Current Status and Future Perspectives ("Now and Future") of Clean Energy Technologies in AIST

OBARA Haruhiko
Department of Energy and Environment,
National Institute of Advanced Industrial Science and Technology (AIST), Japan

1. Introduction (Times New Roman or Times-Roman 12 pt)

Japan has a long history of research and development in energy technologies to ensure energy security and independence. For example, Japan's long-term Sunshine Project to develop 'new energy' technologies, such as renewable energy, started in 1974, and the long-term Moonlight Project to develop energy conservation technologies was begun in 1978. These led the world-scale research and development of 'new energy,' and became a solid foundation for the progress of the present renewable energy society. As a further challenge in responding to the recent global environmental problems and changes in the energy supply strategy after the 2011 Fukushima disaster, research and development at the national level has been accelerated while linking academic, public and private sectors. The 2018 "Fifth Strategic Energy Plan" gives insight into Japan's energy policy toward 2030 and 2050 and aims for widespread renewable energy use. In view of the global momentum toward decarbonization that gained more than ever at the Paris Agreement, it is important to set goals that are more ambitious than before. To that end, AIST explores and pursues all possible options for achieving this energy transition.

2. R&D activities related to clean energy technology

The department of Energy & Environment at AIST is promoting green innovations to reduce greenhouse gas emissions by utilizing technologies for efficient and reliable renewable energy production, hydrogen-based, safe and high-density energy storage, efficient thermoelectric elements, and diffusion of these technologies into the society.

AIST has established two research centers to emphasize its commitment to green innovation: the Fukushima Renewable Energy Research Institute, AIST (FREA), established in April 2014, and the Global Zero Emission Research Center (GZR), established in January 2020. GZR addresses fundamental technologies pertaining to solar power, thermoelectric power, hydrogen related materials, carbon utilization, artificial photosynthesis and assessments for decarbonation. FREA focuses on renewable energy technologies such as solar, wind, geothermal, energy management technologies for smart grid, and hydrogen-based energy storage/carriers, all from an application-oriented point of view.

Both research centers will play a role as a global open innovation platform for decarbonization, and ultimately for a zero-emission society, through collaboration with academia and industry all over the world.

3. Specific research activities in next generation energy management systems with batteries, renewable energy, hydrogen, CCUS, and related technologies

The following are some of the state-of-the-art clean energy technology research activities conducted at AIST.

- Renewable energy (PV)

High-efficiency PVs are expected to promote new applications such as in vehicles, aircrafts, etc. Tandem device configurations are promising in improving PV efficiency. We have developed a brand-new wafer bonding method named, "smart stack". Under this concept, we have found that metal nanoparticles between cells show good bonding characteristics with low

resistivity and high transparency. In addition, this allows for the significant flexibility of device combinations including all kinds of conventional PVs.

- Next generation energy management system with batteries

Energy storage, particularly rechargeable batteries, plays an important role for a next-generation energy management system. We are developing post lithium-ion batteries, such as all-solid-state, lithium-sulfur, and potassium-sodium ion batteries to improve the energy density of batteries. For example, we have succeeded in enhancing energy density for sulfide electrodes using amorphous materials. We are also researching the reaction mechanisms during charge and discharge to design high-performance electrode materials. This shows the analysis of the degradation mechanism on lithium cobaltate cathode by Transmission Electron Microscope etc., and we obtained effective surface coating methods which improve the cycle performance.

- Hydrogen

Ammonia is one of the high-density hydrogen carriers. However, ammonia synthesis from variable renewable energy and direct combustion for power generation are challenging research topics. We have developed a new catalyst and process for producing ammonia from renewable hydrogen, and a low-NO_x operation of a direct ammonia-fired turbine. The combination of these technologies can contribute to the establishment of an entire value chain of ammonia energy carrier systems.

- CCUS

We are developing a methanation process as a CO_2 utilization technology that produces methane using hydrogen from renewable energies and CO_2 retrieved from thermal power plants. We study the catalyst activity and optimization method of the methanation process together with industry, academia and the government.

