Hydrogen in the Energy System Decarbonization

EXECUTIVE SUMMARY

An event organized under the auspices of the

Experts' Group on R&D Priority Setting and Evaluation(EGRD)

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Online

Hosted by the Institute of Applied Energy

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Introduction

On 24 November 2021, EGRD organized a webinar on 'Hydrogen in the Energy System Decarbonization' together with the Institute of Applied Energy as the official host of the event. The meeting gathered more than 110 senior officials and experts from leading government agencies and the research community from around the world.

Background and Rationale

Hydrogen is mainly used today as feedstock for industrial applications, such as refining in the oil and gas sector or for ammonia production. Recently, the role of hydrogen and its potential use have expanded as many governments see its vital role in the decarbonizing industry, transportation, and building sectors or for coupling between these sectors. Countries worldwide are developing new hydrogen strategies and policies to promote the production and use of hydrogen through cost reduction and demand creation. Today, Hydrocarbon resources are the primary sources of hydrogen production. Further efforts will be needed to promote hydrogen from renewable energy sources and CO2-recovery fossil fuels to reduce CO2 emissions from the energy sector.

Summary of Discussions

This webinar looked at the hydrogen in the clean energy transition from different angles: hydrogen strategies in energy and industrial policies, challenges related to the large-scale zero-carbon hydrogen energy carrier production with large-scale demand creation, and research development priorities in international cooperation.

- Reduction of costs and accelerated scale-up of technologies

The key to the widespread use of hydrogen energy is creating a large-scale carbon-neutral hydrogen supply at a low cost and corresponding market creation. This means that it is vital to provide low-cost production from fossil fuels with CCS and renewable energy sources. Regarding demand, the expansion of industrial use, where the potential market expected will be significant, and the development and diffusion of technologies in sectors where GHG reduction is relatively difficult, such as heavy-duty vehicles, shipping, and aviation, will have a significant effect.

- Innovative research enhancement to prepare next-generation GHG reduction opportunities

There are still various opportunities for technology development from low TRLs to high TRLs in the hydrogen value chain at production, transport, storage, and demand. We should accelerate research and development to improve economics and efficiency of use, consistent with available regional resources.

- Overcoming social barriers

Safety is a top priority for the large-scale production and use of hydrogen. In addition to technical and economic issues, it is essential to ensure that institutional matters such as regulations and standards do not become obstacles to the widespread use of hydrogen energy.

Recommendations
Activities to close the supply-demand gaps and opportunities in hard-to-abate demand sectors • In addition to producing hydrogen that matches the size of demand, transportation and storage infrastructure should be built, especially when the distance between supply and demand is significant. • The key is the creation of an initial market and the availability of interregional and long-distance transport, which would expand as the scale of demand gradually increases. • On the demand side, there is a need for further technology development and cost reductions in hard-to-abate sectors such as high-temperature heating and feedstock for the industry, and heavy-duty vehicles in transport.
Comprehensive system evaluation of the hydrogen value chain • By sharing and disseminating the research results of systems evaluation among the stakeholders, we should establish the acceptance of the economic and social value of hydrogen energy at the level of policymakers, industry, local governments, and citizens. • The capability of comprehensive system evaluation should be strengthened to identify the benefits of the hydrogen value chain.
Promotion of safety, standardization, and social acceptance research on hydrogen energy use • R&D on safety, standardization, certification and social acceptance facilitate promotion to adjust the actual situation of hydrogen use in the region. • Acceptable institutional frameworks should be proposed as a result of R&D to avoid obstacles to hydrogen energy use.
Cooperation through various channels for RD&D • In addition to bilateral and multilateral international frameworks, such as the Hydrogen Technology Collaboration Programme or Mission Innovation's Hydrogen Mission, stakeholders should accelerate other local-local, cross-border regional, and public-private cooperation to share hydrogen-related knowledge and experience.

Agenda and presentations are available here.

