^{2}CNER Seminar Series Presentation

33	Harry L. Tuller	72	Prof., Department of Materials Science and Engineering, Massachusetts Institute of Technology, USA	Engr. Sc. D., Functional electroceramic materials	・Distinguished Life Membership in American Ceramic Society (2016) ・Senior Member, IEEE (2016) ・President, International Society of Solid State Ionics (2015) ・Fellow, Electrochemical Society (2014) □Helmholtz International Fellow Award (2012) □Somiya Award of the International Union of Materials Research Society (2012) □Outstanding Achievement Award, High Temperature Division, Electrochemical Society (2010) □McMahon Award, Alfred University, NY (2009) □Orton Award, American Ceramic Society (2008) □FH Norton Award, American Ceramic Society (2007) □Von Humboldt Award (1997-2002) □Fulbright Award (1989-1990)	January 20, 2018- January 31, 2018	Joint Research, Participation in I2CNER Annual Symposium and International Workshops as Principal Investigator
34	J. Steven Brown		Vice Provost and Dean of Graduate Studies, The Catholic University of America, USA	Ph.D., Mechanical Engineering	□ASHRAE Distinguished Service Award (2015) □International Journal of Refrigeration Best Paper Award (2013/2014) □Elected Fellow of ASHRAE (2013) □ASHRAE Journal Paper Award (2010)	January 30, 2018- February 1, 2018	Participation in I^2CNER Annual Symposium and International Workshops
35	Colin Atkinson		Emeritus Professor, Department of Mathematics, Imperial College London, UK	Ph.D., Applied Mathematics and Mathematical Physics	・Fellow of the Royal Society (1998)	January 30, 2018- February 2, 2018	Participation in I^2CNER Annual Symposium and International Workshops
36	Pega Hrnjak		Director, Air Conditioning and Refrigeration Center (ACRC); President, Creative Thermal Solutions (CTS); Research Professor, Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, USA	Ph.D., Fluid Mechanics	・J&E Hall Medal (2012) ・Gustav Lorentzen Medal (2011) ・Ritter von Rittinger award (2008)	January 31, 2018- February 1, 2018	Participation in I^2CNER Annual Symposium

37	Gautam Biswas	61	Director, Indian Institute of Technology Guwahati (IIT Guwahati), India	Ph.D., Fluid Mechanics	・Distinguished Alumnus Award from Indian Institute of Technology Kharagpur (2016) ・J.C. Bose National Fellowship (2011)	January 31, 2018- February 1, 2018	Participation in I^2CNER Annual Symposium
38	Liwei Wang		Vice dean, Institute of Refrigeration and Cryogenics, Mechanical Engineering School, Shanghai Jiao Tong University, China	Ph.D., Sorption Technology for Refrigeration	・Science and Technology Award for Chinese Youth ・National Second Award for the Natural Science Research ・National 100 Outstanding PhD Theses ・IIR Young Researchers Award (James Joule Award) ・First Award of Natural Science Research in Shanghai City ・Royal Society International Incoming Fellowship in UK ・EU Marie Curie International Incoming Fellowship	January 31, 2018- February 2, 2018	Participation in I^2CNER Annual Symposium and International Workshops
39	Ugur Pasaogullari		Associate Director, Center for Clean Energy Engineering, University of Connecticut, USA	Ph.D., Mechanical Engineering	・Early Career Development Awards (2011)	January 31, 2018- February 2, 2018	Participation in I^2CNER Annual Symposium and International Workshops
40	Wilhelm A. Meulenberg		Head of the Division “Gas Separation Membranes” at the Institute for Energy and Climate Research – Materials Synthesis and Processing: IEK-1, Forschungszentrum Jü lich GmbH, Germany	Ph.D., Metallurgy and Materials Science	・Professor, Faculty of Science and Technology, University of Twente, Netherland ・Co-author (2014), Structural and functional properties of $SrTi_{1-x}Fe_xO_{3-\delta}$ ($0 \leqslant x \leqslant 1$) for the use as oxygen transport membrane, Separation and Purification Technology, 147, 414-421. DOI: 10.1016/j.seppur.2014.12.020	January 31, 2018- February 2, 2018	Participation in I^2CNER Annual Symposium and International Workshops
41	Jong Hak KIM		Professor, Department of Chemical and Biomolecular Engineering, Yonsei University, South Korea	Ph.D., Chemical Engineering	・Electrochemical devices including solar cells and fuel cells ・Design of functional polymers, inorganic nanomaterials and nanocomposites ・Polymer electrolytes for facilitated transport membranes ・Formation of metal nano-particles and nano-membranes ・Thermodynamics and phase separation of polymer solution or polymer blends ・Polymer membranes for gas separation and filtration	February 2, 2018	Participation in I^2CNER Annual Symposium

