Energy Outlook

International Institute for Carbon-Neutral Energy Research

June 2019

Inspiring Future Generations:

The Importance of Carbon Capture Storage and a Discussion on Incorporating Sustainable Resources

Special Interview I

Jill Engel – Cox
Director, U.S. National Renewable Energy Laboratory

Kenshi Itaoka
Professor, Energy Analysis Division, I^{2}CNER, Kyushu University

Andrew Chapman
Associate Professor, Energy Analysis Division, I^{2}CNER, Kyushu University

Special Interview II

Michael Celia
Director, Princeton Environment Institute
Princeton University

Takeshi Tsuji
Professor, CO_2 Storage Division, I^{2}CNER, Kyushu University

wpi World Premier International Research Center Initiative
I^{2}CNER
KYUSHU UNIVERSITY
ILLINOIS

Andrew Chapman
Associate Professor
Energy Analysis Division
I²CNER, Kyushu University

Kenshi Itaoka
Professor
Energy Analysis Division
I²CNER, Kyushu University

Jill Engel-Cox
Director
Joint Institute for Strategic Energy Analysis
U.S. National Renewable Energy Laboratory

Special Interview I

Exploring Renewable Energy: A Discussion on Incorporating Sustainable Resources into Our Everyday Lives

As the global demand for energy resources grows, it is imperative that sustainable solutions are considered. However, systems that harness these renewable energy sources come with their own sets of challenges. In this discussion, Professors Kenshi Itaoka and Andrew Chapman from I²CNER's Energy Analysis Division and Dr. Jill Engel-Cox, Director of the Joint Institute for Strategic Energy Analysis at the U.S. National Renewable Energy Laboratory (NREL), share their thoughts on the current research being done to create clear pathways toward adopting sustainable resources in communities around the world.

Examining Renewable Energy Technologies

Andrew Chapman: Please tell us a little bit about your role.

Jill Engel-Cox: At NREL, I am the Director of an institute called the Joint Institute for Strategic Energy Analysis (JISEA), which is a collaboration between the U.S. National Renewable Energy Laboratory (NREL) and partner universities. JISEA analyzes energy systems and energy systems transformation across multiple sectors. We leverage experts within a larger analysis group within NREL. NREL is one of the U.S. Department of Energy National Laboratories, and it is the only laboratory that's focused exclusively on renewable energy and energy efficiency. There are about 1,800 researchers and support staff within NREL. We focus on all types of renewable energy including solar, wind, and geothermal as well as looking at storage, transportation, and batteries.

Kenshi Itaoka: So, you are looking into systems?

Engel-Cox: Right. We certainly have many researchers that look very specifically at technology development, but NREL realized long ago that it was very important to have an analysis group that looks at policy, economics, transformations, and scenario analysis. These types of analysis are very important to go along with the actual technology development.

Chapman: What would you say is NREL's current focus?

Engel-Cox: There are lots of things that we are focused on. Currently, renewable energy has grown to be more commercial, particularly certain types including solar, wind, and hydropower. The focus has mainly been on power generation, transportation, and buildings. Now, we're starting to think about what other sectors we need to focus on. We've started looking at the industrial sector, and the agricultural sector as these are some of the areas where renewable energy hasn't been fully addressed yet.

Itaoka: I'm interested in this aspect, as I feel that for industry, especially those such as iron or cement industries that there is no good solution yet.

Engel-Cox: Yes, on the power side, we're still doing a lot of work on the integration. Many cities and states are starting to think about going 100% renewable or 100% low carbon. That is very easy to say, but it is very hard to actually achieve. NREL is doing a number of projects in terms of helping cities and states model what that actually looks like.

Assessing Locations and Understanding Energy Requirements

Chapman: One of the issues that I was really interested in talking to you about is the two different approaches. Do you pursue a fully centralized approach or the decentralized approach? Perhaps, there is a combination that can get people to their renewable energy targets?

Engel-Cox: It depends on the location itself and what baseline you begin with in the area. You need to consider what kind of existing grid systems are already there, how centralized the system is now, and what existing power systems are already built. If you are in a place that does not have good energy access and you are just building it now, you are going to take a different approach, possibly a more decentralized micro-grid approach, than if you were in a place that had the existing grid infrastructure with very large systems already. The starting point is going to make a big difference. Also, the natural resources in the region are going to make a difference. If you look at a country like Iceland, they have huge geothermal resources, which will lead to a different type of solution than if you were in a place that has a lot of solar or a lot of wind. It also depends on the human resources and the decision the community makes about which way they want to go.

Itaoka: Currently, Japan uses an almost 100% centralized grid[1]. How does that differ to the situation in the United States?

Engel-Cox: The U.S. is getting close to 20% renewables, but nearly half of that is hydropower. There are specific locations that have large hydropower plants. That said, there's just under 2% solar and close to 7% wind nationally. But that is very different depending on which state you are looking at, some of the states have a very low percentage of renewables, and some states have a very high percentage. California, for example, is a leading state and they are getting close to 50% renewables with hydro and over 25% with non-hydro renewables, like solar and wind. Also, certain areas have done a lot of promotion for very decentralized systems like rooftop solar systems for houses. Los Angeles has declared that they are going to become 100% renewable and NREL is working quite closely with them to do the modeling on that.

Itaoka: Can you tell us about the approaches being considered for energy storage?

Engel-Cox: There are different things that people are looking at for storage. We are even looking at the possibility of taking out-of-service electric vehicle batteries and creating better storage out of them. It depends on whether you need just a few hours of energy, if you need it seasonally, or if you need multiple days of energy. We are still at the point where there is a lot of experimentation about what kind of storage is going to work, and it is going to be different in different places. You are probably going to need a mix. I did a lot of work in Saudi Arabia, and their energy demand is very interesting because it is double in the summer what it is in the winter because of air conditioning, but they do not need so much hourly variability because it is relatively consistent. It is actually much different in the summer than it is in the winter, so that they need seasonal storage. In other places, like in the U.S., it peaks in the late afternoon when everybody comes home.

It is going to be interesting when we get to the point where we need to train consumers to behave in a certain way, but then we might have to train them to behave differently later. With this in mind, we are starting to look at smart technologies and how you automate this so that it is the equipment itself that knows when it should charge to better balance demand.

