Scenarios for Realizing Carbon Neutrality

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Global warming is a global issue that should be tackled by the entire human race over the long term. Rather than simply addressing the global warming issue, it is necessary to achieve a balance between the 17 goals of the SDGs (United Nations Goals for Sustainable Development) and the 3Es (energy security, economic efficiency, and environmental compatibility), which are the basic goals of Japan's energy policy. If we lower the baseline of CO_2 emissions through social innovations to achieve the SDGs, and then build a system to produce and efficiently use clean secondary energy such as electricity and hydrogen without CO_2 emissions through technological innovations, we can create a scenario for the realization of carbon neutrality, which will solve the global warming problem.

Introduction

The Russian invasion of Ukraine, which began in February 2022, is causing a serious energy crisis. The major difference from the two oil crises of the 1970s being that this crisis occurred as the world as a whole was making a major move toward achieving carbon neutrality (decarbonization) as a measure against global warming. Of course, there are many other differences from those days. The prices of not only oil but also natural gas and coal are increasing rapidly, and the energy demand of developing countries is larger than that of developed countries.

Even before the invasion, energy prices were on the rise as fossil resource development was curbed by the trend toward decarbonization and reduced demand due to the spread of the new coronavirus infection. Then came the invasion. Russia is the world's largest exporter of natural gas and one of the top three exporters of oil and coal. The sanctions against Russia have led to a sharp decline in Russian energy exports to Europe and other countries, but imports by China, India, and other emerging economies have complicated the situation. Particularly serious is the price of natural gas in Europe, where the spot price in 2022 is 10 times higher than it was two years ago. Europe is expected to increase its imports of liquefied natural gas (LNG) in the future, and competition for LNG has begun, with LNG prices skyrocketing. This will hinder developing countries from switching from coal to natural gas and will be an obstacle to global warming countermeasures. Despite the energy crisis, global warming countermeasures cannot be halted.

In order to solve the global warming problem, it is ultimately necessary to achieve net zero greenhouse gas emissions (carbon neutrality). The long-term goal of the Paris Agreement is to "keep the global average temperature increase below 2°C above pre-industrial levels and pursue efforts to limit it to 1.5°C." To achieve this goal, the goal was to achieve a decarbonized society, in other words, carbon neutrality, in which global greenhouse gas emissions are reduced to virtually (net) zero by the second half of this century. However, the IPCC Special Report on the 1.5°C target (2018) stated that carbon neutrality must be achieved by 2050 in order to reach the 1.5°C target, and this triggered a movement to raise the long-term target to carbon neutrality by 2050, with Europe taking the lead. The increased ambition to achieve carbon neutrality by 2050 quickly spread around the world, including the U.S. under the Biden administration. The Paris Agreement's effort target is now becoming the main goal. More than 80% of Japan's greenhouse gas emissions are energy-derived CO_2. This paper will consider how to achieve carbon neutrality in the midst of the energy crisis.

Carbon Neutrality Achieved through Innovation

Energy systems that optimally realize carbon neutrality will require the mobilization of various innovations in both technology and society. The central focus is on secondary energy media that can be used cleanly and efficiently, with electricity being used at present, and hydrogen being used as a fuel and heat source in the future. Figure 1 shows the composition of the realization of carbon neutrality by placing electricity and hydrogen at the center and arranging various innovations.

Since electricity and hydrogen can be produced from a variety of resources, technological innovation can lead to low-carbon and decarbonization. Assuming CCUS (CO_2 Capture, Utilization, and Storage) technology, the use of fossil resources as well as nuclear power and renewable energy is not excluded. However, since power sources with naturally fluctuating output, such as photovoltaic and wind power, are expected to be introduced on a large scale in the future, the role of energy storage technologies, including electrolytic hydrogen storage (PtG), will become important. In addition, flexibility and robustness will be required for power networks that interconnect naturally fluctuating power sources.

The use of electricity will continue to increase with the development of the digital society, the electrification of the transportation sector, and the increase in heat supply by heat pumps. Distributed power sources such as photovoltaic power generation and cogeneration, storage batteries for electric vehicles, and hot water storage tanks for heat pump water heaters will also be increasingly utilized.

