エネルギー経済
IEEJ Energy Journal

Special Issue

January 2023

based on "The 7th IEEJ/APERC Joint International Energy Symposium"

Mapping the Energy Future

一般財団法人 日本エネルギー経済研究所
The Institute of Energy Economics, Japan

PREFACE

Chairman & CEO,
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Tatsuya Terazawa

This fiscal year marks the 7th convention of this international symposium, first held in 2016 jointly with the Asia Pacific Energy Research Centre (APERC) to commemorate the 50th anniversary of the establishment of the Institute of Energy Economics, Japan (IEEJ). Due to the impact of the COVID-19 pandemic, it was held as an online symposium this fiscal year (as in the two previous years) on April 28.

The overall theme of the 7th Symposium was "Multiple Pathways to Carbon Neutrality – Reality, Innovation, and Resilience." This theme was set against the backdrop of an awareness of the vital need for innovation toward realizing carbon neutrality, beyond what has been done so far, amid growing ambition for carbon neutrality among nations in response to COP26 held in November 2021. Moreover, as the pathways taken by developed countries to carbon neutrality are not the same as those taken by emerging and developing countries, particularly in Asia, there has been widespread recognition of the importance of realistic and multiple pathways that reflect the circumstances of each country. Furthermore, while discussions had focused on carbon neutrality until last year, perspectives on how to stabilize the energy market have also attracted strong interest following Russia's military operations in Ukraine on February 24, 2022. This reality could not be overlooked.

This Special Issue of the IEEJ Energy Journal (in collaboration with the IEEJ/APERC International

巻 頭 言

一般財団法人 日本エネルギー経済研究所
理事長　寺澤 達也

日本エネルギー経済研究所設立50周年を記念して、APERC（Asia Pacific Research Center: アジア太平洋エネルギー研究センター）との共催で2016年に始めた国際シンポジウムも、今年度で７回目を迎えました。コロナウイルス感染拡大のため、昨年度、一昨年度同様、今年度もオンライン形式で4月28日に開催されました。

今回の全体テーマは、「カーボンニュートラル実現に向けた複線的な道筋　～リアリティ・イノベーション・レジリエンス～」でしたが、この背景としては、2021年11月のCOP26を受けてカーボンニュートラルへの野心が強まる中で、カーボンニュートラルの実現のためには、これまでの延長線上を超えたイノベーションが不可欠であるとの問題意識がありました。また、先進国によるカーボンニュートラルへの道筋と、アジアを中心とする新興国・途上国の道筋は同一ではなく、各国の状況を反映した現実的かつ複線的な道筋が重要との認識の広がりがありました。さらに、2022年2月24日のロシアによるウクライナ侵攻を受け、昨年までのカーボンニュートラルを中心に焦点が当たった議論から、どのようにエネルギー市場の安定を図るかという視点にも強い関心が集まったことも見逃せない現実でした。

本「エネルギー経済」特別号（合同シンポジウム連携版）は、登壇された弊所研究員に、各人のメッセージを論文として改めて整理していただいたものに加えて、そのほかの特別研究員、及び弊所の研究員が、同じテーマについて書き下ろし

Energy Symposium) is a compilation of the messages from each IEEJ researcher who took the podium, edited as articles, as well as articles on the same theme penned by other Distinguished Fellows and researchers of IEEJ.

The following are the three sub-themes, which address the interests and concerns of many.

The first is “Decarbonization technology development and commercialization leading to carbon neutrality,” which covers the outlook on the development of decarbonization technology and issues with commercialization.

The second is “Asian developing countries’ pathways to carbon neutrality,” which examines the approach to realistic and multiple pathways based on the actual circumstances of Asian developing countries.

The third is “Stabilization of energy prices and supply/demand balance during the transition period to carbon neutrality.” Concerning the important issues confronting the world now, such as soaring energy prices and destabilization of supply, this takes an in-depth look into the future outlook during the transition period and investment approaches aimed at stabilizing markets.

Nine months have passed since the convention of this symposium, but we are keenly aware that the issues raised above are becoming increasingly important. With regard to decarbonization technology, we have moved beyond technological development and reached the stage of seriously questioning how we can proceed with commercialization. Asian developing countries, which are taking a direct hit from the soaring energy prices,

た論文を集大成したものです。

以下の３つのサブテーマがあり、多くの皆様のご関心事項に対応したものになっています。

第一に、「カーボンニュートラル実現に資する脱炭素技術の開発・社会実装」というテーマで、脱炭素技術の開発の展望と社会実装の課題について取り上げています。

第二に、「アジア新興国のカーボンニュートラル実現への道筋」というテーマで、アジア新興国の実情を踏まえた、現実的かつ複線的な道筋の在り方について掘り下げています。

第三に、「カーボンニュートラル実現に至る移行期間でのエネルギー価格及び需給の安定化」というテーマで、エネルギー価格の高騰、供給の不安定化など、まさに世界が直面する重要な課題について、移行期間における今後の展望と市場安定化に向けた投資のあり方について踏み込んでいます。

本シンポジウムが開催されてから９か月が経過しましたが、以上のような課題はますます重要性を増していると痛感しています。脱炭素技術については、技術開発以上に社会実装をどのように進めて行くのかが真剣に問われている段階に来ています。エネルギー価格高騰の荒波の直撃を受けるアジア新興国にとっては、今後のエネルギー政策の在り方を深刻に見つめ直す状況にあります。エネルギー価格及び需給の安定化は世界のすべての国々にとっての緊要の課題であり、カーボンニュートラル実現だけでなく、移行期間をできるだけ円滑に乗り越えて行くための投資のあり方がまさに問われていることは

now have to seriously reconsider their energy policies for the future. Stabilizing energy prices as well as demand and supply are pressing issues for all countries around the world. In addition to realizing carbon neutrality, there is no doubt that questions are also being raised about investment approaches that can help countries to ride through the transition period as smoothly as possible.

