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Energy, Environment and Economy

Challenges for achieving both energy security and carbon neutrality

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Executive summary

Global energy supply and demand outlook (Reference Scenario)

Energy consumption will continue to increase despite energy efficiency that will improve to address climate change and energy security

- Under the Reference Scenario, and from the perspective of climate change and energy security, the rate at which the world's energy intensity per unit of gross domestic product (GDP) will decline is faster than in the past. However, as the macroeconomy expands beyond the rate of decline, global energy consumption in 2050 will increase by 1.3 times from 2020 to 17 649 million tonnes of oil equivalent (Mtoe). The Reference Scenario incorporates past trends and the expected effects of the extension of energy and environmental policies and technologies to date.
- The lack of upstream investment and the Russian invasion of Ukraine have raised concerns about a stable and sufficient supply of fossil fuels to meet the overall consumption which will continue to increase at an annual rate of 0.8%. The use of natural gas will grow at an annual rate of 1.3%, mainly to supply the power generation sector and will approach oil which is the largest energy source. Oil will expand at an annual rate of 0.7%, increasing mainly in the aviation, shipping, and petrochemical feedstocks sectors. Against the backdrop of air pollution and climate change, coal will peak around 2030 and begin to decline, falling below 2020 levels in 2050.
- Expectations for more non-fossil energy are growing as many countries aim to become carbon neutral. Solar photovoltaics, wind, and others will see the largest growth, increasing 3.9 times in 2050 compared to 2020. However, the share of non-fossil energy in total primary energy consumption will increase only slightly, from 20% in 2020 to 23% in 2050.
- Consumption in China, which had until recently driven the global demand growth, will peak around 2030 before turning downward while demand in India, the Middle East and North Africa, and the Association of Southeast Asian Nations (ASEAN) will continue to increase. India's consumption will surpass that of the United States and ASEAN's will surpass that of the European Union in the 2040s, making Emerging Market and Developing Economies in the energy and environmental fields all the more important.

Middle Eastern oil producers take advantage of their low production costs to lead crude oil supply. Russia is suffering from a severe shortage of upstream investment due to embargoes and sanctions, and its rate of decline is accelerating.

- In the medium-term, until 2030, the Organization of the Petroleum Exporting Countries (OPEC) and non-OPEC will both increase crude oil production. However, in Europe and Eurasia, where oil production was expected to decline over the medium to long term even

before the Ukrainian war, the impact of Western countries' embargoes and sanctions will deepen Russia's lack of upstream investment and accelerate the pace of decline. Production in North America, led by the United States which increased output dramatically in the 2010s, will peak around 2030.

- From 2030, OPEC, especially the Middle East OPEC members with their abundant oil reserves and cheap production costs, will become increasingly prominent despite increases in production from Latin America. The share of OPEC crude oil in the global oil supply will rise from 34% in 2020 to 44% in 2050.
- Total world crude oil trade will increase as a result of rising oil demand. Imports will fall in Organisation for Economic Co-operation and Development (OECD) countries, where demand will decline, but imports from non-OECD countries will increase at a faster pace. Asia's dependence on imports will continue to rise, and while inflows from the Americas will increase, the Middle East will remain the largest supplier. Non-OECD Europe/Central Asia, especially Russia, will see an accelerated decline in exports to Europe and become more dependent on the Chinese market.

The LNG market is expanding due to abundant supply potential, but the outlook is uncertain

- The United States, the world's largest producer and consumer of natural gas, will continue to increase its production of natural gas, especially shale gas. Until about 2030, production will increase at an annual rate of about 1% and then stabilise.
- Australia, which slightly surpassed Qatar as the world's largest exporter of liquefied natural gas (LNG) in 2020, will experience steady growth in production. The increase is in part due to projects centring on the provision of complementary gas to existing LNG production facilities. The increase will moderate after 2030.
- In the Russian Arctic, construction is progressing for a second major LNG export project which had reached the investment decisions. However, the future of this project is uncertain due to the Russian invasion of Ukraine in February 2022.

Achieving decarbonisation is, realistically, a long-term commitment

- Decarbonisation has accelerated faster in Advanced Economies such as the United States and Europe. Emerging Market and Developing Economies have announced their intention to become carbon neutral, despite a long run coal demand that will expand in Asia, including India and ASEAN excluding China, and Africa. Global coal production will increase until the early 2030s in response to demand but after that, it will start to decline; the downward trend will intensify in the 2040s.
- Steam coal production will increase from 5 950 Mt in 2020 to 6 537 Mt in 2040 mainly due to increased demand for power generation. It then begins to slowly decline, reaching 6 311 Mt in 2050. Production of coking coal, used mainly as a raw material for steel production, will gradually decline from 1 014 Mt in 2020 to 824 Mt in 2050.

