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

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1. Introduction

Japan is heavily dependent on import of fossil energy resources such as oil, gas, and coal for its primary energy supply. This dependence is strongly influenced by the geo-political situation of the countries of the origin and the surrounding regions. After the first oil shock triggered by the 4th Middle East War in 1973, Japan adopted a diverse energy-mix policy by balancing the share of oil, gas, coal, nuclear and renewables in its primary energy and combined it with energy efficiency actions by promoting and pursuing R&D of new technologies for enhancing conversion efficiency, recovery and utilization of unused/waste energy.

In March 2011, Japan was struck by the Great East Japan Earthquake, which led to an unprecedented accident at the Fukushima Daiichi Nuclear Power Plant. The social, environmental and economic impact of the accident was significant, prompting policy makers to re-think Japan's energy policy. In light of this, the "Fifth Strategic Energy Plan" was drafted and published in 2018. The plan provides a framework for the energy policy of Japan towards year 2030 and 2050. It outlines a new energy-mix policy that calls Japan for energy transition towards clean energy by increasing the share of renewable energy in the primary energy while further strengthening its efforts to realize a secure, sustainable and affordable energy supply and active contribution to the global momentum for decarbonization as described in the Paris Agreement. To meet the challenges for energy transition and decarbonization, we are and will continue to explore and pursue all the possible options.

2. R&D activities related to clean energy technology

AIST is Japan's largest comprehensive R&D institute with 11 research bases carrying out research in seven major research fields. Department of Energy and Environment with five full-fledge research units and three research centers in addition to two Open Innovation laboratories, is the cradle of Energy and Environment research of Japan. It is leading Japan's across the board energy research and technology development especially in the clean energy field by promoting green innovation to solve global energy and environmental challenges related in particular to greenhouse gas emissions. The department is promoting R&D of new and efficient energy technologies that include;

1) technologies that promote clean energy transition by increasing the share of renewables such as photovoltaic power, wind power, geothermal power and others.
2) technologies for H_2 storage as energy carrier, and high-density energy storage materials (batteries) for stabilization of fluctuating power generation issues of renewable energy and decarbonization of transportation sector.
3) power electronics-based technologies with wide band-gap semiconductors, SiC, GaN, Diamond for smart power grids, intelligent energy management systems, large-size PCSs, as well as EVs, trains, electric aircrafts etc.
4) technologies for more effective use of conventional and non-conventional energy resources, such as thermoelectric conversion, improving efficiency of internal-combustion engines, chemical looping technology for direct, concentrated and economical CO_2 capture.

The department is also working to disseminate these technologies into the society.

Fukushima Renewable Energy Institute, AIST(FREA)

To improve Japan's energy situation, and in line with the new energy policies, AIST opened the Fukushima Renewable Energy Research Institute, AIST (FREA) in April 2014, focusing on renewable energy research. The mission of FREA is to become a global open innovation platform for renewable energy research through collaboration between academia, industry, and the global network. The center's main research themes are solar and wind power generation, geothermal utilization, energy network, and production and utilization of hydrogen energy carriers.

3. Specific research activities in hydrogen, CCUS, and related technologies

AIST strategy is to develop a complete package of technologies, from production to utilization, for renewable energy use. Among all the renewable energies, hydrogen is a much sought-after clean energy source. We produce (renewable) electricity from renewable sources such as solar, wind etc. and use it to produce H_2. AIST is thus, promoting technologies related to hydrogen "production", "storage" and "utilization". Our research on H_2 production is focused on producing hydrogen by water electrolysis using electricity from renewable sources. We are also doing research on the development of new catalysts for more efficient water electrolysis. For storage, we are actively pursuing technologies for storing H_2 as energy carrier. For that, several types of hydrogen carriers such as MCH (methyl cyclohexane), ammonia, and formic acid are examined in AIST. A pilot scale ammonia synthesis plant has been constructed at FREA to demonstrate ammonia synthesis from hydrogen produced by renewable electricity. For utilization, we are developing an integrated system for zero-CO_2 emissions from buildings by supplying hydrogen as fuel for fuel cells for energy/electricity requirements of the household/buildings.

Ammonia synthesis plant in FREA

To demonstrate our commitment and technological advancement in H_2 production, storage, transportation, and utilization from renewable energy sources, we plan to deliver hydrogen produced at FREA for energy applications at Tokyo Olympics next year.