The system of electric power transmission and distribution is undergoing major changes as a result of the power system reform, and it is expected to shift from the traditional form of supplying electricity in response to demand to network formation and operation that integrates supply and demand. The use of digital technology will support such network innovation.

The industrial sector is expected to utilize hydrogen as well as promote further electrification. The theme of 2022 Masao Horiba Awards was also on analysis and measurement technologies that contribute to the utilization of hydrogen. In addition to the use of hydrogen in fuel cells, demand for hydrogen is expected to increase for combustion power generation and heat utilization, including use as fuel ammonia, and as a raw material for various synthetic fuels and chemical substance synthesis with the progress of carbon recycling. Of course, the hydrogen used in this process must be produced in a CO_2-free manner.

If the super-smart society (Society 5.0) realizes a sharing circular economy, not only will energy demand be greatly reduced through the substitution of energy and materials by information, but the system integration of energy and information will be further advanced, and distributed resources such as facilities located on the demand side will

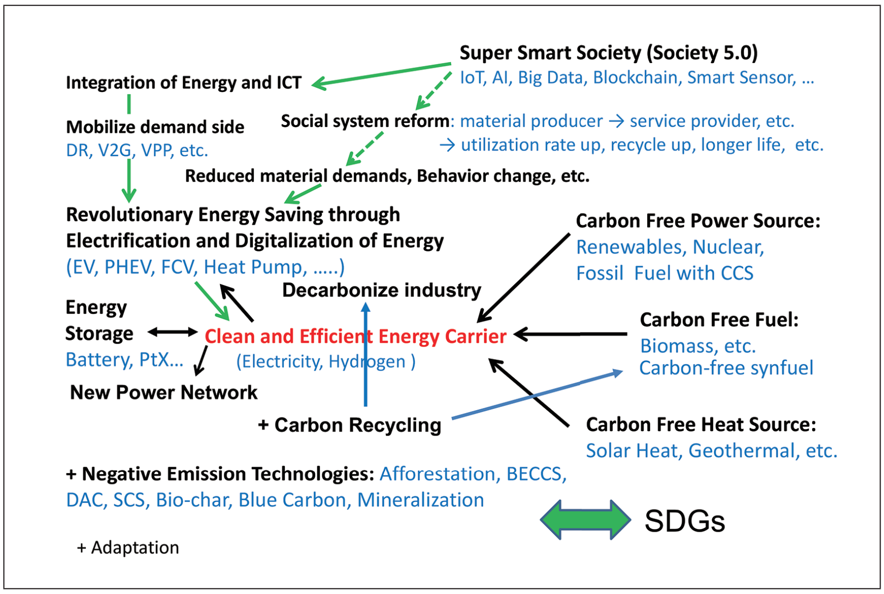

Figure 1 Composition of carbon neutral realization.

be utilized more efficiently. The number of information devices such as smart phones that realize various functions through application software will continue to increase, and the substitution of energy and materials by information is expected to advance at the device level as well. As a result, we can envision the possibility of revolutionary energy savings through electrification and digitalization. However, it will be necessary to cope with the increased demand for electricity associated with information processing, such as blockchain, and it will be necessary to coordinate with innovations in the information field, such as quantum computers.

Composition of Carbon Neutral Realization

If we look at human economic activities as a whole, such as steelmaking, cement production, chemical industry, and agriculture, it will be difficult to achieve zero emissions of greenhouse gases even if all the above measures are implemented. Therefore, it is necessary to prepare technologies to capture CO_2 from the atmosphere, such as afforestation, DAC (CO_2 capture from the atmosphere), BECCS (biomass energy use with CCS (CO_2 capture and storage)), and mineral fixation of CO_2 using waste concrete.

Then, it is necessary to strike a balance between adaptation to possible global warming and realization of goals other than global warming in the SDGs (United Nations Goals for Sustainable Development). From a broader perspective, if the baseline of CO_2 emissions can be lowered through social innovations aimed at achieving the SDGs, and if clean secondary energy such as electricity and hydrogen can be produced and used efficiently without CO_2 emissions through technological innovations, a solution to the global warming problem can be found. emission-free production and efficient use of clean secondary energy such as electricity and hydrogen through technological innovation.

