What is Energy in the Age of Zero Emissions?

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2020 has been a turbulent year for society, for the economy and for energy. The spread of the Corona virus has dealt a serious blow to the world economy causing energy consumption to decline sharply with a direct hit to the oil and gas industry. The competing views between Saudi Arabia and Russia at the start of the year regarding the impact of COVID-19, caused sufficient turmoil in the crude oil market for prices to plunge further down in early spring. Since then, the corona pandemic continued its spread and countries have been struggling to find a way to economic recovery. The sudden appearance of this new uncertainty has had huge impacts on individual health and life anxiety which are more direct and tangible than the familiar public concerns over climate change.

In this paper, last year, I wrote that a major structural change in the energy system was emerging but I was not expecting the pandemic to further push the energy transformation. In Japan and Asia, it had been viewed until 2020 that the energy transformation was strongly influenced by Europe's commitments and by the financial community demonstrating an increased seriousness for decarbonization. Since the arrival of COVID-19, all this is happening with a sense of increasing swirling speed, as if caught in the rapids.

For example, Prime Minister Suga recently announced Japan's intent of aiming at net carbon neutrality, the Chinese President Xi made a declaration of decarbonization and the US President-Elect Joe Biden is perceived for the moment as an additional runner in the decarbonization race.

This is clearly the beginning of the era of zero emissions. **Is it possible to achieve zero emissions by 2050** with only renewable energy and nuclear power that can be considered as clean energy? At the IEEJ/APERC symposium 2020, we asked U.S. experts this simple question.

The Current Situation: The Corona Virus, and Energy-Environmental Policy

In 2020, the disaster caused by the corona virus introduced a sense of impasse in our economic and social life, and its impact on the economy spread beyond people's expectations. The intensity of its effects within the different forms of energy was divided.

In each country, lockdowns and bans on mobility were imposed to limit the damage caused by the pandemic. The economic and social impacts rapidly spread through the value chain from industries such as food and beverage, retail trade, as well as transport industries such as aviation and railways, to other industries such as manufacturing, agriculture and fisheries. Issues of employment and income rapidly developed. Regarding energy, as shown in Fig. 1, the largest negative impact hit oil because of banned or restricted transport. In addition to that, the impact of

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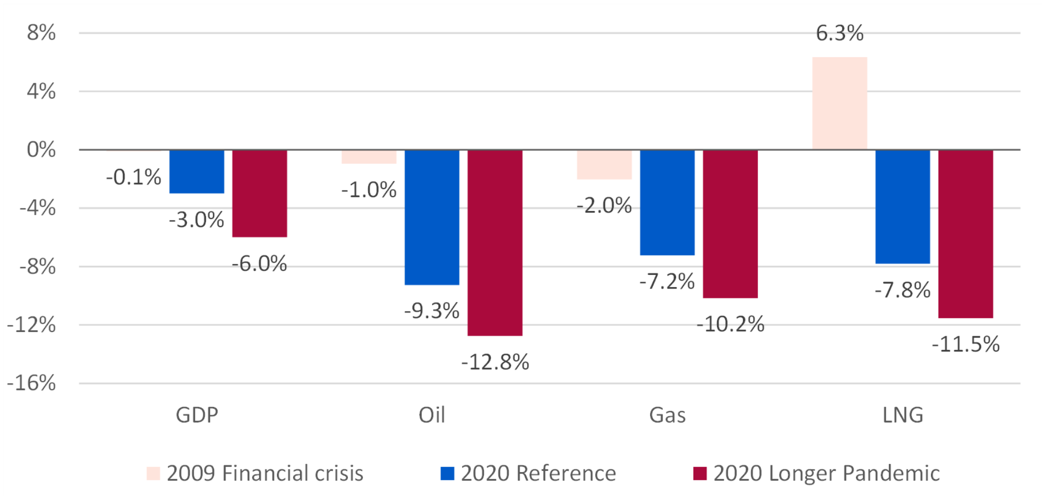
the economic slowdown negatively affected natural gas and LNG demand, resulting in a large market oversupply creating pressures for lower international energy prices.

Fig. 1 Global GDP and Energy Consumption y/y 2020



Source: S. Suehiro and K. Koyama, "A Study on the Impact of "City-wide Lockdown" on Global Energy Demand", and others

Policies in Europe that combined economic recovery stimulus with climate change countermeasures, such as green recovery in the EU and sustainable recovery suggested by the IEA, attracted lots of attention. Climate change countermeasures were quickly recognized as an essential part of the important agenda of combating the global economic slowdown. However, due to differences in energy supply and demand structures and industrial structures, the country's responses are not uniform.