Establishing Community Support for Energy Initiatives

Chapman: I think you raised an excellent point. The first thing is training people about how to act. In Australia, we have this issue with net feed-in tariffs[2] versus gross feed-in tariffs[3]. Under a gross feed-in tariff, you are able to use energy without much thought, engendering specific behaviors. However, if you have a net feed-in tariff, the idea is not to use the electricity you generate, but to sell it. This gets back to the broad point that, generally we agree that we can train people how to do things based on an economic benefit, but can you talk more about how important community support is as well? Is there some kind of activity that we can capture in our research that is equivalent to community support?

Engel-Cox: In some cases, it is voting. In many states such as California, they have systems where if you are going to be spending public money or increasing taxes, it has to be voted on. There are country-wide tax incentives for some of the renewables that you put on your home and also for developers. It is a combination of people voting for it, and then also financial incentives. I think the interesting thing that we need to think about is there are always the early adopters, the ones that are excited. They are the ones that install the solar panels even when it is a 20-year payback, which is beyond what might be logical from a purely financial decision, because they want to support advanced technologies. As long as there is enough incentive and the system will not lose them money, they will do it. Then there is the next level, which is probably where we are now, which is it makes sense, it pays back in about 8-years, people think it is neat that they can get almost free electricity, so they do it. That hopefully drives prices down so that you can pick up some of the later stage people. But then there's the question of how we get to the larger consumer base. Also, you have to consider how to reach those that do not have a house to put a panel on, or maybe have trees or do not have a south-facing roof or an appropriate setup. In the U.S. right now a popular solution to these issues is community solar, which is a system installed at a town level and you can buy into it.

After the interview, the three pose for a photograph in front of the I²CNER building

Designing Creative Solutions

Chapman: We found some similar trends in Japan. Some of it was encouraging, and some of it was discouraging. I think with Japan we found that only a small percentage were early adopters. Then, there is a very big group in the middle and an equally large group at the bottom that just waits for the government to say they have to begin using a particular system. I think Japan might be different than the U.S. because a lot of people live in apartments. We already have some community wind energy, what would a community solar system look like in Japan?

Engel-Cox: In the U.S., some of the community solar systems have been built on old landfills, which might work for Japan. It is land you cannot build houses on, and you cannot put agriculture there, but it is the perfect place to put community solar.

Chapman: That is unique thinking because if you think about a landfill, you assume that's the end of the use for that land.

Engel-Cox: We are also noticing a significant increase in commercial solar because some businesses are saying they want to be zero-carbon or 100% renewable. They have massive roof space on warehouses and buildings where they could install large solar systems. There is also a challenge between a technical solution like smart grids[4] or demand-side management and then the social acceptance of them. It is very easy for technologists to think something is wonderful and will work well, and then to forget about the human side of the issue. People think, 'I don't want someone changing my home heating system or my electric car.' I think one of the big challenges is for the technology people to work with the social scientists, economists, and others to think about how to bring these solutions forward in a way that people are going to be excited about and accepting of them and not resistant.

Itaoka: Thank you for joining us today to discuss important energy issues and challenges for the future. It has been a pleasure to hear your ideas, and we look forward to pursuing fruitful collaborations in the future.

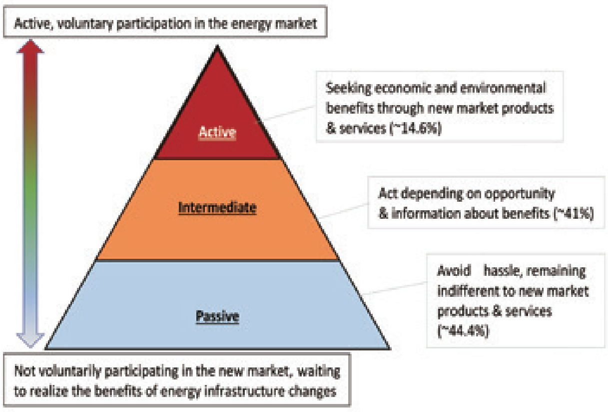


Figure 1.
Consumer activeness tiers in the Japanese energy market

Notes

1 Grid Centralized Energy: The electricity generated by centralized generation is distributed through the electric power grid to multiple end-users. Centralized generation facilities include fossil-fuel-fired power plants, nuclear power plants, hydroelectric dams, wind farms, and more. (EPA.gov)

2 Net feed-in tariff: A plan where the owner of a solar system is only paid for any extra unused energy that their system produces.

3 Gross feed-in tariffs: A plan where the owner of a solar system is paid for all energy produced by the system connected to the grid.

4 Smart Grid: A network that is able to detect and respond to changes in the amount of energy being used.

Special Interview II

Inspiring Future Generations: The Importance of Carbon Capture Storage and Understanding Human Environmental Impacts

Carbon Capture Storage (CCS)[1] and the exploration of how to reduce CO_2 emissions is a global issue of great importance. Professor Takeshi Tsuji, Lead Principal Investigator for the I^{2}CNER CO_2 Storage Division, interviewed Professor Michael Celia, the Director of the Princeton Environmental Institute at Princeton University, about the current state of CCS research and the potential future implications of the field. They also delved into the importance of guiding future generations to explore these problems in the hopes of finding lasting solutions.

Research as a Collaborative Effort

Takeshi Tsuji: Thank you very much for making time for this interview. Your talk at our Annual Symposium yesterday must have motivated I^{2}CNER members very much. Firstly, please tell us how you became involved with I^{2}CNER.

Michael Celia: When I^{2}CNER decided to include a significant CCS component, I^{2}CNER members contacted me to ask if I would join the external advisory board as the person who is involved in CCS activity. The first time I met you was when I went to my first I^{2}CNER meeting, three or four years ago. Then I wound up being really impressed with your work. I think the work that's going on here with CCS is really interesting and important.

Tsuji: Before I came to I^{2}CNER, my specialty was geophysics/geology. Specifically, large-scale geological formation investigations and large-scale CO_2 behavior monitoring using a geophysical approach.