Rebuilding the 3 E's with Nuclear Energy

There are various opinions about nuclear power, but it is certainly an effective technology for combating global warming as an energy source that does not emit CO_2. At the GX (Green Transformation) Implementation Conference in August 2022, Japan made clear its stance on replacing and building new nuclear power plants to make full use of nuclear energy. The government has announced that it will move forward with the restart of existing nuclear power plants, and has begun to take concrete steps to extend operation periods and develop next-generation reactors. In February 2023, the Japanese government adopted a cabinet decision on a basic policy toward the realization of GX and drafted a law on the promotion of a smooth transition to a decarbonized growth-oriented economic structure.

In the wake of the Russian military invasion of Ukraine, the importance of energy security and economic efficiency has been reaffirmed in energy policy, which had been biased toward global warming countermeasures, and the basic policy of simultaneously achieving the 3 E's of energy security, economic efficiency, and environmental measures is being reaffirmed. In this context, it is noteworthy that the government has begun to actively address nuclear energy policy, which it had avoided for political reasons.

However, the harsh reality surrounding nuclear power will not change. We cannot expect a revival of nuclear power unless we focus on priority policies with realism. In this regard, I believe that restarting nuclear power plants and extending their operation periods should be carried out as a matter of course, but I feel that the development of next-generation reactors is in jeopardy. It is true that new and additional facilities are needed to develop human resources, but this can be handled with innovative light water reactors with enhanced safety. What is questionable in the discussion of next-generation reactors is that fast reactors and nuclear fusion are still being discussed. These have been promoted through national projects and international joint development, but even after more than 50 years of development, they have not reached the goal of commercialization.

Since the late 1950s, various types of reactors have been developed, including fast breeder reactors, high-temperature gas reactors, and molten salt reactors, but in the 1960s, light water reactors were eventually commercialized and introduced worldwide. The United Kingdom, which developed and commercialized the gas reactor, has also chosen the LWR as its future reactor of choice for new construction.

Among the next-generation reactors, I am focusing on the small modular reactor (SMR), which is expected to improve safety and economics through mass production of small reactors. The smaller the reactor, the larger its surface area relative to its volume, and the easier it is to cool than larger reactors. This is called inherent safety improvement. On the other hand, a module is a production system in which a set of components with uniform standards is manufactured in a factory and assembled as a unit, and the unit is further assembled and constructed on site. This can be likened to a prefabricated house. Conventional nuclear power plants are one-of-a-kind, with construction taking place on site, even for the same design type, while SMRs are expected to have high quality control and shortened construction periods because most of the parts will be manufactured in a factory.

The SMR concept has actually been around for a long time. None of them were realized, but as I recall, GE was developing a sodium-cooled fast reactor named PRISM in the 1980s. There was also a plan to build a high-temperature gas-cooled reactor developed by Germany as a modular reactor in South Africa. However, it could not compete with the light water reactors in practical use.

Among the SMRs that are once again in the spotlight, we believe that the concept of using small light water reactors is promising. This is because small LWRs are already in practical use to power submarines, aircraft carriers, and icebreakers. Japan has a long history of developing LWRs, including the "Mutsu". The reason why small-sized LWRs have not been commercialized except for military use and icebreakers is largely due to the social reason that the market could not be developed due to concerns about nuclear power. However, small power reactors can be used in remote areas and as mobile power generating vessels. We have high expectations for the development of SMRs for light water reactors.

Importance of Expanding the Field of View

Mobilization of various technological and social innovations to achieve carbon neutrality requires an expansion of horizons. In terms of spatial expansion, various efforts will be required, ranging from local community initiatives to international collaboration and sectoral coupling to link industries and demand categories. On the time axis, efforts during the transition period leading to the realization of carbon neutrality will also be important. The realization of carbon neutrality requires efforts from a wide range of perspectives, including technology, society, local economies, and international politics.