Related programs/projects conducted by the institute (further information on programs/projects can be found in the template)

Renewable energy (PV)

- "Research and development of high efficiency and low-cost solar cells using single-crystal CIGS and smart stacked multijunction technologies" (2015-2019)
- "Research and Development of ultra-high efficiency solar cell modules using multijunction technologies" (2020-2022)
- "International collaborative R&D for low-cost and high-durability solar cells" (2020-2023)

Next generation energy management systems with batteries:

- "Development of Lithium-ion battery with high performance for severe temperature conditions" (2015-2019).
- "Analyzing the Reactions of Electrolyte and Cathode in a Lithium/Sulfur- and Lithium/Metal Sulfide Battery (AReLiS)" (2019–2020)
- "Metal-free redox flow battery for introduction of renewable energies into the grid" (2020-2023)
- "Enabling the manufacturing of advanced solid-state batteries" (2020-2022)

Hydrogen

- "Research and development of hydrogen production technology by thermal decomposition of methane" (2019-2020)
- "Advancement of alkaline and polymer-electrolyte water electrolysis" (2018-2022)
- "Development of efficient and durable catalyst for hydrogen production from formic acid" (2020-2022)
- "Approach to the Development of P2G System Technology Aiming to Build a CO_2-Free Hydrogen Society in Yamanashi Prefecture" (2016-2021)
- "Development of Ammonia Synthesis Process from CO_2 Free Hydrogen" (2014-2018)
- "Advanced Evaluation and Analysis Technology on Degradation of SOFC Stacks"

(2020-2024)
- "Development of novel thermochemical hydrogen compressor using high pressure metal hydride" (2020-2023)

CCUS
- "Production of useful chemicals using solar energy" (2017-2022)
- "Development of Basic Technology for Next Generation Thermal Power Generation (Development of CO_2 Utilization Technology)" (2017-2020)
- "Cutting-Edge Research for Development of CO_2 Utilization Technology (Electrochemical Direct Decomposition of CO_2)" (2019-2020)

4. International collaboration

4-1 International alliance/networking development

AIST has concluded comprehensive MOUs with the following nine RD20 members in the field of energy and environment as of 1st September 2020: National Research Council of Canada (NRC, Canada), Chinese Academy of Sciences (CAS, China), Joint Research Centre of the European Commission (JRC, EC), Commissariat à l'Energie Atomique et aux energies alternatives (CEA, France), Centre National de la Recherche Scientifique (CNRS, France), Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. (Fh-G, Germany), Agency for the Assessment and Application of Technology (BPPT, Indonesia), and National Renewable Energy Laboratory (NREL, USA). In terms of clean energy technology, AIST, Fraunhofer Institute for Solar Energy Systems and National Renewable Energy Institute are co-organizing both the Terawatt Workshop and the Gigaton Hydrogen workshop series to discuss and share the challenges and opportunities for large-scale deployment of solar photovoltaics and hydrogen. We hope we can enhance international collaborations with other RD20 members and institutes worldwide for clean energy technology R&Ds.

4-2 International joint R&D activities

Since the 1st RD20, AIST has signed twenty-two joint research contracts with various institutes around the world for clean energy technology R&Ds. These include fourteen newly signed contracts with seven countries (including four contracts with RD20 members) and eight extended contracts with five countries and organizations (including three with RD20 members).

5. Future perspectives (beyond 2030)

In January 2020, Japan formulated the "Environment Innovation Strategy" to create innovations in the energy and environment fields. This strategy aims to realize a feasible cost level for innovation deployment, and to contribute to significant GHG reduction not only in Japan but also worldwide. The strategy includes "Innovation Action Plans," which serve as "technology compasses" to establish innovative energy and environmental technologies by 2050. There are five key sets of technologies outlined in the Plans: non-fossil energy, energy network, hydrogen, carbon recycling and CCUS, and zero-emission agriculture, forestry and fisheries. Since AIST is conducting progressive research in these key sets of technologies, we will contribute to the realization of the "Innovation Action Plans" by implementing full research, i.e., from fundamental to applied research, for clean energy technologies with the ultimate goal of achieving a zero-emission society.

Dr. OBARA Haruhiko, Vice-President

National Institute of Advanced Industrial Science and Technology (AIST)

Dr. OBARA Haruhiko is currently Vice-President of the National Institute of Advanced Industrial Science and Technology (AIST), and Director-General of the Department of Energy and Environment, AIST.

Dr. OBARA graduated from the Department of Applied Physics, the University of Tokyo, and joined the Electrotechnical Laboratory of the Agency of Industrial Science and Technology, a predecessor of the current AIST, in 1987. He received his Ph.D in Applied Physics from the University of Tokyo in 1990. He began his career as a research scientist in superconductivity, and e xpanded his research to thermoelectric energy conversion. He was a postdoctoral researcher in DPMC, University of Geneva, from 1993 to 1994, and was a visiting professor in the faculty of industrial science and technology, Tokyo University of Science, from 2015 to 2019. He participated in various energy conservation technology projects, and is now the project leader of the Research and Development Project for Innovative Thermal Management Materials and Technologies, founded by the New Energy and Industrial Technology Development Organization (NEDO).

Dr. OBARA was appointed Vice-President of AIST and Director-General of the Department of Energy and Environment in 2020. ORCID : 0000-0002-5683-1837