As a result to the pandemic, CO_2 emissions are expected to decline significantly in 2020. The rate of decline is almost the same as the CO_2 reduction rate that would be required "every year" to achieve the two-degrees target by 2050, giving the impression that the possibility of achieving the target has increased. In reality, though, if you look at the power generation sector, many countries have fossil fuel facilities that would be considered extremely difficult to replace with renewable energy and nuclear power alone, while meeting the increasing demand for electricity in the future. Other rising issues include meeting thermal demand for industry, electrification of transportation fuels, and conversion to non-fossil fuels. In particular, the emerging economies in Asia, Africa, and Latin America, where economic growth and energy consumption are expected to increase in the future, would find it difficult to decarbonize without the full cooperation of the international community.

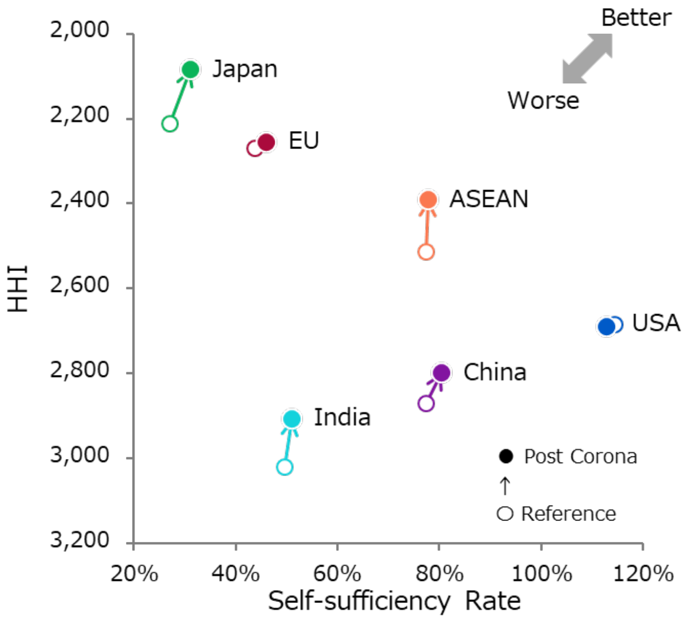
Against this backdrop, a series of decarbonization declarations took place around the world. The magnitude and sudden disappearance of energy demand caused by the pandemic may have induced such trend. The impact of lower demand hit hard the international energy companies and energy producers, which have also been under pressure from the financial community. Emphasis on ESG investments in recent years, and the deterioration of the investment environment caused by the Corona pandemic accelerated the movement or conversion from business models centered on fossil fuels towards decarbonization.

Challenges for Decarbonization in Asia

Last year's symposium took up the subject of energy transformation and pointed out the different sentiments between Europe, the United States, Asia, and other countries towards global warming countermeasures (especially decarbonization). Even with the Corona pandemic, the uncertainties and unpredictability associated with climate change remain high, and long-term investments still have difficulties in attracting funding. And yet, political declarations toward decarbonization continue amid prolonged economic losses and increasing uncertainties caused by the pandemic. This is due to the belief that climate change countermeasures can drastically contribute to the economic recovery, as symbolized by the green recovery in Europe.

In IEEJ Outlook 2021, we depict a scenario where structural changes in economic and social conditions, caused by the pandemic, are prolonged. In the scenario, through a scenario planning exercise, experts identified "emphasis on security" and "progress of digitization" as important elements that bring about structural changes resulting from the disaster. The emphasis on energy security will lead to diversification of energy sources in Asian countries and a shift toward indigenous resources (improving self-sufficiency rates). As shown in Fig. 2 and compared to the reference scenario, the self-sufficiency rate increases and the diversification of energy sources in each country progresses (moves towards the upper right corner). Advances in digitalization will encourage an increase in demand for electricity, therefore, securing clean power supplies will

Fig. 2 Changes in Self-Sufficiency Rate and Primary Energy Consumption Composition in Post-Corona World Transformation Scenario



Source: Institute of Energy Economics, Japan, IEEJ Outlook 2021, (October 2020) become an increasing challenge.

One of the major differences between European and Asian countries is that many Asian countries do not yet have electricity or gas connected by transmission lines or pipelines with surrounding countries. Each country will consequently introduce measures according to its energy supply and demand structure. A drive to use domestic energy sources has the potential to intensify not only the use of renewable energy but also the use of coal which is abundant. All means of decarbonization in Asia, including carbon capture, storage, use and sink, are essential.