This Special Issue not only reflects on the symposium, but also offers the opportunity to consider anew the various problems that we are faced with. I hope that it can provide useful hints and ideas for the future.

January 2023

間違いありません。

本特別号が、シンポジウムを振り返るだけでなく、直面する諸課題について見つめ直す機会となり、今後に向けた有益な示唆を生み出すことにつながることを祈念しています。

2023年1月

Writer's Profile

Tatsuya Terazawa

Tatsuya Terazawa was appointed as Chairman and CEO of the Institute of Energy Economics, Japan (IEEJ) in July 2021. Before joining to IEEJ, he supported then Minister Yasutoshi Nishimura as the Senior Advisor of the Cabinet Office between January and June 2021 to assist on the Government response to the Covid-19 pandemic and the formulation of the Growth Strategy including the "Green New Deal". Earlier, he served at the Ministry of Economy, Trade and Industry (METI) of Japan where he held prominent positions namely the Vice-Minister for International Affairs. Mr. Terazawa has been the Senior Specially Appointed Professor at the Tokyo University of Science, teaching international negotiations since January 2020. He is a graduate of the University of Tokyo's Faculty of Law. He also studied at Harvard University in the United States, where he earned an MBA in 1990. He was born in January, 1961 in Osaka, Japan.

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寺澤　達也（てらざわ たつや）

大阪府出身。1984年東大法学部卒、旧通商産業省入省。90年米ハーバード大学ビジネススクール修士（MBA）。2011年野田内閣総理秘書官、15年貿易経済協力局長、17年商務情報政策局長、18年経済産業審議官を歴任。19年の退官後、内閣官房参与（経済安全保障担当）、内閣府参与（西村経財大臣補佐）。21年7月より現職。東京理科大学上席特任教授。

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1. Decarbonization Technology Development and Commercialization Leading to Carbon Neutrality

カーボンニュートラル実現に資する脱炭素技術の開発・社会実装

Development and Social Implementation of Decarbonization Technologies to Contribute to the Realization of Carbon Neutrality◆

Toshiyuki Sakamoto*

Introduction

It goes without saying that it is necessary to mobilize various technologies to realize carbon neutrality. According to IEA, with a view to achieving net-zero emissions by 2050, CO_2 emissions that needs to be reduced by 2030 can mostly be reduced through the technologies that have already been rolled out in the market. However, about half of the emission reductions required to be achieved by 2050 needs to be reduced further through technologies that are currently in the demonstration or prototyping phases. Our greatest challenge is how we can accelerate the development and social implementation of decarbonization technologies.

The author of this paper served as the moderator for the First Session of the 7th IEEJ/APERC International Energy Symposium, where Japanese and American experts presented their opinions and engaged in a panel discussion on the topic “Development and Social Implementation of Decarbonization Technologies to Contribute to the Realization of Carbon Neutrality”.I shall reflect on these discussions in the following sections.

Renewable Energy, Hydrogen

Firstly, Dr. Shigeru Niki (Director General, Sustainable Energy Unit, Technology Strategy Center (TSC), New Energy and Industrial Technology Development Organization (NEDO), Japan) explained that if only existing technologies are used, the marginal abatement cost for reducing global GHG emissions by 80% would be as enormous as approximately US$1,000/ t-$CO_2$. Taking a different angle from IEA’s analysis, he pointed out that it is possible to reduce the cost of emissions reduction significantly by introducing more innovative technologies through discontinuous innovation; on other words, he emphasized the importance of technological development.

On top of that, Dr. Niki set out the following points concerning technologies related to renewable energy: (1) solar power; (2) wind power; (3) geothermal energy; (4) electricity storage technologies; and, (5) hydrogen.

(1) The cumulative installed capacity for solar power worldwide in 2020 exceeded 700GW, and annual installed capacity reached 112GW. As there is a limited amount of land suitable for the

◆ The author is responsible for compiling this paper and summarizing the discussions of the First Session of the 7th IEEJ/APERC International Energy Symposium.

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installation of solar power facilities, there are high expectations for the development of new modules that make it possible to install solar power panels on water, farmland, side-walls, and cars.

(2) The International Renewable Energy Agency (IRENA) predicts onshore and offshore wind power generation capacities to reach 5,044GW and 1,000GW respectively by 2050. Japan's offshore wind power vision plans to realize offshore wind capacity of 10GW by 2030, and aims to reduce power generation cost to 8-9 yen/kWh by 2030-2035.

(3) The adoption of geothermal energy is advancing at a pace of 400MW per year, but it now trends to stagnate in Japan. If we could utilize supercritical geothermal energy resources in Japan, we would be able to generate a projected scale of more than 100MW of electricity per region.