[1] Introduction Session- Setting the Scene

Toshiyuki Sakamoto, CERT Vice-chair and Board Member of Institute of Energy Economics Japan, and **Hidechika Koizumi**, Director of International Affairs Division, Agency for Natural Resources and Energy Ministry of Economy, Trade and Industry presented welcome remarks. **Atsushi Kurosawa**, EGRD Vice-chair and Research Director of the Institute of Applied Energy, welcomed the participation as a host organization, and **Birte Holst Jørgensen**, EGRD Chair, Technical University of Denmark, provided an overview of EGRD activities.

Uwe Remme, Head of IEA' Hydrogen and Alternative Fuel Unit, presented key findings of IEA's Global Hydrogen Review 2021. The estimated hydrogen demand was 90 million tonnes in 2020, and industry and refining sectors consume them. It could reach 120 million tonnes in 2030 under zero emission pledges. New low-carbon hydrogen production projects are underway, and around 17 million tonnes of hydrogen by 2030 could be from fossil fuel with CCS and renewable electrolysis.

Matthijs Soede, Clean Hydrogen Mission Director, European Commission, stated the status of the Clean Hydrogen Mission of Mission Innovation (MI) which was launched in June 2021. The EU has started creating MI hydrogen valleys from generation to end-use with three pillars, research and innovation, demonstration in hydrogen valley, and creating an enabling environment. After COP26, Clean Hydrogen will discuss potential action plans, implementations, and progress reviews.

[2] Hydrogen Policies Session

Hiroki Yoshida, Deputy Director, Hydrogen and Fuel Cell Strategies Office, Advanced Energy Systems and Structure Division, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (METI), illustrated the latest Japanese energy policies and actions towards a hydrogen-based economy. The government of Japan has set a cost reduction target for hydrogen to 3 USD/kg by 2030 and less than 2 USD/kg by 2050, with the goal of amarket volume of 3 million tonnes of hydrogen by 2030 and 20 million tonnes of hydrogen by 2050. Towards the goal, the government focuses on policies for the entire hydrogen system, including the demand side, production, and transportation infrastructure. In the sixth strategic energy plan, hydrogen/ammonia's share is 1% in the power generation mix in 2030. Large volume hydrogen imports from overseas are under the plan due to the limited Japanese domestic energy resources. Japan is also taking a leading role in facilitating international dialogue on hydrogen technologies and fuels. The Governments has hosted the Hydrogen Energy Ministerial Meeting in Japan annually since 2018. At the most recent meeting in October 2021, more than 30 governments shared their intended policy directions for scaling up the production and use of hydrogen.

Luca Pollizi, Policy Officer, Research and Innovation Policy on Hydrogen, European Commission, provided an overview of EU's hydrogen policies. The European Commission supports the transition to the Hydrogen Economy in three dimensions: Union-level, national and regional, and international.. The Hydrogen Strategy stated production targets for Europe, 1 million tonnes of hydrogen by 2024 and 10 million tonnes of hydrogen by 2030. Public-private partnerships at the Joint Undertaking support hydrogen projects in Europe and abroad, and blended funding mechanisms like the Catalyst Fund support activities between EU member countries. Many EU member countries' plans are to be published and distributed to improve the commitments across Europe to long-term objectives, at the regional dimensions, more than 19 regions to embrace hydrogen technologies.

Eric Miller, Senior Adviser, Hydrogen & Fuel Cell Technologies Office, Office of Energy Efficiency & Renewable Energy, US Department of Energy, summarized the status of the US hydrogen policies. In the US, federal goals include net-zero emissions by 2050 and a 100% carbon-pollution-free electric sector by 2035. Hydrogen will decarbonize sectors, particularly in hard to abate sectors such as heavy-duty transport and industry. Hydrogen production facilities in the Gulf region produce hydrogen from natural gas reforming for oil refineries. Over 1600 miles of hydrogen pipeline are located mainly in the Gulf area, and the world's most extensive storage cavern is in the US. Hydrogen Earthshot was launched in June 2021, and its tag line "111" ambitious goal is to achieve 1 USD per 1 kg of clean hydrogen in 1 decade. Advanced pathways in the Hydrogen shot include direct water splitting by solar energy, thermochemical, and biological fermentation. Regional opportunities in natural resources and end-use have diversities. Transportation from production to end-use is the key to leveraging the hydrogen cost in the United States. The US Hydrogen Program of the US Department of Energy will cover renewable energy, fossil energy and carbon management, and nuclear energy. The US is very active in hydrogen-related international activities.