Electricity generation is expanding rapidly in Asia. Natural gas-fired power generation is the biggest source of electricity

- Global electricity generation will grow at an annual rate of 1.8%, rising to 45 777 TWh in 2050, 1.7 times higher than in 2020. 95% of that increase comes from Emerging Market and Developing Economies. Continuing its rapid economic growth, electricity generation in Asia will increase at an annual rate of 2.1% to reach 23 313 TWh in 2050, roughly half of the world's requirements.
- Although coal has the largest current share of the global power generation mix, natural gas will be the largest source of electricity in 2050. With a continuing upward trend in electricity demand in both Advanced Economies and Emerging Market and Developing Economies, ensuring a stable supply of natural gas remains an urgent and a long-term issue.
- In Advanced Economies, renewable energy will overtake natural gas as the largest source of electricity in the first half of the 2020s due to its rapid adoption. Of these, solar photovoltaic and wind, which have output variability, will account for 25% of the electricity generated in 2050. Measures to deal with these output fluctuations and the expansion of the network connecting the sites suitable for power generation and the location of demand will be issues.
- In Emerging Market and Developing Economies, renewable energy, especially wind, will continue to increase and replace coal as the largest power source in 2050. However, the role of coal-fired power generation in supporting the robust demand for electricity is no small matter, and it is necessary to develop a highly predictable investment environment and address environmental issues, such as air pollution.
- The role of nuclear is being recognised anew in Japan, Europe, and other countries from the perspectives of climate change countermeasures and ensuring energy security, especially after Russia invaded Ukraine. However, although new construction starts are underway, mainly in Asia, nuclear will not grow faster than the rate of increase in electricity demand through 2050, reducing its share of the power generation mix to 7%.

Advanced Technologies Scenario

Even under the Advanced Technologies Scenario, reaching global carbon neutrality by 2050 is far from being achieved. Further promotion of energy efficiency and climate change measures will require the full mobilisation of all means possible.

- The "Advanced Technologies Scenario" anticipates maximum carbon dioxide (CO_2) emission reduction measures based on the application opportunities and acceptability in society, including the full-scale introduction of newly factored hydrogen, and enhanced energy security measures. It should be noted that this outlook is a forecast-type of exercise that projects in the future based on the premise of the introduction of technology, etc. It contrasts with a backcast-type analysis that defines a future "landing point" and charts a possible path to reach it. Global final energy consumption under the Advanced

Technologies Scenario will be reduced by 5.2% in 2030 and 23.5% in 2050 compared to the Reference Scenario.

- Primary energy consumption will decline by 4.4% relative to the Reference Scenario in 2030 but will increase relative to 2020. After 2030, the reduction will accelerate as energy efficiency continues to improve. The reduction from the Reference Scenario in 2050 will only reach 18.5%, which is less than that of final energy consumption of 23.5%. This is due to the increased use of electricity and hydrogen, which have energy transformation losses.
- Fuel switching will also advance, reducing fossil fuel primary energy consumption by 1.1 Gtoe relative to the Reference Scenario in 2030 and 5.1 Gtoe in 2050. Despite a substantial growth in non-fossil energy of 0.4 Gtoe in 2030 and 1.8 Gtoe in 2050, the world cannot continue to maintain and improve its economy, society, and livelihoods without fossil fuels, even in the Advanced Technologies Scenario.
- Energy-related CO_2 emissions will be 31.2 Gt in 2030 (down 1.4% from 2020) and 16.9 Gt in 2050 (down 46.5%). In this scenario, CO_2 emissions would significantly reduce to levels equivalent to the *Announced Pledges Scenario* of the International Energy Agency (IEA) released in its "World Energy Outlook 2021". Consequently, such scenario is still far from a worldwide "Net Zero" emissions. The reduction from the Reference Scenario will amount to 20.1 Gt in 2050, of which China and India accounted for 38.1%.
- One of China's 2030 targets for Nationally Determined Contribution is to reduce CO_2 emissions intensity per GDP by more than 65% from 2005 levels, which is roughly equivalent to the Reference Scenario results. India's target of a 45% reduction in intensity, in its 2022 update, is roughly equivalent to results in the Advanced Technologies Scenario. On the other hand, the set targets to reduce emissions by the United States (50% to 52% reduction from 2005 levels), the European Union (55% reduction from 1990 levels), and Japan (45% reduction from 2013 levels), will fall short of the Advanced Technologies Scenario results.
- As expected, the Advanced Technologies Scenario requires less investment in fossil fuels than in the Reference Scenario, but further low-carbon investment in renewable energy and energy efficient equipment is required. The investment required in the 2040s, under the Advanced Technologies Scenario, is $35 trillion (at 2015 prices), $20 trillion more than in the 2010s, or an increase of $6 trillion from the Reference Scenario in the 2040s. The cumulative global energy investment requirement by 2050 will reach $88 trillion, or an average of $2.9 trillion per year.