As for "Carbon dioxide Capture and Utilization (CCU)", we have commenced preliminary research on direct carbon capture technology, carbon utilization/conversion technology for producing renewable chemical feedstock by reacting H_2 with CO_2. We have successfully demonstrated chemical looping technology that enables direct, concentrated and economical

CO_2 capture. In addition, we are also pursuing research in other clean energy areas such on artificial photosynthesis for producing hydrogen and other useful chemicals.

Related programs/projects conducted by the institute

- Advancement of Hydrogen Technologies and Utilization Project/Research and Development of Novel Hydrogen Production Technology through Thermal Decomposition of Methane (2019-2020)
- Development of Technology for Next Generation Thermal Power Generation Project/Development of Fundamental Technology for Next Generation Thermal Power Generation Project/ Development of CO_2 Utilization Technology Project (2017-2019)
- Development of Technology for Next Generation Thermal Power Generation Project / 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 a number of comprehensive and specific MOUs with overseas institutes. Our international activities include joint projects, researcher exchanges, joint workshops and seminars etc. Through these activities, our global relationship has been strengthened, which should be beneficial for both sides. For us, such collaborations are important for carrying out and accomplishing Full Research. AIST is promoting worldwide collaboration among high-level research institutes with cutting-edge technologies. We believe that such collaborations among the research institutes in G20 members are important for carrying out innovation in clean energy technologies.

4-2 International joint R&D activities

AIST is undertaking the development of innovative energy technologies with financial support from the Ministry of Economy, Trade and Industry (METI). As part of a Basic Research and Renewable Technologies Cooperation between Japan and the U.S., research on over 30 topics pertaining to clean energy technologies were carried out at AIST between 2010 and 2014. These topics cover a wide range of fields, including bio-Fuels, renewable energy, artificial photosynthesis, and hydrogen generation. The international joint research program for innovation energy technology, which includes Li ion battery and thermoelectric technologies as new topics, began in 2015. Since 2017, the program, which had to date only included the U.S. as a partner country, has gradually been expanded. As examples of international collaborations, AIST is working on artificial photosynthesis with a research institute in the US, and on hydrogen carriers with research institutes in the US, Germany, and Switzerland.

Related programs conducted at the institute

- International Joint Research Program for Innovative Energy Technology
  # Hydrogen production and storage technology using CO_2
  -development of clean hydrogen carrier system using CO_2 recycling technology-
  # Production of useful chemicals with sunlight
  # Development of an efficient and economical hydrogen storage and utilization technology for the realization of CO_2 free hydrogen society

5. Future perspectives

Japan is aiming to increase the share of power generated by renewable energy such as solar and wind in the future. However, variability of power generation is a serious issue for introducing renewable energy in a large scale, as it may at times lead to unused excess power

generation. For that, R&D of more efficient, durable, and affordable technologies to use renewable energy with “anytime-anywhere” application flexibility is needed. Therefore, integration of conversion, transportation and storage technologies is inevitable for large scale introduction of renewable energy. AIST is carrying out research on several renewable resources for power generation with this integrated approach. The power generated from renewables such as solar and wind is used to produce H_2. AIST is also promoting “Power to X” approach by converting the excess power to liquid fuels such as methanation technology, thus enabling storage of excess power. Our R&D is not only limited to H_2 energy, and we are also making efforts to develop new next generation technologies such as artificial photosynthesis technology. In addition, Japan, being a volcanic country, has nearly 200 GW untapped potential for geothermal power. We are, therefore, actively promoting R&D of supercritical geothermal power generation technologies.

Vice-President Dr. Tetsuhiko Kobayashi

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

After receiving Ph.D in Engineering from Osaka University, Japan, Dr. Kobayashi joined Government Industrial Research Institute, Osaka (GIRIO) (The current AIST Kansai Center) in 1984. He began his career as a research scientist of electrochemistry and catalysis for energy conversion and environmental protection. After gaining experience at AIST Kansai Center, Dr. Kobayashi led various research and development project such as lithium-ion batteries and fuel cells.

Dr. Kobayashi was appointed Director-General of Department of Energy and Environment, AIST in 2014 and later became Vice-President of AIST in 2015. ORCID : 0000-0002-6952-8669