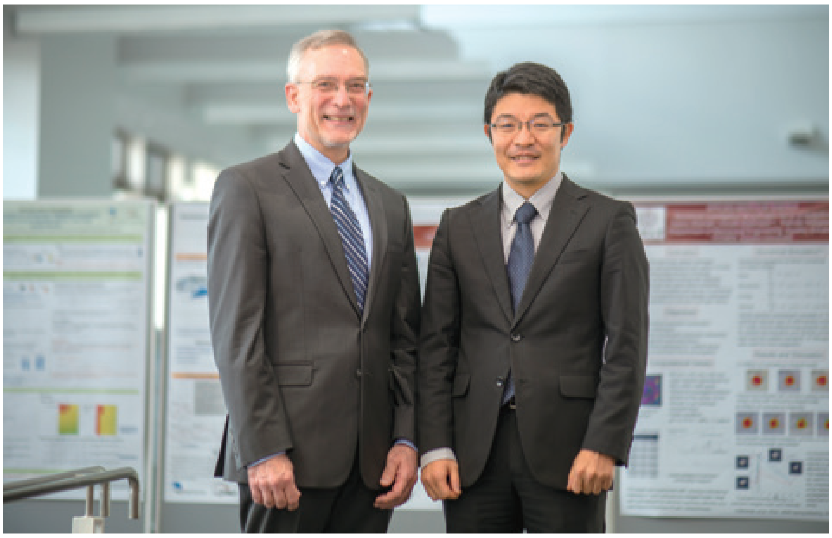
Celia: It's an important point – the fact that you approach this with a seismology background. I think it gives a different perspective and you are thinking about one of the major issues with CCS which is: 'How should we think about the risk of creating earthquakes by injecting huge amounts of fluid underground?', You need expertise in earthquakes and seismology in order to think about that problem in the right way. If you just look at CCS in terms of research, 25 years ago there was no research in CCS because it didn't exist. People from hydrology, from petroleum engineering, and from other various backgrounds started working on the problem. Almost everybody who was working on the problem came at it from just the fluid flow perspective. However, the idea that we had to think about the mechanics of the rocks and whether or not there are going to be any possibilities of earthquakes at the surface came later. For me, one of the interesting parts about working on a relatively new area is to observe how the research itself

Michael Celia
Director
Princeton Environmental Institute
Princeton University

Takeshi Tsuji
Lead Principal Investigator / Professor
CO_2 Storage Division
I^{2}CNER, Kyushu University

develops. It attracts people from these different groups that come in and make different contributions.

Tsuji: It's true, CCS is a very good chance to collaborate and gather many specialists, and our research can help other fields as well.



Considering CCS Projections

Tsuji: Could you please talk about the importance of CCS in view of the 2018 IPCC[2] Report that says that we are on track for a 3-4℃ temperature rise by the end of the century?

Celia: I think that every study that I have seen indicates that CCS needs to play a major role in serious carbon mitigation strategies. If you look at any projections for 2 degrees or 1.5 degrees, instead of the 3 to 4 degrees that you pointed out, you see that CCS is expected to ramp up between now and mid-century to significant levels – gigaton per year levels. If you look at the 1.5-degree report, for example, you can see that many scenarios will have net negative emissions[3] in the second half of this century. The major technology that is currently expected to be able to do that is the combination of bioenergy with CCS, that is an order of 10 gigatons a year ramping up. All of these scenarios for how we can realistically solve the carbon problem involve massive amounts of CCS. The challenge that we have is to go from where we are today, to what these future projections are assuming will happen. In all of these, CCS plays a central role and I think our responsibility is to figure out how we can ramp up the activity.

Achieving Negative Emissions

Tsuji: In your presentation at the I²CNER Annual Symposium yesterday, you talked about negative emissions. I think it is tough, but it is a very important concept for carbon reduction. Can you talk a bit about your views on negative emissions?

Celia: Yes, negative emissions means that either humans design a technology to take CO_2 out of the atmosphere and then do something with it to keep it out of the atmosphere (the likely thing to do is to put it underground) or we allow vegetation to take CO_2 out of the atmosphere (which happens by photosynthesis), and then we use the vegetation products as the fuel source, and then we capture those emissions and put them underground. In either case, we use those processes coupled with the carbon storage to basically have a net negative accounting for the amount of carbon that is going from the earth into the atmosphere. At the moment, there is no viable human-made technology that works at scale for the extraction of huge amounts of CO_2 from the atmosphere. That's why the technology that is referred to as 'BECCS'[4] (bio-energy with carbon captured storage) is what's pointed to in these reports. That's the technology that we know has some reasonable chance to work right now. Ideally, there will be a group of new technologies that can take carbon out of the atmosphere and redirect it in ways that will keep it out of the atmosphere. The thing that we have to remember is that the only way that any of these things makes a difference, is if the amount of carbon we're talking about is massive– gigatons of CO_2 per year. The scale of the problem really has to be emphasized because it's a massive undertaking and many different technologies are required. We also need to be thinking about the geological part of this, the underground part of this, at these scales because it is important to achieve those levels.

Exploring the Popularity of CCS

Tsuji: Yes, it is important to reduce large amounts of CO_2, and CCS could achieve the large-scale CO_2 emission reduction. Another question I have is: given the importance of CCS, what is its status in the U.S. and possibly worldwide?

Celia: In the U.S., CCS has not taken off as any sort of large industry so far. Whether that happens in the future remains to be seen. However, in the U.S., there are interesting possibilities at the moment. About a year ago in 2018, a new tax bill was passed. In that tax bill are tax credits for CCS. The tax credits are at a significant level, up to $50 per ton if you capture the CO_2 and use it for direct storage, and up to $35 a ton if you use it for enhanced oil recovery.

Tsuji: The general perception is that CCS has not gained traction worldwide toward decarbonizing the environment. Could you please elaborate on possible reasons? What are the main roadblocks for accelerated deployment of CCS projects?

Celia: I think the reason is largely economic. My


A scene from the interview

own opinion is that if there is a system in place where, at the large scale, there's profit to be made by putting CO_2 underground then a "CCS industry" will develop. The appropriate regulations will either be written or be modified in whatever ways are necessary to allow it to happen. Until that happens, I think that we spend a fair amount of time thinking about public perception and how negative perceptions might be the reason for the lack of large-scale development of CCS. I don't want to minimize its importance of public perception, but in most parts of the world there are all sorts of infrastructure projects that are built, including pipelines. In the U.S. we have pipelines that will take natural gas from the Gulf of Mexico region to where I live in the North East, and we've got natural gas storage sites for the seasonal storage of gas, and all sorts of things like that, that already exist. The idea that we wouldn't be able to build a similar pipeline for CO_2, I don't believe that is the case. My own sense, and perhaps this is just a hopeful statement, is that the idea that there is a negative perception about CCS, comes through in what we see in specific surveys. Instead of saying 'Do you want us to build a pipeline that will be operated by an oil company?' to which the answer is probably, 'Well, I think that's not a good thing,' the more reasonable question is, 'Will you work with us to solve the climate problem?' I think that in terms of gaining traction and public perception, it would be good if we could present this quite directly as an important green technology that will help to solve the climate change problem.