(4) Electricity storage technologies are vital in the adoption of variable renewable energy. Storage batteries are suitable for short-cycle variations, while pumped storage generation and hydrogen are suitable for long-cycle variations.

(5) Hydrogen is an important technology in decarbonization as it enables the storage and transportation of a large amount of energy over long distances. However, reducing the cost of CO_2-free hydrogen poses a challenge. To supply hydrogen cheaply, it is essential to lower the cost of mass production to begin with. Hence, one of our options is to produce hydrogen in countries with rich renewable energy resources, and then transport the hydrogen to Japan. Under the current circumstances, there are various issues from the production of hydrogen to its transportation and use. Costs need to be reduced in each area, with water electrolysis devices being a representative example. It is also important to reduce the cost of renewable energy.

Nuclear Power

Mr. John Kotek (Senior Vice President, Policy Development & Public Affairs, Nuclear Energy Institute (NEI), United States of America) presented a report on the nuclear power technology trends in the U.S. Of the total amount of power generated in the U.S. in 2021, 19% was generated by nuclear power. Many power companies have established greenhouse gas reduction targets, and in addition to electricity storage technologies and energy-saving, there is also a need for low-carbon power sources that are cheap and stable. Hence, they are focusing on nuclear power as one of such potential energy sources.

The Biden administration's policy is to significantly increase the capacity of nuclear power generation. Mr. Kotek introduced the Bipartisan Infrastructure Act, which covers a credit program for nuclear power plants that are in operation as well as financial assistance toward advanced reactor demonstrations, and the Build Back Better (BBB) Act, under which the government is reviewing tax deductions for nuclear reactors and clean power generation. The BBB Act was later enacted as the Inflation Reduction Act, which incorporates tax deductions for nuclear power generation (commencing in 2024 and ending in 2032, and allocation US$30 billion over a ten-year period). This can be described as generous support, accounting for approximately 20% (US$160.3 billion over a ten-year period) of the support needed to promote decarbonized power sources.

Various types of nuclear reactors are now being developed in the U.S., including micro-reactors, SMR, high-temperature gas reactors, liquid metal cooled reactors, and molten salt reactors, to name a few. Mr. Kotek introduced the following three examples of projects that are ongoing in the U.S.

(1) A sodium-cooled fast reactor is under development, with support from the Bipartisan Infrastructure Act. Its output is 345MW, and is capable of reaching peak output of 500MW through the storage of liquid sodium.

(2) The pebble-bed high-temperature gas reactor, which was selected for the Advanced Reactor Demonstration Program (ARDP), can produce output of 80MW by using tri-structural isotropic (TRISO) particle fuel. It is anticipated to be a potential industrial heat source as it is operated at high temperatures.

(3) NuScale's pressurized water reactor is made up of 4 or 6 small modular reactors (SMRs) or 12 SMRs, with each module producing an output of 77MW. The total output for 12 SMRs is 924MW. It is possible to adjust total output quickly by adjusting the output of each module.

Furthermore, in order to utilize nuclear power and expand its use, including the aforementioned new types of reactors, it is important to give investors a sense of security. There is also the issue of how to attract financing, and the question of how to ensure the proper implementation of the final disposal of nuclear waste cannot be ignored. Mr. Kotek explained that in introducing new types of reactors, it is essential to develop technologies to make them even safer than existing reactors, and to present thorough explanations so that society can accept such new types of reactors.

Consumers and governments seek low-carbon electricity. Hence, there are growing expectations of nuclear power generation that can supply clean electricity cheaply, and of nuclear power as a source of hydrogen and heat. In addition, the global market is also focusing on nuclear power from the perspective of energy security.

Last but not least, with regard to nuclear power and the need of reducing dependency on Russia in the face of the Ukraine crisis, the U.S. also depends on Russia in some aspects of nuclear fuel supply, such as resource production and fuel manufacturing. In this respect, Japan-U.S. cooperation should be an effective countermeasure. Also, Europe's nuclear power supply-chain somehow depends on Russia, and the need to change suppliers is likely to emerge in the future. When that happens, the Japanese and U.S. nuclear industries will be required to play an even greater role, and it will present a good opportunity for both countries.

Carbon Capture, Utilization and Storage (CCUS)

Mr. Yoshikazu Kobayashi (Senior Economist, Manager, CCUS Group, Fossil Energies & International Cooperation Unit, IEEJ, Japan) presented a report on Japan's initiatives in the areas of carbon capture and utilization (CCU) for using CO_2, and carbon capture and storage (CCS) for storing CO_2.

Mr. Kobayashi explained the following points with regard to CCU.

(1) Among the various CCU methods, Japan is putting effort into carbon recycling, which involves manufacturing products by chemically changing CO_2. Carbon recycling technologies include converting plastics and chemical fibers into raw materials, manufacturing of synthetic fuels known as "e-fuels," and mineralization to enable the absorption of CO_2 into concrete or other materials.

(2) The government has announced its roadmap for carbon recycling technologies. By 2030, it will promote the adoption of relatively cheap technologies that do not use hydrogen, such as mineralization technology. By 2040, it aims to introduce technologies such as synthetic fuels, which require high costs but are also highly effective in reducing emissions. To introduce these technologies, the government will provide support by utilizing the Green Innovation Fund of 2 trillion yen. Carbon recycling products cost more for the same quality, so creating a market to evaluate their environmental value is an issue.