[3] Hydrogen Demonstration Session

Motohiko Nishimura, Deputy General Manager, Hydrogen Strategy Division, Kawasaki Heavy Industry (KHI), introduced KHI activities in the international hydrogen value chain project. KHI aims for a hydrogen supply chain to produce hydrogen from affordable overseas resources and transport it to Japan in a liquefied form. Green hydrogen technologies will scale in the future; however, hydrogen from fossil fuel with CCS over time. In the pilot project, hydrogen is produced liquefied and loaded in Australia, transported to Japan, and unloaded. The pilot demonstration includes hydrogen production by gasification in Latrobe valley, pressurized hydrogen land transport and liquefaction at -253 degC at Hastings, and liquefied hydrogen carrier ship. The gas turbine uses 100% pure hydrogen in the demonstration, supplying energy to the surrounding buildings. It is the world's first example of heat and power supply using pure hydrogen in urban areas, and no objection from neighboring residents about hydrogen handling. Kobe city office frequently held forums on future energy for decarbonization, contributing to public acceptance. From 2020, 40,000 tonnes cargo tank and 50,000 tonnes onshore tank are under development. Commercialization demonstration is the next large project in Japan, funded by a Clean Innovation Fund.

Michel Berger, Professor of University of Applied Science Westkuste, presented a demonstration as a 'Real Lab.' 30MW electrolyzers will provide three products: hydrogen, oxygen, and heat. The plan includes hydrogen cavern storage for the instability of the variable renewable power system. Other sector couplings are hydrogen blending in the urban gas supply network and integration of the cement industry. If the project consumes one-quarter of all the electricity available, this will influence the region. The lab also works for the testbed to identify two kinds of risks. One is regular business risks, another is political or general risks that cannot be accepted by the companies as a market barrier, like the definition of green property, border taxes, green certification, tax exemptions, import structure of hydrogen, electricity availability, policy continuity, approval processes, and infrastructures. The lab created the regulation list from the context of introducing new energy systems in the region. The survey revealed about 13,000 rules. CO2 to methanol synthesis path is added, parallel to the known Fischer-Tropsch process producing power to liquid (PtL) crude before refining. There are three different ways, methane, PtL crude, or methanol. Methanol is the feedstock in this profitable production chain, transport sector, and industry sector. One other process to produce ammonia is the Haber-Bosch process, as we have a fertilizer production close to the region. There is a step-by-step electrolyzer scale-up plan and its final target scale is 2GW for comprehensive applications.

[4] R&D Priorities Session

Yuki Ishimoto, Vice Director, Hydrogen Energy Group, the Institute of Applied Energy, introduced the energy system analysis role to find clues for R&D prioritization. The hydrogen energy system has a wide variety of outputs depending on objectives, for example, technical, environmental, and economic performances. And energy system analysis with reasonable assumptions can provide many clues for improvement in energy, CO2 emissions, and cost. The first example was hydrogen production cost estimate via alkaline water electrolysis, and as a robust conclusion, investment cost reduction should be considered both in small and large systems. The second example was a cost analysis of long-distance hydrogen transport of three energy carriers: liquefied hydrogen, toluene and methylcyclohexane (MCH), and ammonia. The scope of the study includes hydrogen production, carrier conversion, loading terminal, seaborne transport, receiving terminal, dehydrogenation/cracking, and delivery. Both input and output of the system are pure hydrogen. The scale-up effect is significant in liquefied hydrogen carriers, and waste heat integration in MCH and ammonia or direct use of ammonia will reduce the cost. The competitiveness of hydrogen carriers also depends on demand technology types. Energy system analysis of hydrogen can provide many valuable clues for R&D prioritization.