Energy security strategy to address the Ukraine crisis and the energy transition

- A growing number of Asian countries are declaring themselves as also aiming at carbon neutrality. In addition to building a new energy infrastructure, free of carbon emissions, the world must focus on big problems that cannot be solved easily in the limited time we have (between 30 and 40 years). The problems include the mass disposal of existing

equipment and job displacement, due to reworking the energy system. There is also a great deal of uncertainty surrounding the specific means of realisation.

- Asia faces a variety of challenges stemming from energy security. In emerging and developing Asia, where high economic growth is expected, it is essential to provide stably and inexpensively a large amount of energy. Considering the current trend toward a return to coal due to soaring energy prices, the amount of renewable energy available and their integrating costs, the transition from coal to natural gas is the realistic path forward. In doing so, the first phase of switching from coal to natural gas will involve increasing supply investments outside Russia while presenting a practical solution to the supply and cost problem. In the second phase, decarbonisation will be achieved by adding various measures, including the use of renewable energy and decarbonised natural gas.

- The so-called "4R technologies" is a tool to realise the decarbonisation of fossil fuels. Among them are the use of blue hydrogen produced by capturing CO_2 generated during manufacturing, the introduction of carbon capture and storage (CCS) technology in manufacturing plants and power plants, and carbon recycling technology that uses the captured CO_2 for other purposes.

Response to strengthening stable power supply and importance of nuclear power generation

- Under electricity deregulation, power generation facilities that are used infrequently in the market – with fewer generating opportunities – will be suspended and decommissioned. The introduction of renewables power generation has been expanded based on government support measures and in part caused the suspension and abolition of thermal power generation in many developed countries due to the decline in operating rates and the deterioration of profitability. As a result, the remaining power supply capacity of the entire electricity system declined. With a sudden surge in demand for electricity triggered by extreme heat or severe winter, combined with output declines and outages of power generation facilities (also caused by heat and cold waves), there are situations in which the balance between supply and demand becomes tight.

- Until now, the assessment of a stable supply of electricity has been to evaluate the possibility of a shortage of generating capacity (kW shortage) in response to increased demand. As decarbonisation policies proceed in the future, it is expected that dependence on a small number of power sources will increase. Another major issue is how to assess the risk of a shortfall in the amount of electricity generated (kWh shortage) when facing unforeseen events in a power source that the system heavily depends on.

- In a climate dominated by low-carbon arguments, the sharp rise in global fossil fuel prices since around 2021 and the Russian invasion of Ukraine in February 2022 put greater emphasis on securing a stable supply of energy. The role of nuclear in energy security is once more being recognised in Japan, Europe and elsewhere. The importance of its utilisation as a stable large-scale baseload power source under fossil fuel-fired power generation constraints has been highlighted anew.

- France and other countries announced ambitious nuclear targets while analysing the best mix with renewables. Plans to build new nuclear power plants are also underway in the United Kingdom and Eastern European countries. Expanding the operation of existing nuclear power plants and restarting them in Japan attract global interest. Attention is being paid to initiatives such as the introduction of a Regulated Asset Base (RAB) model, which is under consideration in the United Kingdom and can be considered as providing regulated returns to secure new investment in nuclear that will simultaneously achieve decarbonisation and stable supply.
- Nuclear is considered important from the standpoint of energy security, but it is also important for companies and countries in which nuclear is developed. A series of new projects by Western companies have faced delays in construction times and higher costs that far exceeded their original estimates. In one instance, it was pointed out that the company lost its construction know-how and was forced to change its design after construction began, due to regulatory requirements.