In September 2020, the Chinese government declared decarbonization by "as early as 2060". China's economic recovery is ahead of other countries, but as the difficulties of transportation and trade increase, its function as the world's factory is shifting to Southeast Asia and India. It seems as if China had an intention to lead the global society while positioning climate change countermeasures as a trigger for future economic growth in China. Decarbonization, which is a challenge to be met by 2050, has become increasingly important also for an industrial policy of gaining supremacy through science and technology and industrial technology in each country.

Last October, Japan's Prime Minister Yoshihide Suga announced carbon neutrality by 2050. Carbon neutrality target is expected to strengthen Japan's industrial policies, including decarbonization and development of innovative technologies.

Weight of Technological Development

The key to achieve sustainable economic growth while addressing climate change towards 2050, or the end of this century, depends whether innovative technologies will be utilized in the future. As announced in January 2020, the Cabinet Office's "Environment Innovation Strategy" is a long-term growth strategy, which has been developed to be in compliance with the Paris Agreement. The Strategy advocates the development of innovative technologies to reduce greenhouse gas emissions not only in Japan but also around the world. Under 16 research themes, 39 technologies for decarbonization, including hydrogen and carbon recycling technologies, are considered in addition to clean energy, such as nuclear power and renewable energy or storage batteries.

Hydrogen has been of increasing interest in Europe and the United States for several years. A series of energy-related international conferences held in Japan in the fall of 2020 focused on technologies that will be fundamental to future energy use. Many ministers and CEOs,[1] demonstrated a high level of international interest in this field. In Europe, hydrogen could be produced from renewable energy while in Asia, hydrogen may be produced from a combination of fossil fuels and CCS.

Saudi Arabia, this year's G20 presidency, is advocating the concept of "carbon circular economy". By applying the principles of a circular economy to carbon, it is possible to focus on technologies and processes that utilize carbon dioxide removed during fossil fuels combustion (CCU) in manufacturing processes and others. It is an effort to define the principles of a circular

[1] ICEF, Hydrogen Ministerial Meeting, Carbon Circular Economy Council, etc.

economy as a comprehensive concept that would accelerate the technological development and social implementation internationally. The 4 main areas are presented in Table 1. A series of fossil fuel decarbonization technologies is important in Asia, where short-term energy transformation with only renewable and nuclear is difficult.

Table 1 Major "4R" Technologies in the Carbon Circular Economy

Reduce	Reuse	Recycle	Remove
Reducing the amount of carbon entering the system	Reusing carbon without chemical conversion	Recycling carbon with chemical conversion	Removing carbon from the system
• Energy and materials efficiency • Renewable energy, including hybrid use with fossil fuel • Nuclear energy, including hybrid use with fossil fuel • Advanced ultra-super-critical technologies for coal power plants • Hydrogen (blue/green) fuel cells for long-distance heavy-duty vehicles • Ammonia produced from zero-carbon hydrogen (blue/green) for power generation and ships • Direct reduction in steel making by using CO_2 free hydrogen (blue/green)	• Carbon capture and utilization (CCU) • Use CO_2 at carbon utilization facilities, such as at greenhouses for enhancing crops • Bio-jet fuels with reed beds • Algal synthesis	• CCU • Artificial photosynthesis • Bioenergy recycle in the pulp and paper industry • Bioenergy with carbon capture and storage • Carbamide (urea production using CO_2 as feedstock) • Coal ash concrete curing with absorbing CO_2 • Electrochemical reduction of CO_2 • Fine chemicals with innovative manufacturing processes and carbon recycling • Fischer-Tropsch exothermic of carbon dioxide with hydrogen syngas • Hydrogenation to formic acid • Oil sludge pyrolysis • Sabatier synthesis (CO_2 methanation: exothermic of carbon dioxide with blue/green hydrogen) • Thermal pyrolysis	• CCS • Direct air capture (DAC) • Carbon dioxide removal • Fossil fuels-based blue hydrogen

Source : Mansouri, N. Y. *et al.*(2020) "A Carbon Management System of Innovation: Towards a Circular Carbon Economy"