Mirela Atanasiu, Head of Unit Operation and Communications, Fuel Cells and Hydrogen Joint Undertaking (FCH JU), introduced Mission Innovation Hydrogen Valley Info-Sharing Platform and related activities in detail. Hydrogen Valley is a tool to push hydrogen technologies in decarbonizing our society, in particular for regions with a very concrete plan to decarbonize the areas and well-established solutions/plans. In addition, EU is supporting project development for less advanced regions, and for the rest of the regions, mostly in central-eastern Europe, is lately providing also technology learning and awareness. The Hydrogen Valley Platform contains now around 34 valleys from 19 countries. In the report released in June 2021 (which analyses these valleys), the Hydrogen Valleys’ key remaining barriers all over the world are funding gaps, ensuring technology readiness, and adequate legal and regulatory support. Under Mission Innovation 2.0, EU will continue to develop this concept and fund valleys, including collaborating with the other co-leads and extend the Platform, towards a goal of 100 valleys by 2030.

Jose Bermudez, Energy Technology Analyst, Hydrogen and Alternative Fuels, IEA, introduced IEA views on gaps in research and hydrogen technologies for commercialization from Global Hydrogen Review and Special Report on Clean Energy Innovation. Boosting innovation across the whole value chain is needed, but there is a significant imbalance with technologies; demand technologies are less developed. The imbalance can become a barrier to the adoption of low-carbon hydrogen. In the hydrogen-related Technology Readiness Level (TRL) map, some low-carbon hydrogen productions are close to commercialization today or commercial ready like Proton Exchange Membrane (PEM) or alkaline water electrolysis. Solid Oxide Electrolyzer Cell (SOEC) and Anion Exchange Membrane (AEM) will still require innovation in manufacturing capacity scale, lower electricity prices, to become competitive. Technologies for low-carbon hydrogen production from fossil fuels and CCUS (using high capture rates) are not commercially available yet. However, this seems not to be a technology issue but a lack of regulatory frameworks that force developers to go beyond partial capture (50-60%).
Innovation in end-use is critical since most demand technologies are under prototypes or demonstration. Only some technologies are pre-commercial, and most of them are, like in the case of light-duty vehicles or domestic heating, the applications in which we do not expect the creation of significant demands for hydrogen. Other direct electrification alternatives are more efficient, cost-competitive, and already available in the market. Large portions of total potential hydrogen will remain for technologies for the use of iron and steel, heavy transport, or fuel production. In the analysis of R&D budgets from governments, hydrogen accounts for 6% of all energy budgets around the year2000. Net Zero Emissions by 2050 roadmap estimates that 90 billions USD of public money need globally as quickly as possible to demonstrate several key energy technologies. Around half of those should be dedicated to hydrogen-related technologies. In the case of high-end technology, it is a matter of urgency. IEA estimated that avoided CO2 emissions will be 60 Gt CO2 in the net-zero scenario in 2050. Most emission reduction comes from critical technology still being developed or requirement commercialization, such as co-firing ammonium hydrogen in coal and natural gas power plants, producing chemicals from renewable hydrogen, hydrogen for heavy-duty vehicles and steelmaking, or the use of hydrogen and hydrogen-derived fuels in shipping and aviation.

Maria Holgado, Hydrogen Technology Collaboration Program (TCP) Technical Secretariat coordinator, introduced its activities. Hydrogen TCP was established in 1977 as an international research collaboration body on hydrogen, and currently counts with 33 members, including 24 countries. There are more than 40 tasks, and over 250 experts involved in the network. Recent active tasks were Task 37 'Hydrogen safety,' Task 38 'Power to X and hydrogen to X,' Task 39 'Hydrogen in Marine Applications,' Task 40 'Energy storage and conversion based on hydrogen,' and Task 41 'Data and Modeling.' 7 new Tasks are in definition, including underground hydrogen storage, renewable hydrogen production, offshore hydrogen value chains, hydrogen from nuclear energy, safety and regulations, codes, and standards (RCS) of large-scale applications, and hydrogen export value chains, hydrogen in the mining, mineral processing and resource sectors. Topics under discussion are sustainability, islands and isolated regions, hydrogen in emerging economies, hard to abate sectors such as industries, and heavy-duty transport. The TCP focuses on R&D needs and delivering publicly available results and findings. The Hydrogen TCP covers the whole hydrogen value chain in collaboration with other TCPs and can be the technical/operational branch to propose topics for other international initiatives.