He explained the following points with regard to CCS.

(1) Japan stored 300,000 t-CO_2 at Tomakomai in Hokkaido from 2016 to 2019. By 2024, it plans to conduct demonstration experiments of transporting the CO_2 generated by multiple domestic coal-fired power generation plants by ship, and storing them.

(2) The government has also formulated a roadmap on CCS. It plans to commence the operation of CCS by 2030 with a view to storing 120 – 240 million t-CO_2 in 2050. To realize the full-scale adoption of CCS, there is a need to establish laws and regulations concerning CCS. There is an increasing number of CCS projects by individual corporations in Southeast Asia and Australia, so there is also the prospect of transporting and storing CO_2 overseas in the future.

(3) Concerning the social acceptance of CCS, it is important to encourage acceptance by thoroughly explaining the importance of CCS. When doing so, it is also necessary to explain the vital need of CCS in order to fill the gap between the climate change targets and what can be achieved in practical terms by building upon existing technologies. Also, regions where petrochemical industries have been the mainstay will lose their economic infrastructure for the future. By reconsidering CCS as a green industry, however, they can potentially transform their economic base, changing it to the CCUS industries.

Furthermore, Mr. Kobayashi explained the following points that CCU and CCS have in common.

(1) The Asia CCUS Network was established to share knowledge about CCUS, and it has built an international CCUS network comprising 13 national governments and more than 200 corporations. To deploy CCS/CCUS technologies, we face the challenges of reducing costs, monitoring storage, introducing measurement and verification systems, and securing storage locations in Japan.

(2) As for the question of where to capture CO_2 from, it is important to prioritize and narrow down the targets for carbon capture. If we were to regard CCUS as a last resort, it seems effective to use it in hard-to-abate industries. It is inefficient to introduce both CO_2 capture and ammonia co-firing in coal-fired thermal power, so it is likely that only one of the two will be adopted.

Conclusion

While we could not cover all the technologies in this session, I think we were successful in holding in-depth discussions on renewable energy, hydrogen, nuclear power, and CCUS. With regard to technological development, we can say across the board that there is a need to first explore the potential of a wide range of technologies from a technology-neutral perspective, without trying in vain to decide on the winner. In promoting new technologies, the predictability of investments is an important point. Under the current circumstances, in order to promote hydrogen despite its high cost, it is also necessary to put in place measures to reduce the risks to business operators, such as the Contract for Difference (CfD) scheme implemented in the UK. In the U.S., in addition to the government's proactive stance toward nuclear power, the Congress has also demonstrated rare bipartisan support, which in turn provides nuclear power developers with a sense of security. Even if the Inflation Reduction Act included support measures for nuclear power generation, if there were any risks of project cancellations due to changes in the administration, it seems highly unlikely that any developers will decide to make huge investments in nuclear power. Furthermore, with regard to new types of reactors and new technologies such as CCS, it is extremely important to ensure social acceptance for promoting their widespread adoption.

Writer's Profile

Toshiyuki Sakamoto

Mr. Sakamoto worked for policy planning and implementation on energy, climate change and industry competitiveness for 30 years at the Ministry of Economy, Trade and Industry or METI, the Japanese Government. After leaving the METI, he engaged in renewable and hydrogen energy businesses at two private companies, and thereafter was appointed to the current position in June 2020.

カーボンニュートラル実現に資する脱炭素技術の開発・社会実装について ◆

坂本　敏幸 *

はじめに

カーボンニュートラルを実現するためには、様々な技術を総動員することが必要であることは論を俟たない。IEA によると、2050 年のネットゼロ達成に向けて、2030 年までの CO_2 削減量は概ね現在市場に展開済の技術で削減可能とされているが、2050 年に向けた必要削減量については、その半分程度が、現在は実証段階かプロトタイプ段階の技術により削減される必要がある。脱炭素技術の開発とその社会実装を如何に加速させるかが最大の課題であろう。

2022 年 4 月 28 日に開催された、第 7 回 IEEJ/APERC 国際エネルギーシンポジウムの第 1 セッションでは、筆者がモデレータとなって、「カーボンニュートラル実現に資する脱炭素技術の開発・社会実装」と題して、日米の専門家から意見を伺い、パネル討論を行った。以下、その議論を振り返りたい。

再生可能エネルギー、水素

まず、日本の仁木 栄氏（新エネルギー・産業技術総合開発機構（NEDO）技術戦略研究センター サステナブルエネルギーユニット長）からは、既存の技術のみを前提とすると、世界の GHG 排出量を 80%削減するための限界削減費用は約 1,000 ドル/t-CO_2 と膨大なものになるとの説明があった。IEA の分析とは違った切り口で、非連続なイノベーションにより革新的技術の導入ができれば対策費用の大幅な削減が可能となること、すなわち技術開発の重要性を指摘した。

その上で、仁木氏は、再生可能エネルギー関連技術である①太陽光、②風力、③地熱、④蓄電技術、及び、⑤水素の各論点について次のとおり述べた。

① 2020 年の全世界の太陽光発電の累積導入量は 700GW を超え、年間設置容量は 112GW に達した。太陽光発電は設置に適した土地が限られているため、新たに水上・農地・壁面・車載への対応が可能となるモジュールの開発が期待されている。