42	Amgad Elgowainy		Senior Scientist and Team Leader, Argonne National Laboratory, USA	Ph.D., Mechanical Engineering	· The DOE's Office of Technology Transition's Technology Commercialization Fund (TCF) Award(2017) for the project · Two-Tier Tube-Trailer Consolidation Technology for Fast Fueling of Hydrogen Fuel Cell Electric Vehicles	February 2, 2018	Participation in I^2CNER International Workshops
43	Robert Gross		Reader, Energy Policy and Technology; Director, Centre for Energy Policy and Technology (ICEPT), Imperial College London, UK	Ph.D., Energy Policy	· Chair of the Council of the British Institute of Energy Economics(2014) · Commissioner, Commission on Scotland's Energy Future, Scottish Government (2013-2014) · Specialist Advisor, Energy and Climate Change Select Committee, House of Commons (2012-2013) · Specialist Advisor, Energy and Climate Change Select Committee, House of Commons (2011) · Chair, Technical Advisory Group, Persistence Factor Methodologies, Carbon Trust (2010-2012) · Specialist Advisor, European Union Select Committee, House of Lords (2008)	March 1, 2018	I^2CNER Seminar Series Presentation
44	John Rose		Research Prof., School of Engineering and Materials Science, Queen Mary University of London, UK	Ph.D., Engineering	· Fellow of the UK Institution of Mechanical Engineers and of the American Society of Mechanical Engineers. · Member of the UK Heat Transfer Committee and of the UK Heat Transfer Society · UK editor of International Journal of Heat and Mass Transfer, International Communications in Heat and Mass Transfer, Experimental Heat Transfer	March 9, 2018	I^2CNER Seminar Series Presentation

Appendix 6 FY2017 State of Outreach Activities

* Using the table below, show the achievements of the Center's outreach activities in FY2017(number of activities, times held).
* Describe those activities that have yielded novel results or that warrant special mention in the "Special Achievements" space below.
* In appendix 7, list and describe media coverage (e.g., articles published, programs aired) in FY2017 resulting from press releases and reporting.

Activities	FY2017 (number of activities, times held)
PR brochure, pamphlet	7
Lectures, seminars for general public	23
Teaching, experiments, training for elementary, secondary and high school students	44
Science café	1
Open houses	1
Participating, exhibiting in events	4
Press releases	13

<Special Achievements>

WPI Science Symposium

・I^2CNER ran a booth, and Prof. Andrew Chapman gave a lecture at "Science Café," February 2018.

Nijou Junior High School Students' Visit to I^2CNER

・As part of a local government-run active learning program, 60 students from Nijou Junior High School (Itoshima City, Fukuoka) visited I^2CNER and other research centers at Kyushu University, September 2017. Prof. Motonori Watanabe and Dr. Thomas Bayer gave lectures, and Prof. Keigo Kitamura performed a hands-on experiment in front of the students. The event was broadcasted by 2 TV stations.

Special Lecture by Prof. Fujikawa for Highschool Students

・Prof. Shigenori Fujikawa gave a special lecture for students at the awarding ceremony of the Fukuoka-prefectural competition of "Japan Highschool Science Championships," September 2017.

Prof. Ogo's Press Conference

・A press conference was held for Prof. Ogo's research results (published in the article "One Model, Two Enzymes: Activation of Hydrogen and Carbon Monoxide") and one TV station broadcasted it, June 2017.

American Association for the Advancement of Science (AAAS) Annual Meeting

・Director Sofronis served as a panelist in one of the AAAS workshops, February 2018.

Appendix 7 FY 2017 List of Project's Media Coverage

* List and describe media coverage (e.g., articles published, programs aired) in FY2017 resulting from press releases and reporting.