Critical mineral issues and energy, and economic security

- To achieve carbon neutrality, a massive adoption of renewable energy, electric vehicles, hydrogen and other low-carbon technologies is necessary. A new energy security challenge is emerging, caused by tight supply and demand for rare minerals (critical minerals), which are considered essential for these technologies. Like for fossil fuels, these resources are unevenly distributed around the globe.
- In the Advanced Technologies Scenario, the supply and demand for lithium, cobalt, neodymium, and dysprosium will be tight by the mid-2030s, mainly due to the increased penetration of electric vehicles. For nickel and cobalt, there are concerns that the cumulative demand by 2050 will exceed the sum of the total recycled supply and the resource reserves to cover long-term demand.
- Resources are concentrated in Chile, Argentina, Australia, and China for lithium, Indonesia and the Philippines for nickel, the Democratic Republic of Congo for cobalt, and China for the rare earth's neodymium and dysprosium.
- There are short-term and long-term perspectives on energy security. Unlike "flow-type" commodities such as oil and natural gas, which can face a significant impact in the event of a sudden supply disruption caused by some disturbance, "stock-type" materials are more resistant to short-term risks because even if a supply disruption occurs, the portion already imported can be incorporated into renewable energy facilities to provide energy. On the other hand, from a long-term perspective, it will be difficult to achieve carbon neutrality based on renewable energy, electric vehicles, hydrogen, etc., unless measures are prepared in advance to address the tightening of global supply and demand and uneven distribution of resources for critical minerals. While it will be essential to increase production at existing mines and promote the development of new mines for those types of ore that are feared to be in short supply, there are concerns that resource development

and export controls will be tightened in supplier countries in the future. Therefore, it goes without saying that demand countries are required to not only strengthen resource diplomacy aimed at securing interests, but they are also required to reduce import dependency and increase recycling rates to diversify sources of procurement, and to promote the development of technologies for non-use and reduced usage, as well as alternative technologies.

- On the other hand, supplier policies and the prospects for developing recycling, shifting and alternative technologies all involve uncertainty. Therefore, from the perspective of energy and economic security, consideration should also be given to balanced technology choices aimed at avoiding excessive reliance on specific carbon-neutral technologies[1].

Economic impact of green investment

- When investments in climate change measures create a virtuous cycle of emissions reductions and economic growth, it is called "Green growth". The results, however, may not be realised or they may appear differently in different economies and entities. It could create new disparities – (1) among developed economies and emerging/developing economies, (2) between developed and emerging/developing economies, (3) between economies that rely on fossil fuel exports and those that do not, and (4) within the population and citizens of the same economies.
- The cumulative additional green investment and consumption to realise the Advanced Technologies Scenario amounts to $14 trillion (at 2015 prices). If this green investment and consumption were carried out in a "No Financial Constrained" situation where the total amount of funds available could be increased at will, the GDP in 2050 would increase by $20 trillion (11.2%, an annual average of 0.4%). On the other hand, under a "Financial Constrained" situation in which the total amount of funds cannot be changed due to limited economic and financing capacity, GDP would be reduced by $6.2 trillion (3.5%, an annual average of 0.1%). "Financial constrained" means that incremental green investments will be offset by declines in investment and consumption in other areas.
- Under the No Financial Constrained Case, GDP and output would increase in many economies, but would decrease in economies such as those in the Middle East and the former Soviet Union that are highly dependent on mining (fossil fuels). In the Financial Constrained Case, GDP and output will decrease in many economies. However, in some developed countries and China, the decrease in the value of energy imports due to green investment and consumption is significant and GDP and output will increase, outweighing the decrease in investment in other sectors due to financial constraints.
- Investment is a new demand and a source of growth. However, if other investments are reduced in proportion to new investments in a situation of financial constraints and

[1] With the permission of the Japan Oil, Gas and Metals National Corporation (JOGMEC), this article presents a part of the results of its commissioned study, "Survey of Mineral Resource Supply and Demand to Achieve Carbon Neutrality" (FY2022), and details of the results will be reported at a seminar scheduled to be held by JOGMEC on 10 November 2022.

budget constraints, no new demand is created as a total amount. In addition, green investment is unlikely to be a source of growth because it is not itself an investment to expand production capacity. Relaxing financial constraints and providing sufficient funds are the key to achieving green growth.

- For smooth financing, it is necessary to use not only government budgets but also green finance, which is mainly funded by the private sector. It is important to clarify the direction of the environmental policies to limit risks and encourage investment. How to limit negative economic impacts and how to even out the different impacts between economies and industries is important.

The tables for IEEJ Outlook 2023 are currently available at
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The full text will be available early 2023 at the same URL.

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