Motivating Future Generations

Tsuji: How do you view the role of CCS research in academic institutions like I²CNER?

Celia: At Princeton, we've offered a special topics course on CCS a couple of times. The thing about CCS is that the 'capture' part is really a problem of engineering technology. How do you build something to do gas separation or think about new materials? It's really a chemical engineering and material science question. The 'storage' part is earth science, geosciences, and some parts of civil engineering. Overall, there are so many different disciplines involved in CCS, so it helps to sometimes break it up into the 'capture' and the 'storage' parts. While we may not have a curriculum specifically for CCS, the tools that we need to do the work exist in many programs in many different universities. That gives me optimism that even if we don't develop specific CCS courses, there will be a number of students, both undergraduate and graduate, who are trained with the skill sets to allow them to contribute in important ways to solving these problems.

Tsuji: How can we motivate young scientists to carry out research in this area? Are there future opportunities for employment?

Celia: I think the best motivation is to invite them to come and save the world. In some sense, that's the advertisement because I think that's what we are actually trying to do in some grand sense. If you think that an uncontrolled warming planet is an existential threat to our species, and to several other species on the planet, then, it's not an exaggeration to say, 'Come and save the world, at least the world as we know it.' That's what solving the climate problem is, and if CCS is going to play a major role, then that's how we motivate students. Our job is to give our students the tools, the perspective, and the context to go out and make meaningful contributions no matter what they ultimately choose as a profession. I'm very optimistic about this cohort of young scientists and I am comfortable putting my faith in that group to go out and solve the problems that my generation created through the emission activities that we see going on today.

Tsuji: I agree that our works for CCS are directly related to the biggest problems for human beings. I continue our research activities for carbon emission reduction, and also try to educate young scientists to save our planet earth. I really enjoyed this talk with you. Thank you very much.

Notes

1 Carbon Capture and Storage (CCS): The process of separating and capturing CO_2 and then storing it underground.

2 IPCC: Intergovernmental Panel on Climate Change.

3 Negative emissions: A reduction in the amount of CO_2 that is in the atmosphere.

4 BECCS (bio-energy with carbon captured storage): A technology that has the potential to mitigate greenhouse gases.

Special Lecture by Prof. Michael Celia
(Feb. 1, 2019)

Prof. Celia delivered a special lecture to Prof. Tsuji's research group and those from the Department of Earth Resources Engineering at Kyushu University. He talked about the importance of understanding the basics of hydrology, including groundwater flow paths while referring to a groundwater contamination case depicted in "A Civil Action," a best-selling nonfiction book by Jonathan Harr.


Prof. Celia during his lecture

2019 I²CNER Annual Symposium group photo

Special Reports

Prof. Celia delivers his invited lecture

An audience member poses a question

Participants discuss during the poster session

2019.1.31

2019 I²CNER Annual Symposium Energy Transitions and the Role of CCS toward a Carbon-Neutral Energy Society

The "2019 I²CNER Annual Symposium: Energy Transitions and the Role of CCS toward a Carbon-Neutral Energy Society", which took place at the I²CNER building on Kyushu University's Ito Campus in the city Fukuoka on January 31, attracted 150 participants from academia, industry, and public offices.

At the Annual Symposium, top-level researchers and government officials from Japan and overseas gathered together to discuss world-wide challenges for the energy transitions required for a low-carbon energy society, including the creation of renewable energy, and the role of CCS (Carbon Capture and Storage). During the invited lectures, Professor Geert Verbong from Eindhoven University, Professor Michael Celia from Princeton University, and 6 other speakers introduced their state-of-the-art research achievements covering physics, economics, and even politics. During the poster session, which showcased I²CNER's latest research results, participants from a broad range of research fields actively engaged in discussions.

“Kyushu University Energy Week” is a week-long sequence of international workshops and symposia hosted by various energy research centers of Kyushu University. Energy Week is held every year and the I²CNER Annual Symposium and International workshops are some of Energy Week's key events.

HYDROGENIUS and I²CNER Joint Research Symposium

I²CNER and the Research Center for Hydrogen Industrial Use and Storage (HYDROGENIUS), Kyushu University, held the "HYDROGENIUS & I²CNER Joint Research Symposium" at the Ito Campus on January 30, 2019. The collaborative symposium is cohosted every year by I²CNER's Hydrogen Materials Compatibility Division and Thermal Science and Engineering Division, as well as HYDROGENIUS' Fatigue and Fracture Division, Tribology Division, and Thermophysical Properties Division, with researchers from both institutes and their invited colleagues further deepening discussions. Under the themes of "Hydrogen-Materials Interactions" (Hydrogen Materials Compatibility / Fatigue and Fracture), "Hydrogen in Tribological Processes" (Hydrogen Materials Compatibility / Tribology), and "Thermal Issues for Hydrogen and New Refrigerants for Energy Systems" (Thermal Science and Engineering / Thermophysical Properties) , the participants shared their latest achievements and insights.

I²CNER International Workshops

Following the Annual Symposium, I²CNER held its "International Workshops" at the the Ito Campus on February 1, 2019. The participants discussed the latest research activities for each theme below:

1) "Materials for Photo & Electric Energy Conversion"
Molecular Photoconversion Devices Division and Electrochemical Energy Conversion Division

2) "Carbon Capture and Utilization Research for Negative Carbon Emissions"
Catalytic Materials Transformations Division and CO_2 Capture and Utilization (CCU) Division

3) "Monitoring and Modeling CO_2 Storage Reservoirs"
CO_2 Storage (CS) Division

4) "Sharing innovations in Energy Transition research"
Energy Analysis Division

5) "Applied Mathematics Challenges in Energy Systems"
Applied Math for Energy; Co-host: Institute of Mathematics for Industry