② IRENA は 2050 年には陸上風力が 5,044GW、洋上風力が 1,000GW になると予測している。日本の洋上風力ビジョンでは 2030 年までに 10GW の洋上風力発電を計画し、2030-2035 年までに発電コストを 8～9 円/kWh へ削減することを目指している。

③ 地熱発電は年 400MW のペースで導入が進められているが、日本では停滞傾向にある。日本では超臨界地熱資源を活用できれば 1 地域当たり 100MW 以上の規模が実現可能と見込まれている。

④ 変動再エネの導入のためには蓄電技術が重要である。短周期変動では蓄電池が適しており、

◆ 本稿は、筆者の責任において、第 7 回 IEEJ/APERC 国際エネルギーシンポジウムの第 1 セッションの議論の概要をまとめたものである。

* (一財) 日本エネルギー経済研究所　理事　環境ユニット担任

長周期変動には揚水発電や水素が適している。

⑤　水素は長距離大量輸送や貯蔵が可能であるため脱炭素において重要技術であるが、CO_2フリー水素のコスト低減が課題となっている。水素を安価に供給するためにはそもそも大量生産をしないとコストが下がらないので、再エネが豊富な国で水素を作って日本に運んでくることも選択肢に入る。現状、水素の製造から運搬、利用に至るまで、様々な課題がある。水電解装置を代表とする各領域でコストダウンが必要。再エネコストを下げることも重要である。

原子力

米国のジョン・コテック氏（米 原子力エネルギー協会（NEI）上級副会長）からは、原子力発電について米国での技術動向が報告された。米国では 2021 年の総発電電力量のうち 19%が原子力発電であったこと、電力会社の多くは温室効果ガスの削減目標を定めており、蓄電技術と省エネに加えて安価で安定した低炭素電源が必要であり、その一つとして原子力発電に注目していることの説明があった。

バイデン政権では原子力発電を大幅に増やしていく方針であり、超党派のインフラ法案では稼働中の原子力発電所のクレジットプログラムや先進炉実証への資金援助をしており、Build Back Better 法案では原子炉やクリーン発電に対する税額控除を検討していることの紹介があった。なお、BBB 法案については、その後インフレ抑制法として成立し、原子力発電への税控除（2024 年開始、2032 年終了。10 年間で 300 億ドル）が盛り込まれた。脱炭素電源を促進する支援（10 年間で 1,603 億ドル）の２割程度が割かれており、手厚い支援と言えよう。

また、現在米国では、マイクロリアクター、SMR、高温ガス炉、液体金属冷却炉、溶融塩原子炉などの様々な原子炉を開発しており、米国で現在進行中のプロジェクトとして 3 件が以下のとおり紹介された。

①　超党派のインフラストラクチャー法案の支援を受けナトリウム冷却高速炉を開発中である。出力は 345MW であり、液体ナトリウムを貯蔵することでピーク時には 500MW を出力することができる。

②　先進的原子炉設計の実証プログラム（ARDP）を受賞したペブルベッド型高温ガス炉は TRISO 燃料を使用することで 80MW の出力が可能であり、高温で稼働するため産業用の熱源としても期待されている。

③　NuScale 社の加圧水型軽水炉は､4 基/6 基もしくは 12 基のモジュールから構成されており、各モジュールが 77MW の出力を持つ。12 基の総出力は 924MW となる。各モジュールの出力を調整することで迅速に総出力を調整することが可能である。

さらに、こうした新型炉を含め、原子力の利用やその拡大のためには、投資家に安心感を与えることが重要であること、金融をどう引き付けるかも課題、核廃棄物の最終処分をどのように確実に実行していくかも無視できない点であること、新型炉の導入に当たっては、既存の炉よりさらに安全になるように技術開発を行い、それを丁寧に説明して社会に受容してもらうことが重要になるだろうとの説明があった。

消費者と政府は低炭素電力を求めており、安価でクリーンな電力を供給できる原子力発電、さらに水素や熱を供給する原子力への期待は高まっている。加えて、エネルギー安全保障の観点からも世界市場で原子力は注目されているとのことであった。

最後に、ウクライナ危機による脱ロシアの動きと原子力については、核燃料の供給について、

米国においても資源生産や燃料製造の点でロシアに頼っている部分はあり、その点、日米協力が有効な対抗手段になるだろう。欧州の原子力も、サプライチェーンにおいてロシアに依存している部分があり、今後サプライヤーの転換を進めていく必要が出てくるであろうし、その際に日米の原子力産業に求められる役割は大きくなり、チャンスになるだろうとのことであった。

CCUS

日本の小林 良和氏（日 日本エネルギー経済研究所化石エネルギー・国際協力ユニット CCUS グループ グループマネージャー）からは、CO_2 を活用する CCU と CO_2 を貯留する CCS について日本における取組が報告された。

CCU については、以下の説明があった。

① 日本では CCU の中でも CO_2 を化学的に変化させて製品を製造するカーボンリサイクルに力を入れている。カーボンリサイクルの技術にはプラスチックや化学繊維の原料化、e-fuel といった合成燃料の製造、コンクリートなどへ CO_2 を吸収させる鉱物化がある。

