

6. INTEGRATED RESEARCH CENTER FOR CARBON NEGATIVE SCIENCE

2025 Activities

Introduction

The Integrated Research Center for Carbon-Negative Science (ICaNS) was established in August 2022 to promote research in carbon-negative science toward the realization of a carbon-neutral society by 2050. Currently, the balance between carbon dioxide emissions and absorption has been disrupted, resulting in excessive emissions and significant impacts on the Earth in the form of climate change. Restoring this balance is difficult using “zero-emission” technologies alone and requires the development and implementation of more active carbon dioxide fixation processes, so-called “carbon-negative” technologies. The Center aims to develop such technologies in collaboration with the Graduate School of Engineering and the Graduate School of Energy Science at Kyoto University. It also seeks to cultivate human resources in “carbon-negative science,” an emerging field.

In the fiscal year (FY2022), three major research projects were launched: 1) Solar Energy Utilization for CO₂ Capture and Conversion, 2) Conversion of CO₂ into Useful Substances, 3) Biological Utilization of CO₂. In the current fiscal year (FY 2025), we continued to advance these priority research projects, building on the efforts of the previous fiscal year, and further strengthened our educational framework for “carbon-negative science.” We also held seminars on carbon-negative energy science and carried out renovations to the Center’s laboratories and the installation of new experimental equipment.

1. Solar Energy Utilization for CO₂ Capture and Conversion

The objective of this group is to establish novel science and technology for the efficient utilization of solar energy for CO₂ capture and conversion into valuable materials. In FY2025, the following studies were primarily conducted in this group: high temperature optical properties of carbon nanotube membranes and their applications for solar energy harvesting; robotic fabrication and novel optical physics of quantum materials toward carbon negative energy science; development of functional light-element nanoribbons using vector synthesis technology; use of lasers for carbon negative science; laser nitrogen fixation using KU-FEL; chiroptical signal amplification in amorphous silica.

2. Conversion of CO₂ into Useful Substances

This project group aims to convert CO₂ into useful substances. We are particularly interested in electrochemical methods of conversion. By using high-temperature molten salts as electrolytes, for example, CO₂ could be converted into a wide variety of valuable carbon materials, such as diamonds, carbon nanotubes, and graphite. If aqueous solutions, organic solvents, or ionic liquids are used as electrolytes at relatively low temperatures, CO₂ can be converted into methane, ethylene, and other materials. In FY2025, we investigated the conversion of CO₂ into graphite by molten salt electrochemical process. We selected the NaCl–KCl–BaCl₂ system as a molten salt capable of carbon electrodeposition at temperatures of 800 to 950 °C. It was confirmed that higher electrodeposition temperatures are more advantageous for graphite deposition. We also succeeded in observing carbon electrodeposition in a molten LiCl–KCl–K₂CO₃ in-situ using a transparent electrolytic cell and a high-speed camera.

3. Biological Utilization of CO₂

This project focuses on bio-related methods, materials, and enzymes with the aim of contributing to carbon-negative science. In FY2025, research was conducted on the development of tools to gain a deeper understanding of biological cells and their energy conservation, as well as on technologies to enhance and extend the activity of enzymes, particularly those related to CO₂ fixation. By modifying CO₂-fixing enzymes and improving substrate specificity to enable the production of high-value-added molecules from CO₂, we sought to improve the efficiency of CO₂ fixation through novel reactions. Membranes, reactors, and processes were developed to promote biomass utilization and establish efficient biorefineries. New microbial enzymes and metabolic pathways capable of utilizing CO₂ or preventing its release were identified. Furthermore, ruthenium-based catalysts effective for polyolefin degradation were developed. Joint research continues to pursue these common goals and contribute to the development of a bio-based society.

4. Education Activity

As in previous years, the content on “Carbon-Negative Energy” was incorporated into the existing undergraduate course “Advanced Energy Science.” At the graduate level, “Carbon-Negative Energy” was also integrated into the Graduate School of Energy Science’s courses “Social and Environmental Energy Science I and II,” as in the previous year. Furthermore, the concept of “Carbon-Negative Energy” was introduced to visitors to our institute.

5. Other Activities



Fig. 1-1 An argon glove box with purification system.



Fig. 1-2 A box-type electric furnace.



Fig. 1-3 A drying oven.

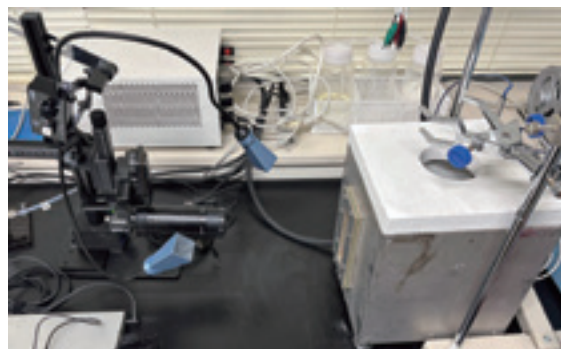


Fig. 1-4 An in-situ observation system for molten salt electrolysis.

We further upgraded Laboratory 3-5 in the main building of the Uji Campus. As for experimental equipment, an argon glove box with purification system, a box-type electric furnace, a drying oven, and an in-situ observation system for molten salt electrolysis, as shown in Figs 1-1, 1-2, 1-3, and 1-4.

ICaNS Events

June 9: ICaNS Program-specific Associate Professor Appointments Committee meeting was held.

December 12: Symposium Session of ICaNS Midterm Report was held.