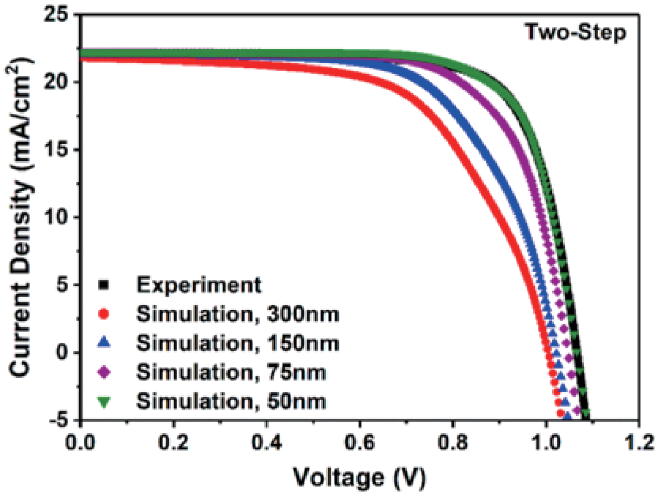
A lecture scene from International Workshop

Research Highlights

1 Computational Analysis of the Interplay between Deep Level Traps and Perovskite Solar Cell Efficiency

Kara Kearney, Gabseok Seo, Toshinori Matsushima, Chihaya Adachi, Elif Ertekin, and Angus Rockett
Journal of the American Chemical Society
DOI: 10.1021/jacs.8b06002

Hybrid perovskite solar cell performance largely depends on the deposition method; specifically, efficiencies of 13.5% and 17.7% were observed for perovskite films processed with a one- and two-step method, respectively. However, the origin of the difference in efficiency remains unclear. With computational analysis, we discovered that in the case of one-step processing, traps are present throughout the bulk of a perovskite film, while for two-step processing, the traps are isolated at the substrate/perovskite interface. We used both a composition and structural analysis to determine that the traps are caused by a lack of an ordered structure throughout the film in the one-step cell and organic vacancies at the substrate/perovskite interface in the two-step cell. These findings open a way to the fabrication of hybrid perovskite solar cells with even higher efficiencies and, therefore, contribute to a reduction of carbon dioxide emission for a sustainable society.

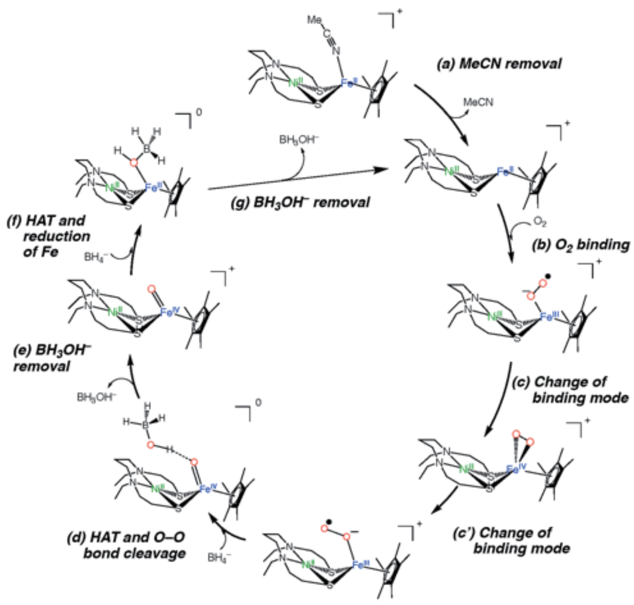


Experiment and simulations of hybrid perovskite solar cell performance

2 DFT study on Fe(IV)-peroxo formation and H atom transfer triggered O_2 activation by NiFe complex

Miho Isegawa, Akhilesh K. Sharma, Seiji Ogo, Keiji Morokuma
Organometallics
DOI: 10.1021/acs.organomet.8b00098

Reagents that are used in most industrial oxidations are expensive and are not environmentally friendly. On the other hand, oxygen is abundant and clean. Thus, oxygen is the ideal oxidant. Recently, Prof. Ogo's group succeeded in synthesizing an NiFe complex, which performs oxygen activation in the presence of borohydride. The goal of this study was to reveal the mechanism of dioxygen activation by the NiFe catalyst. The calculated Mössbauer parameters for the peroxo intermediate agreed with the experiment, and the molecular orbitals analysis showed that two electrons are transferred from the iron center to dioxygen. Further, it was elucidated that dioxygen activation occurs in the presence of borohydride through H atom transfer. A fundamental understanding of catalytic reactions based on calculated thermodynamic and kinetic data and electronic structure is important in the development of practical catalysts targeted by I[2]CNER.



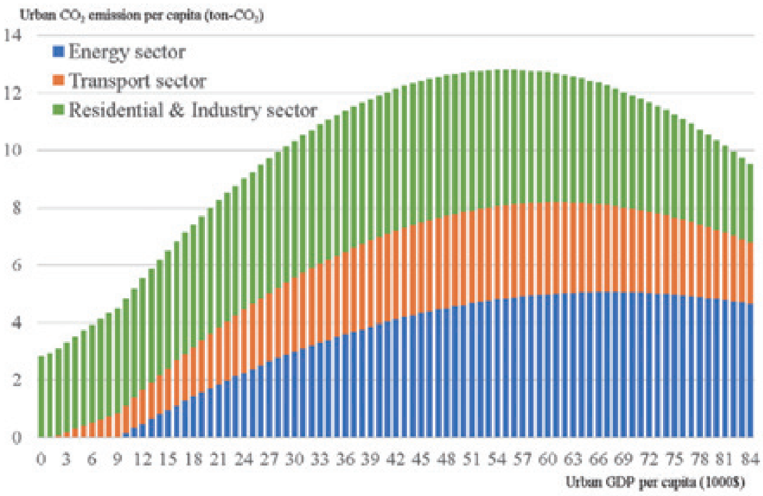
Summary of the catalytic cycle for O_2 activation by the NiFe complex

3 An analysis of urban environmental Kuznets curve of CO_2 emissions: Empirical analysis of 276 global metropolitan areas

Hidemichi Fujii, Kazuyuki Iwata, Andrew Chapman, Shigemi Kagawa, Shunsuke Managi

Applied Energy
DOI: 10.1016/j.apenergy.2018.06.158

This study analyzed the relationship between urban CO_2 emissions and economic growth applying the environmental Kuznets curve (EKC) hypothesis. The results demonstrate an inverted U-shape relationship between urban CO_2 emissions and urban economic growth. Additionally, an inverted U-shape relationship is observed for the transport, residential, and industry sectors. However, the turning points of each inverted U-shape curve varies. This result implies that we can better understand urban policies for reducing urban CO_2 emissions by considering the characteristics of each sector. This research progresses the I²CNER mission to reduce emissions at best cost and to design policies which are fit for purpose in both developed and developing nations.