② 政府はカーボンリサイクル技術のロードマップを公表しており、2030 年までに鉱物化技術等の水素を利用しない比較的安価な技術の導入を進め、2040 年までには排出削減効果が大きいがコストが高い合成燃料等の技術の導入を目指すとしている。政府はこれらの技術導入のため、2 兆円のグリーンイノベーション基金を活用して支援する。カーボンリサイクル製品は品質が同じであるがコストが高くなるため、環境価値を評価する市場の創出が課題である。

CCS については、以下の説明があった。

① 日本では 2016 年から 2019 年にかけて北海道の苫小牧で 30 万 t-CO_2 が貯留された。2024 年にかけて複数の国内石炭火力発電所から出た CO_2 を船で輸送し貯留する実証実験が行われる予定である。

② CCS についても政府がロードマップを策定しており、2050 年時点で 1.2～2.4 億 t-CO_2 を貯留することを想定し、2030 年までに CCS の運転を開始する計画である。本格的な導入のためには CCS に対する法・規制を整備することが必要である。個別の企業では東南アジアやオーストラリアでの CCS プロジェクトが増えており、将来的には CO_2 を国外へ輸送し貯留することも想定されている。

③ CCS の社会受容性については、CCS の重要性を丁寧に説明して受け入れてもらうことが重要だろう。その際には、気候変動目標の達成のために現行技術を積み上げていっても目標との間にギャップが生じ、このギャップを埋めるために CCS が必要不可欠であるということを説明していくことも重要だろう。CCS をグリーン産業として捉え直し、石油化学産業を主要産業としている地域は今後経済基盤を失うので、これを CCUS 産業に転換していくという可能性があるのではないか。

さらに、CCU、CCS 共通の論点として、以下の説明があった。

① CCUS の知見を共有するため、アジア CCUS ネットワークが設立され、13 カ国の政府と 200 以上の企業によって CCUS の国際的なネットワークが構築されている。CCS/CCUS 技術を導入するためには、コスト低減・貯留のモニタリング・計測および検証システム・日本国内での貯留先の確保が課題である。

② どこから CO_2 を回収するのかという点については、優先順序をつけて回収対象を絞っていくことが重要。CCUS を奥の手として捉えるのであれば、脱炭素化が困難な産業用で使うのが有効なのではないか？石炭火力のアンモニア混焼と CO_2 回収を両立させるのは非効率な

のでどちらか一方を採用することになるだろう。

結び

今回のセッションですべての技術を取り上げることはできなかったが、再エネ、水素、原子力、CCUS について突っ込んだ議論ができたと思う。共通して言えることは、まず技術開発は、徒に winner を決めようとせず、技術ニュートラルな観点から幅広い技術の可能性を模索する必要がある。新たな技術の普及に当たっては、投資の予見性が重要である。現状ではコスト高の水素が普及するには、イギリスの CfD（Contract for Difference）のような施策により、事業者のリスクを減らす施策も重要だろう。また、米国では、原子力については、米国政府の前向きな姿勢に加え、議会でもめずらしく超党派のサポートがあるようであり、これが原子力の開発者に安心感を与えていると思われる。折角インフラ抑制法で原子力発電に対し支援策が講じされても、政権が交替してご破算になるリスクがあれば、とても原子力のような巨大投資には踏み切れないであろう。また、新型炉や CCS のような新たな技術については、社会受容性の確保が普及を進める上で極めて重要となる。

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Decarbonisation Technology Development and Commercialisation Leading to Carbon Neutrality: a Policy Perspective

Joan MacNaughton*

As the title above implies, it is the development of a technology and its commercialisation that can deliver carbon neutrality. Completely new technologies are not needed as sufficient technologies already exist, as extensive analysis has shown (for example in reports from the IEA, especially the Energy Technologies Perspectives series; IRENA, as regards renewables; and the Energy Transitions Commission, which has examined hard to abate sectors; as well as numerous academic studies). By contrast, what has lagged behind the identification of technical solutions are the policy, regulatory and fiscal frameworks to facilitate their demonstration, development and deployment, as the prerequisite to commercial viability.

This article will look at how policy has faltered in enabling the scale up of clean technology commercialisation and contrast that with the notable success of renewables. It will offer some lessons policymakers must learn to put us on a path to decarbonisation by 2050.

Renewables in Power Generation

Renewables are a success story, driven by longstanding and extensive incentives or mandates.

Differing approaches have been adopted in the European Union, in countries such as the UK and Germany, Germany and in the United States.

In 2000 the UK government introduced a Renewables Obligation (RO) with a target of 10% of electricity to be supplied from renewables by 2010 (an EU Directive in 2001 also set a 10% target for UK energy overall). The RO included incentives for suppliers to meet interim targets increasing year by year, financial penalties for non-compliance and a system of tradable renewables certificates (which aimed to create an efficient market for resource allocation and to foster innovation). The 10% target was not reached until 2011/12. Progress was impeded by an unfavourable planning regime, as well as delays in providing connections to the transmission and distribution system. The tradable certificate system may also have increased the perception of risk and deterred some investment.

The Germany ‘Energiewende’ was built around a system of feed in tariffs for renewables. It drove more rapid deployment than in the UK, notably of solar panels. It was however more costly.

At the federal level in the US, time limited tax credits provided incentives for renewable projects and there were additional measures in some states. But uncertainty over whether tax

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credits would be renewed created a cycle of boom and bust. The tax credit approach was also only viable for companies which had tax liabilities against which to offset the credits.