The reality, however, is harsh. COP26 in November 2021 was repeatedly reported that Japan won the Fossil Prize, but the reason for the award was Prime Minister Fumio Kishida's announcement of "zero-emission thermal power generation" using hydrogen and ammonia. In addition, Norway received the Fossil Prize for its promotion of CCS (CO_2 Capture and Storage), and France received the Fossil Prize for its announcement to build new nuclear power plants. Zero emissions from thermal power, CCS, and nuclear power are all important measures to combat global warming. To realize the lofty goal of carbon neutrality, narrowing the options by excluding specific technologies in this way is a major obstacle.

The global warming problem has a structure in which the burden of countermeasures is borne by each region, but the benefits of the countermeasures benefit the entire world. In order to deal with the problem of such structure, it is extremely important to maintain coordinated actions throughout the world. Creating a situation where major countries leave or excluding specific technologies will destroy the coordination and lead to the self-destruction of global warming countermeasures. Realizing a tough goal such as global decarbonization requires acknowledging the diversity of technologies and cultures and mobilizing all measures.

In addition to individual innovative technologies that directly contribute to CO_2 reduction, such as hydrogen utilization and CCUS, the realization of carbon neutrality also requires the use of versatile common infrastructure technologies such as digital technology, power electronics, analysis and measurement technology, biotechnology, and urban management technology, which at first glance may seem unrelated to CO_2 reduction.

GX (Green Transformation) Policy Development

In the past few years, policies with various nicknames, such as the Green Growth Strategy and the Clean Energy Strategy, have been proposed, but these trends are now being bundled together in the GX (Green Transformation) Council. The comprehensive approach that energy and environmental policies should have, such as decarbonization to be achieved together with stable energy supply and maximum utilization of nuclear power as well as renewable energy, is beginning to appear with concrete policies. The government is preparing a 20 trillion yen GX Transitional Bond to induce 150 trillion yen in private investment toward carbon neutrality.

While it is politically easy to advocate the adoption of renewable energy as a main source of power and carbon neutrality, both of which are highly supported by the public, it was politically difficult to mention the realization of a stable energy supply and the utilization of nuclear power. The soaring fuel prices and growing concerns about supply instability triggered by the Russian military invasion of Ukraine certainly helped, but another important factor was the foreseeable stability of the government, as no national elections were scheduled in the near future. In this respect, the GX Executive Council's decision was the fruit of a political decision.

However, the draft of the GX Executive Conference is expected to be difficult to materialize because of its diverse content. For example, the introduction of growth-oriented carbon pricing, specifically the introduction of emissions trading (GX-ETS) and a carbon levy, has been proposed, but the details of the system such as the timing of the introduction and the establishment of rules for paid auctions, have only been outlined in broad strokes. It also states that the revenues from carbon pricing will be used to finance the redemption of GX Economic Transition Bonds, but does not indicate the scale of the specific mechanism or the timing of its introduction.

In general, policy measures can be divided into two categories: "carrot" and "stick". In this case, carbon pricing is the stick and the GX Economic Transition Bonds is the carrot. It could be said that the GX Transitional Bonds are a good combination of both, but the specifics of the policy have not yet been finalized, so it is difficult to praise them without giving them credit. I have been involved in renewable energy policies, including the design of the Renewable Portfolio Standard (RPS), which mandates the introduction ratio of renewable energy sources, and the Feed-in-Tariff (FIT) system for renewable electricity, and I am keenly aware of the importance of the details of the system. As the saying goes, "God is in the details," and it is important to point out that specific policy details are crucial in dealing with issues that involve many stakeholders in complex ways.

Conclusion

Global warming is a global issue that should be tackled by the entire human race over the long term, on the order of 100 years. In order to create a sustainable future, we must not only address the global warming issue, but also balance the 17 goals of the UN SDGs and the 3Es (energy security, economic efficiency, and environmental compatibility), which are the basic goals of Japan's energy policy.

As outlined in this paper, a scenario for solving the global warming problem can be envisioned if the baseline of CO_2 emissions is lowered through social innovation toward the achievement of the SDGs, and a system for producing and efficiently using clean secondary energy such as electricity and hydrogen without CO_2 emissions is built through technological innovation.

* This article has been translated by Readout Editorial Office.