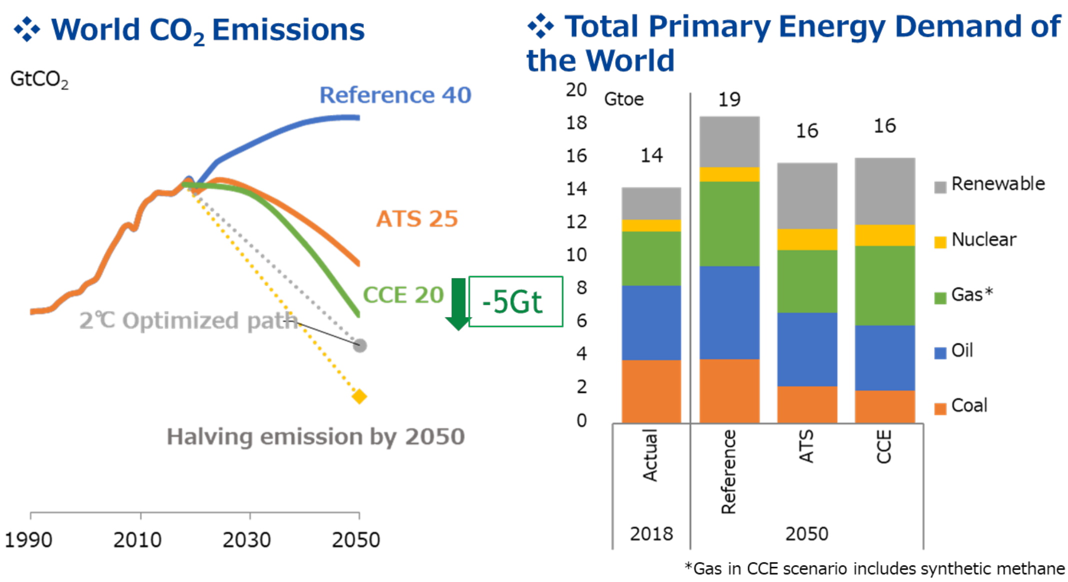
IEEJ Outlook 2021 compares the CO_2 emissions and primary energy demand results of various scenarios (Fig. 3). In the Carbon Circular Economy (CCE) scenario, carbon recycling technologies are significantly introduced in addition to those already assumed in the Advanced Technology Scenario. The CCE scenario will reduce CO_2 emissions by an additional 5 Gt when compared to the Advanced Technology Scenario, in which maximum technological innovation and environmental measures are taken. However, the total amount of primary energy demand will not change significantly.[2] The introduction of decarbonization technologies could significantly reduce CO_2 emissions without drastically changing fossil fuel consumption. Looking at the breakdown within the fossil fuels, increase in the blue hydrogen (hydrogen with CCS) produced from natural gas induced a shift from coal and oil to natural gas. CO_2 emissions will not halve by 2050, therefore, achieving carbon neutrality will require further reductions in technology costs, energy savings, and early additional reductions through the introduction and adoption of innovative technologies.

Our estimates show that hydrogen offers large potential for decarbonization. It is because carbon-free hydrogen, which is under the "Remove" category, has already reached the stage of demonstration and assumed to be promoted ahead of the other 3Rs. However, carbon-free hydrogen and/or ammonia remain imported energy for the Asian energy-consuming countries, including

[2] In fact, the additional conversion demand by 4R technology is expected to increase primary demand a little from the Advanced Technology Scenario and such additional demand could be bigger than this estimate.

Japan. Further developments of technologies under the “Reuse” and “Recycle” categories which are technologies to reduce CO_2 emissions, by utilizing CO_2, domestically, is awaited.

Fig. 3 CO_2 Emissions and Primary Energy Demand in Three Scenarios



Source: Institute of Energy Economics, Japan, IEEJ Outlook 2021 (October 2020)

Summary

Is it possible to achieve zero emissions by 2050 with only clean energies, such as renewable energy and nuclear power? All speakers at the Symposium remarked that it would be difficult because we must not forget the challenge of how to supply available energy economically and cleanly to the additional population of 2 billion people expected by 2050 and the one billion currently in developing and emerging countries that does not yet have energy access. In the development of decarbonization technology, it is important for various countries and companies to cooperate and compete. It is also important to secure a diverse supply of clean energy while lowering costs.

Writer’s Profile

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Ms. Yamashita is responsible for quantitative and qualitative analyses on energy policy issues. In the aftermath of the tsunami and nuclear incident, her team’s analyses and recommendations contributed greatly to the electricity saving campaign and continue to this day to contribute to the debate regarding a national energy mix for Japan. She has been serving as a member of various government councils and committees in the fields of energy and science & technologies. She has been leading miscellaneous international and regional programs in the area of energy cooperation through IEA, APEC, ERIA and IPEEC. She served as a President of the International Association for Energy Economics in 2020 and serves as an Executive Vice President for 2021.

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