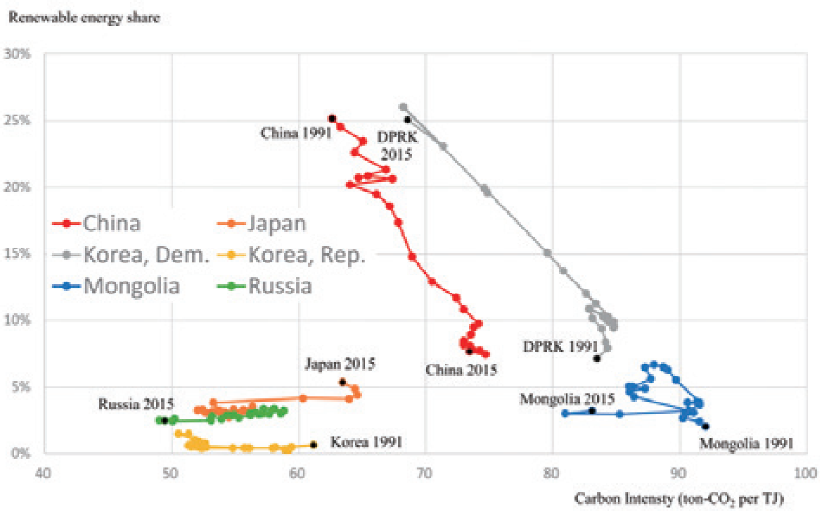
Projection of urban CO_2 Emissions in three sectors based on a parametric approach

4 Key drivers for cooperation toward sustainable development and the management of CO_2 emissions: Comparative analysis of six Northeast Asian countries

Andrew John Chapman, Hidemichi Fujii, Shunsuke Managi

Sustainability (Switzerland)
DOI: 10.3390/su10010244

This study analyzed key drivers of the relationship between economic growth and carbon emissions in six Northeast Asian countries (China, Japan, Republic of Korea, Democratic People's Republic of Korea, Mongolia, and Russia) from 1991 to 2015. We applied a decomposition analysis approach using Logarithmic Mean Divisia Index (LMDI) identifying major contributing factors toward CO_2 emission changes. We found that the key driving factors of CO_2 emissions and energy portfolio trends are different among nations: driven by economic growth in China and Korea, reduced by energy efficiency improvements in Russia and the DPRK, while relatively benign in Japan and Mongolia due to a combination of these factors. These results help I²CNER to better develop and influence regional cooperation policy and to best leverage technological and economic factors.



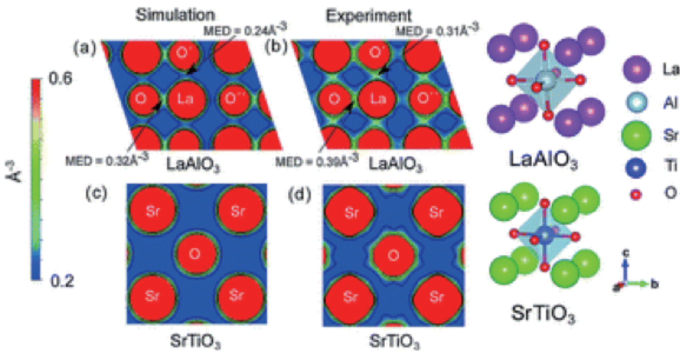
Carbon intensity and renewable energy share for six Northeast Asian countries from 1991 to 2015

Research Highlights

5 A systematic evaluation of the role of lanthanide elements in functional complex oxides; Implications for energy conversion devices

Ji Wu, Kotaro Fujii, Masatomo Yashima, Aleksandar Staykov, Taner Akbay, Tatsumi Ishihara, and John A. Kilner
Journal of Materials Chemistry A
DOI: 10.1039/c8ta01191e

In this fundamental work theory and experiment joint forces to redefine the concept of ionicity and its application on complex oxides applied for electrodes in SOFC (solid oxide fuel cell) devices. We have demonstrated that strictly applied formal charges on ionic species are often incorrect and lead to fundamental misinterpretation of the materials' properties. Using first-principle methods and applying them to a series of rare-earth oxides we have shown lower cationic charges leading to interesting physical properties such as metal-oxygen partial covalency and surface catalytic activity. Applying the experimental high-resolution x-ray spectroscopy and the maximum entropy method, we were able to map the electron density of the metal-oxygen interaction. Our fundamental concept allowed for the design of novel electrode materials for improved surface-oxygen exchange, which is a major milestone in I²CNER's Electrochemical Energy Conversion Division roadmap and will help the widespread of the SOFC technology.

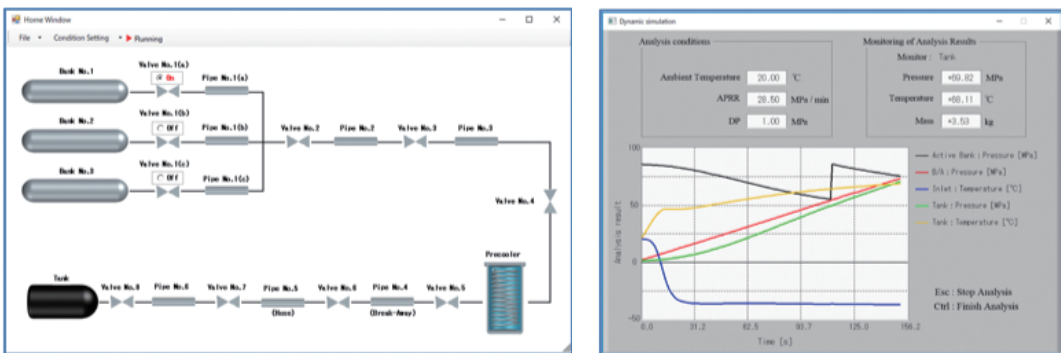


Theoretical and experimental mapping of metal-oxygen electron density in complex oxides applied for energy materials

6 Dynamic simulation for optimal hydrogen refueling method to Fuel Cell Vehicle tanks

Taichi Kuroki, Naoya Sakoda, Kan'ei Shinzato, Masanori Monde, and Yasuyuki Takata
International Journal of Hydrogen Energy
DOI: 10.1016/j.ijhydene.2018.01.111

At hydrogen refueling stations (HRSs), high-pressure hydrogen (up to 87.5 MPa) is quickly filled into Fuel Cell Vehicle (FCV) tanks in about 3 minutes. The hydrogen is pre-cooled to -40°C to ensure that the temperature of the tanks remain below 85°C. A safe, fast, and flexible filling method is required, but the state of hydrogen is hard to predict because the filling processes and surroundings can vary the temperatures and pressures. In this paper, a thermodynamic-based simulation model for estimating the state of the hydrogen flowing through the filling equipment of the HRS is presented based on the mass and energy conservations, including heat transfer from the surroundings. This result corresponds to an application of the high-pressure hydrogen thermophysical properties research in the I²CNER's Thermal Science and Engineering Division roadmap, and contributes to the establishment of a new filling method toward a future hydrogen society.