	Date	Types of Media (e.g., newspaper, television)	Description
1	Apr.-May 2017	Newspaper	**Nikkei Sangyo Shimbun** (Apr. 11), **New Energy News** (May 1) Newspaper articles introducing the development of high performance inorganic metal oxide hybrid catalysts using carbon nanotubes (Profs. Naotoshi Nakashima and Tsuyohiko Fujigaya)
2	Apr.-May 2017	Website	**Bloomberg Technology** (Apr. 24), **The Science Times** (May 2) Web news articles entitled, "New iPhone screen puts blue-colored spotlight on Japan Supplier" and "Organic Laser: Recent Development For Longer Light Emissions," respectively (Prof. Chihaya Adachi)
3	Jun. 2017	Television, Newspaper, Website, Magazine	**Television Nishi-Nippon Corporation** (Jun. 6), **Asahi Shimbun Digital** (Jun. 7), **Nihon Keizai Shimbun** (Jun. 7), **Nishi-Nippon Shimbun** (Jun. 8), **Sankei News** (Jun. 8), **Nikkei Sangyo Shimbun** (Jun. 8), **Phys.org** (Jun. 22), **AZoCleantech** (Jun. 23) **DWV-Mitteilungen** (Sep. 14) Newspaper/web news/magazine articles covering the press release "One Model, Two Enzymes: Activation of Hydrogen and Carbon Monoxide" (Prof. Seiji Ogo)
4	Jul. 2017	Website	**New Electronics** (Jul. 13), **Photonics Media** (Jul. 13) Web news articles entitled, "Harnessing hydrogens for high efficiency OLEDs" and "Hydrogen Could Provide Path to High-Efficiency OLEDs," respectively (Prof. Chihaya Adachi)
5	Aug. 2017	Newspaper, Website	**Nihon Keizai Shimbun's website** (Aug. 29), **Nikkan Kogyo Shimbun** (Aug. 30), **Shinano Mainichi Shimbun's website** (Aug. 30) Newspaper/web news articles covering the press release "Cutting-edge technology for mass production of highly formable Ni-based superalloy" (Prof. Zenji Horita)
6	Sep. 1, 2017	Website	**Nihon Keizai Shimbun's website** Web news article introducing the research on the structural basis of the redox switches in the NAD+-reducing soluble [NiFe]-hydrogenase (Prof. Seiji Ogo et al.)
7	Sep. 2017	Television, Newspaper, Website	**NHK Fukuoka** (Sep. 14), **TVQ Kyushu Broadcasting** (Sep. 14), **Itosima Shimbun** (Sep. 21), **Fukuoka Internet TV** (Sep. 28) TV/newspaper/web news covering local junior high school students' visit to I^2CNER as part of a field trip organized by the Fukuoka prefectural government (Profs. Motonori Watanabe, Keigo Kitamura, and Dr. Thomas Bayer)
8	Sep. 28, 2017	Newspaper	**Kagaku Kogyo Nippo** Newspaper article featuring a special lecture at the Fullerenes-Nanotubes-Graphene General Symposium in Kyoto (Prof. Tsuyohiko Fujigaya)

9	Oct. 2017	Newspaper, Website	**Nikkei Sangyo Shimbun** (Oct. 12), **National Institute for Environmental Studies' (NIES) website** (Oct. 17) Newspaper/web news articles covering the press release "A Fusion of Biomimetic Fuel and Solar Cells Based on Hydrogenase, Photosystem II, and Cytochrome c Oxidase" (Prof. Seiji Ogo)
10	Oct. 2017	Newspaper, Website	**Nihon Keizai Shimbun** (Oct. 17), **Science Portal** (Oct. 24) Newspaper/web news articles entitled, "Reveal structures related to the size of the earthquake in the Nankai Trough" and "Reveal the relationship between 2016 earthquake and 1944 Tonankai mega earthquake," respectively (Prof. Takeshi Tsuji)
11	Oct. 18, 2017	Newspaper	**The Suisan-Keizai Daily News** Newspaper article entitled, "Characteristic features of seismogenic fault controlling earthquake magnitude" (Prof. Takeshi Tsuji)
12	Nov. 2, 2017	Newspaper	**Nikkei Sangyo Shimbun** (Nov. 2) Newspaper article covering the press release "NIR-driven H_2 evolution from water: Expanding wavelength range for solar energy conversion" (Prof. Ken Sakai)
13	Nov. 10, 2017	Newspaper, Website	**Kyodo News,** **Jiji.com,** **Nihon Keizai Shimbun,** **Asahi Shimbun Digital,** **Sankei News,** **Sankei Biz,** **Kyoto Shimbun,** **Saga Shimbun,** **Nishi-Nippon Shimbun** Nishina Memorial Award for the contribution to the development of OLEDs (Prof. Chihaya Adachi)
14	Nov. 25, 2017	Newspaper	**Nihon Keizai Shimbun** (Nov. 25), **Nishi-Nippon Shimbun** (Nov. 26) Newspaper article introducing the research on the crust damage caused by the 2016 Kumamoto earthquake (Prof. Takeshi Tsuji)
15	Dec. 2017-Jan. 2018	Newspaper	**Nikkei Sangyo Shimbun** (Dec. 28), **Kagaku Shimbun** (Jan. 19) Newspaper articles covering the press release "Continuous synthesis of glycolic acid as a next generation fuel" (Profs. Masaaki Sadakiyo et al)
16	Jan. 2018	Newspaper, Website	**Kumamoto Nichinichi Shimbun** (Jan. 20), **Asahi Shimbun Digital** (Jan. 24) Newspaper/web news articles entitled, "Horizontal sliding observed at the Uchinomaki hot spring area" and "Hot spring dormant during the 2016 earthquake," respectively (Prof. Takeshi Tsuji)
17	Mar. 8, 2018	Newspaper	**Nishi-Nippon Shimbun** Special edition for elementary school students: An interview article by kids reporters focusing on hydrogen energy research at Kyushu University (Prof. Kazunari Sasaki)