In 2008, the European Union agreed its '20/20/20' package: a reduction of 20% in CO_2 emissions (compared to 2005), a 20% improvement in energy efficiency, and a 20% share of renewables in the energy mix, all to be achieved by 2020.

A reformed renewables incentive structure called 'Contracts for Difference' was introduced in the UK's Energy Act of 2013. A strike price discovered via competitive auctions was set for renewable power generation with suppliers paid a premium to top up lower market prices; but they were obliged to refund the difference if the market price were higher, which has been the case in the current era of high gas prices.

Carbon Capture and Storage

Analysis has consistently shown that it will be very difficult, or even impossible, to deliver Net Zero by the middle of the century without Carbon Capture and Storage (ie CCS, or if the captured carbon dioxide is reused, CCUS).

But the technology continues to be controversial: criticised by some as a way for fossil fuel companies to extend the life of their business models, as unproven, costly and not commercially viable. These criticisms ignore longstanding evidence that the technology can work (eg from projects injecting CO_2 captured from gas production in Norway and Algeria) and they overlook that, in marked contrast to renewables, CCUS has not yet received the level of support needed to drive increased deployment and bring down costs through economies of scale and learning by doing. To illustrate this, consider the proposal for a CCS funding mechanism using the proceeds from selling 600m unused allowances from the EU Emissions Trading Scheme put to the European Parliament during the enactment of the 2008 package. The Parliament adopted the proposal but redirected half of the money to renewable projects, augmenting the already extensive renewable support at EU member government level and demonstrating yet again the lack of wholehearted political support for CCS.

While demonstrator projects were initiated in many other jurisdictions in the early mid-2000's, many were cancelled because of local opposition, such as the Schwarze Pumpe and Janschwalde power station projects in Germany, or the withdrawal of financial support. Examples here include AEP's Mountaineer project which from 2009 captured CO_2 from the waste stream of a 30MW unit of a coal power plant, transported and stored it in saline aquifers. As well as investment by AEP and development partner Alstom Power, \$50m was offered by the US government. But the State electricity regulator refused to top this up with a small levy on consumer bills on the grounds that there was no benefit to local consumers. The UK Treasury similarly withdrew support for a project which had previously received seed funding, and which then could not benefit from matching '300m' EU funding.

Many governments have now shifted focus towards 'industrial clusters' which not only test CCUS but also build production capacity for hydrogen – a future key contributor to decarbonising some industries and forms of transport (or even potentially domestic heating). In many industrial applications, there are few if any alternatives to CCS for decarbonisation. And ‘negative emission’ technologies, such as for capturing CO_2 from the atmosphere (‘Direct Air Capture’), will certainly be needed to reach net zero alongside nature based solutions.

Conclusions

Space limits the policy approaches which can feature in an article such as this, but they have been selected to illustrate some key lessons on what works to drive the commercialisation of carbon neutral technologies.

i) Policymakers and businesses need to devote considerable effort to explaining the case for these technologies, not only for achieving net zero but also their benefits to host communities and the true level of risk. The abandonment of promising CCS projects at an advanced stage in Germany owing to people’s refusal to accept that storage of CO_2 was safe seems particularly strange in a country using (and storing) large quantities of methane. This is a potentially toxic and explosive gas while CO_2 is something we all exhale when we breathe. Early engagement through trusted interlocutors is crucial.

ii) Businesses need to be involved at the design stage of policies to ensure they are ‘investment grade’ and are technically workable. Market based policy approaches can contribute to greater cost efficiency, but unless they are designed with an eye to perceived risk they can negatively impact the appetite for investment. This is where the German FIT approach seems to have won out over the UK RO, albeit at a cost. Whether speed of scale up matters more than cost effectiveness needs to be addressed upfront.

iii) Investment appetite depends very materially on the predictability of the policy, regulatory and financial regimes – allowing for reasoned judgements concerning lifetime viability of projects. The structure of the EU ETS, with a clear direction of travel and multi-year trading periods largely insulated from day to day political influence offers one model here. This can be contrasted with the highly political decision making process in the US on the extension, or not, of a tax credit regime and its associated risk of a boom and bust cycle which is not ideal for building sustainable supply chains.

iv) Even where political decisions are front and centre, it is possible to give a credible long term signal as did the EU 2008 package. This will positively affect business appetite and the development of the supplier market. The prospect of a huge growth market for solar in Europe must have been a factor in the Chinese government’s thinking in growing its solar industry to compete globally; thus helping to drive dramatic cost reductions, in a way that other countries with nascent solar industries failed to do.

v) Delays from external factors can be avoided by taking a ‘whole system’ approach, considering the planning regime, grid connection availability, or – in the case of CCS and hydrogen – developing business models to ensure the whole complex value chain can operate.

Finally, market based frameworks should be adopted where appropriate, not only to amplify or create the markets for carbon neutral technologies but to enhance cost effectiveness and incentivise innovation. In other cases, different approaches will be needed. But whether market based or not, policies and regulation must be consistent over time, with clear signals on adoption reflecting the state of the technology. The stark reality is that stop and start approaches, particularly in the case of CCS, have not only been wasteful but have delayed the delivery of available emissions reductions by some years – a delay that was far from inevitable had advantage been taken of the state of the technology. This could cost us dear in the future race to get to net zero. Ensuring that the needed policies urgently extend across all sectors and geographies, and are consistent over time, is now the key to driving scale up, and to do it fast.