Development of a simulation software for hydrogen refueling at a HRS based on the present thermodynamic-based model

I²CNER Event Reports

7th WPI Science Symposium

2018.12.27

13 World Premier International Research Center Initiative (WPI) institutes held a science symposium at Nagoya University's Toyoda Auditorium on December 27, 2018. The Institute of Transformative Bio-Molecules, Nagoya University hosted the event this year. This symposium has been held every year in an attempt to make the public, especially high school students who will lead the next generation, familiar with the WPI research. The symposium entitled "Transforming Science" attracted about 900 people. I²CNER ran a booth with 12 other WPI centers and gave a one-minute presentation to audience. Several high school students stopped by the I²CNER booth to ask a wide variety of questions such as the possibilities of renewable energy and advice as to which courses they should take during college to become a researcher at I²CNER.

Presentation at the symposium


I²CNER's booth at the symposium

15th Anniversary Event of JSPS at San Francisco

2019.1.24-25

Director Petros Sofronis and Prof. Toshinori Matsushima (Molecular Photoconversion Devices Division) from I²CNER gave presentations at the 15th anniversary event of the Japan Society for the Promotion of Science's (JSPS) San Francisco office. The event, "World Premier Research in Japan", was held at the University of California, Berkeley and Stanford University on January 24 and 25, respectively.

Since its establishment in 2003, JSPS San Francisco has been promoting academic and research exchange between the U.S. and Japan, and has been working to invite leading researchers from the U.S. to Japan. At this event, 4 WPI centers, Kavli IPMU, AIMR, I²CNER, and ITbM, were invited as examples of highly internationalized research institutions with the best–in-class research achievements in Japan. The two-day event attracted 110 people including faculty, researchers, students, and personnel from industries.


Director Sofronis introduces I²CNER at Stanford University


Prof. Matsushima gives his presentation at the University of California, Berkeley

Awards

IUGG Early Career Scientist Award

Prof. Takeshi Tsuji (CO_2 Storage Division)

Prof. Tsuji conducting research after the Kumamoto Earthquake

On November 5, 2018, it was announced that Prof. Takeshi Tsuji (Lead Principal Investigator, CO_2 Storage Division) will receive the "Early Career Scientist Award" from the International Union of Geodesy and Geophysics (IUGG). IUGG, which is a member of the International Science Council, is a non-profit organization, and is the largest organization in the world for the studies of geophysics. The Early Career Scientist Award was created to enable international researchers in the aeronomy, seismology, hydrology, climatology, oceanography, and cryospheric sciences areas. Prof. Tsuji will receive this award in the seismology area and he is the only Japanese researcher who was selected for this award in 2018. This award is bestowed to up to 10 individuals every 4 years. The award ceremony will take place in Montréal, Canada, on July 13, 2019.

Welcome to I^2CNER

Nobutaka Maeda

Research Associate Professor
(Post-doctoral Research Associate)
Division: Catalytic Materials Transformations Division

Home country: Hokkaido, Japan
Research field: Spectroscopy & Catalysis
I^2CNER member since: April 2019

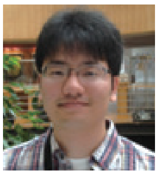
I was originally admitted to Kanagawa University with a sports referral as I wanted to be a member of Hakone Ekiden (a long distance relay race). However, a lecture on “Catalysis” completely pulled me into its world with its profundity and resemblance to mystery novels, which led me to change paths and pursue a PhD. Since then, I have been deeply involved in a harmonious fusion of catalysis and spectroscopy, that is to say, “operando spectroscopy” through my 11-year journey in Switzerland, Italy and China. My research at I^2CNER uses my previous experiences to explore an unprecedented utilization of hydrogen for fine chemicals synthesis and also to offer an operando spectroscopic approach to providing mechanistic understandings. To reset / reboot my mind, I spend my time jogging and boxing on weekends.

Yongpeng Tang

Post-doctoral Research Associate
Molecular Photoconversion Devices Division

Home country: China
Research field: Ultrafine grained metals
I^2CNER member since : April 2019

Metals are widely used in commercial and industrial applications. Researchers are constantly attempting to find a new approach to obtain excellent mechanical properties of metals. Ultrafine grained metal (with a grain size under 100 nm) with unique properties, such as unusual high strength, is an interesting topic. The goal of my research is to design new alloys with unique properties by fabricating ultrafine grained microstructures using severe plastic deformation. Since I^2CNER is one of the World Premier International Research Center Initiative (WPI) centers, it is my honor to have the opportunity to contribute to the research activities at I^2CNER, and I am working hard in hopes of becoming an I^2CNER Principal Investigator in the future. In my spare time, I like to go outside with my family to enjoy outdoor activities.



Takaya Fujisaki

Post-doctoral Research Associate
Electrochemical Energy Conversion Division

Home country: Kagoshima, Japan
Research field: Proton conducting oxides
I^2CNER member since: April 2019

I have been an I^2CNER Post-doctoral Research Associate since April of this year. I received my doctorate degree from Kyushu University in March. My research for this position focuses on proton conducting oxides for fuel cells/steam electrolysis. With the experimental and theoretical technique, I am trying to discover the various properties of metal oxides from the viewpoint of the atomic scale. When I was a high school student, I was very impressed by the concept of a “hydrogen society” that combines renewable energy and hydrogen. From that experience, I decided I wanted to be a researcher in the future. I hope my research will greatly contribute toward creating such a society. Since there are a lot of international researchers in I^2CNER, working with them is a good opportunity to broaden my knowledge of hydrogen and sustainable energy. I sometimes go out with some of the international researchers for a hike or we take a day trip together to enjoy and share our time. Anybody who wants to join us is always welcomed!

Sumitomo Hidaka

Post-doctoral Research Associate
Thermal Science and Engineering Division

Home country: Miyazaki, Japan
Research field: Thermophysical properties, heat transfer characteristics, and basic cycle performance characteristics of next-generation refrigerants
I^2CNER member since: April 2019

Refrigerants are used in refrigerators and air conditioners. In the 1970s, it was discovered that chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are refrigerants that help cause the ozone layer depletion. Since then, hydrofluorocarbons (HFCs) have been used as a refrigerant. However, HFCs also create greenhouse gases that help contribute to global warming. Therefore, our research focuses on hydrofluoroolefins (HFOs) and their mixtures as new refrigerants that have less of an impact on the environment. An understanding of the thermodynamic properties of these new refrigerants is important for the basis to develop industrial equipment. I am using the knowledge from my doctoral degree thesis for my research in I^2CNER’s Thermal Science and Engineering Division. During the weekends, I enjoy playing badminton.

What is WPI?

World Premier International Research Center Initiative

The World Premier International Research Center Initiative (WPI) is a project that was launched by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2007. The WPI seeks to form an ideal research environment within visible research centers that maintain high research standards, where leading researchers will be attracted from all over the world.

For more information:
MEXT Website http://www.mext.go.jp/english/research_promotion/1303822.htm
JSPS Website http://www.jsps.go.jp/english/e-toplevel/index.html

International Institute for Carbon-Neutral Energy Research (I^{2}CNER) Kyushu University

Toward the realization of a low-carbon society, I^{2}CNER aims to resolve the challenges of the use of hydrogen energy and CO_2 capture and sequestration by fusing together sciences from atomic level to global scale.

Kavli Institute for the Physics and Mathematics of the Universe (Kavli IP MU) The University of Tokyo Institutes for Advanced Study, The University of Tokyo

With accumulated research on mathematics, physics and astronomy, this research core works to bring light to the mysteries of the universe, such as its origin, and to provide an analysis of evolution.

Advanced Institute for Materials Research (AIMR), Tohoku University

Integrating physics, chemistry, materials science, bioengineering, electronics and mechanical engineering, AIMR is striving to create innovative functional materials. A mathematical unit joined the team in 2011 to help establish a unified theory of materials science, aiming at the realization of a global materials research hub.

Immunology Frontier Research Center (IFReC) Osaka University

An innovative research center, which pursues the goal of comprehensive understanding of immune reactions through the fusion of immunology, various imaging technologies, and Bioinformatics.

International Center for Materials Nanoarchitectonics (MANA) National Institute for Materials Science

A major focus of our activities is the development of innovative materials on the basis of a new paradigm "nanoarchitectonics," ground-breaking innovation in nanotechnology.

Institute for Integrated Cell-Material Sciences (iCeMS) Kyoto University

Established to integrate the cell and material sciences, the iCeMS combines the potential power of stem cells (e.g., ES/iPS cells) and of mesoscopic sciences to benefit medicine, pharmaceutical studies, the environment, and industry.

Institute of Transformative Bio-Molecules (ITbM) Nagoya University

The goal of ITbM is to develop innovative functional molecules that make a marked change in the form and nature of biological science and technology (transformative bio-molecules). ITbM will connect molecules, create value, and change the world, one molecule at a time.

International Institute for Integrative Sleep Medicine(IIIS) University of Tsukuba

IIIS aims to elucidate the function of sleep and the fundamental mechanisms of sleep/wake regulation and also aims to develop new strategies for diagnosis, prevention, and treatment of sleep disorders. Our goal is to contribute to promote human health through our sleep research.

EARTH - LIFE SCIENCE INSTITUTE (ELSI) Tokyo Institute of Technology

ELSI focuses the origins of Earth and life. Both studies are inseparable because life should have originated in unique environment on the early Earth. To accomplish our challenge, we establish a world-leading interdisciplinary research hub by gathering excellent researchers in Earth and planetary sciences, life science, and related fields.

Nano Life Science Institute (NanoLSI) Kanazawa University

Cells are the basic units of almost all life forms. We are developing nanoprobe technologies that allow direct imaging, analysis, and manipulation of the behavior and dynamics of important macromolecules in living organisms, such as proteins and nucleic acids, at the surface and interior of cells. We aim at acquiring a fundamental understanding of the various life phenomena at the nanoscale.

International Research Center for Neurointelligence (IRCN) The University of Tokyo

IRCN combines life sciences and information sciences to establish the new field of "Neurointelligence". By clarifying the essence of human intelligence, overcoming neuraldisorders, and developing new AI technologies, we will contribute to a better future society.

Institute for the Advanced Study of Human Biology (ASHBi) Kyoto University

ASHBi investigates the core concepts of human biology with a particular focus on genome regulation and disease modeling, creating a foundation of knowledge for developing innovative and unique human-centric therapies.

Institute for Chemical Reaction Design and Discovery (ICReDD) Hokkaido University

ICReDD integrates computational, information, and experimental sciences in order to obtain in-depth understanding of chemical reactions, which enables rational design and rapid development of new chemical reactions.

Editor's Note

- I^{2}CNER holds a variety of events.
  For details, please see: ➡ http://i2cner.kyushu-u.ac.jp/en/
  I2CNER Search
- This issue of the I^{2}CNER magazine, *Energy Outlook*, is a unique edition containing two special interviews discussing how to underpin the future low-carbon energy transition through a combination of renewable energy deployment, socio-technical regime understanding, and utilization of carbon capture and storage (CCS). As always, we are open to any feedback you may wish to share. Thank you!

Energy Outlook vol.22 June 2019
[Published by] International Institute for Carbon-Neutral Energy Research (I^{2}CNER)
I^{2}CNER Administrative Office, 744, Motooka, Nishi-ku, Fukuoka City
Fukuoka Prefecture, 819-0395 (Kyushu University Ito Campus)
☎ +81-(0)92-802-6935 Fax +81-(0)92-802-6939
wpisyogai@jimu.kyushu-u.ac.jp
http://i2cner.kyushu-u.ac.jp
https://www.facebook.com/I2CNER.news
https://twitter.com/I2CNER
[Edit & Design] Kijima Printing, Inc.
[Photography] Osamu Irie
[Edit & Planning] I^{2}CNER Administrative Office
(Tomoya Koga, Yuki Nogami, Shoko Koga)

I²CNER

A World Premier International Research Center

wpi

KYUSHU UNIVERSITY

ILLINOIS