Writer's Profile

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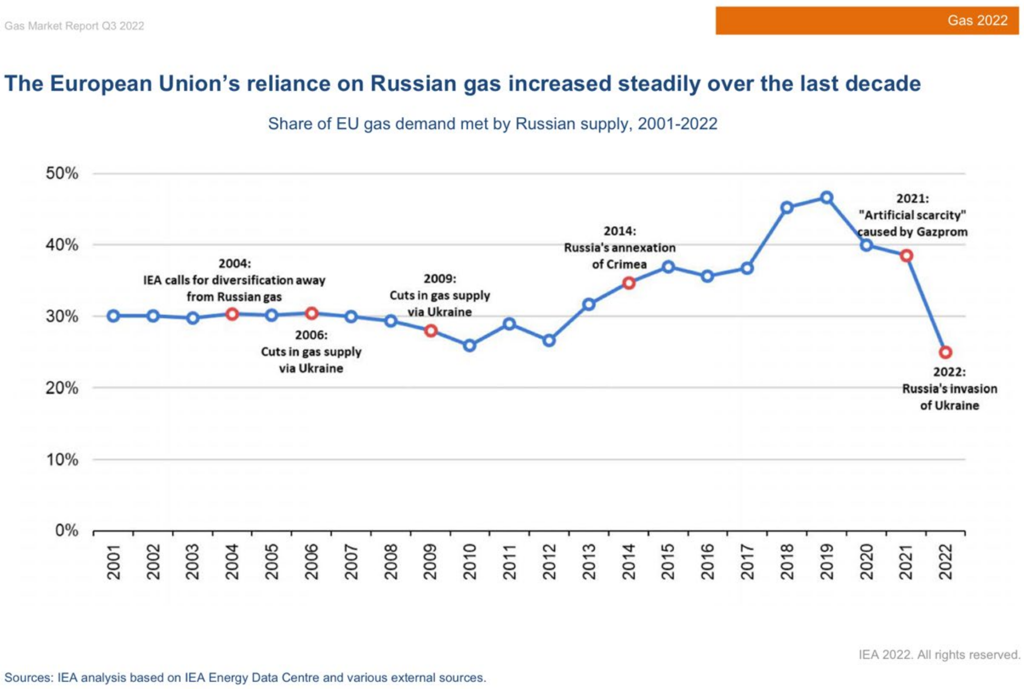
Ms. MacNaughton is a Non Executive Director of Heathrow Airport Holdings Limited, where she chairs the Sustainability and Operational Risks Committee; a Director (Trustee) of the Green Purposes Company. She sits or has sat on several other boards in the academic, public and corporate sectors, including currently the Advisory Boards of the Grantham Institute, the Joint Institute for Strategic Energy Analysis, and Equans UK plc. She is one time Vice Chair of the UN High Level Panel on the CDM, former Chair of the Governing Board of the IEA, former Director General of Energy in the UK Government, former Chair of the Climate Group, and a founding Board member of Powerful Women, where she led the mentoring programme designed to increase the representation of women at senior levels in the energy sector.

The Global Energy Crisis and Climate Crisis: Japan's Contribution Through the Sustainable Use of Nuclear Power

Nobuo Tanaka*

Dr. Fatih Birol, Executive Director of the International Energy Agency (IEA) says that the world is in the middle of its first truly global energy crisis, triggered by the military operations in Ukraine by Russia, the world's largest producer of fossil fuels. IEA was founded in 1974 during the first oil crisis, but the current crisis involves not only oil, but also natural gas, coal, and electricity, with the prices of each rising rapidly to historical highs. Energy security has emerged as an issue of top priority for all countries.

Europe and Russia are verging on becoming embroiled in an energy war. Europe strengthened sanctions on Russia for its military operations in Ukraine, and banned the import of oil and coal from Russia. In retaliation, Russia is gradually tightening its natural gas exports to Europe. Europe is Russia's largest customer for fossil fuels. In particular, natural gas is supplied in large volumes through pipelines, and 75% of that is bound for Europe. On the other hand, even after the annexation of Crimea, Europe increased its dependence on Russia through Nord Stream 1, relying on Russia for close to 50% of its domestic demand at one point and even starting work on Nord Stream 2. This is believed to have emboldened President Putin of Russia. (Graph 1) Angela Merkel,



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former Chancellor of Germany, was the one who had pushed for this. She procured cheap and stable energy sources for the country until the autumn of 2020, and the German economy achieved prominent success within Europe. However, she also committed to reducing the use of coal in response to calls from many German citizens for strong global environmental measures. She also frequently changed policies on the use of nuclear power based on the response from the citizens. In 2008, I was invited to the energy policy dialogue with Chancellor Merkel and German industrial leaders at the German Chancellery. (Photograph) When I asked her why Germany did not proactively use nuclear power, she replied, “Mr. Tanaka, I am a scientist. I am well aware of the importance of nuclear power, and how to utilize it. But I need votes to do so in Germany.” That was during the era of the grand coalition with the Social Democratic Party, which was anti-nuclear power, so she changed the policy direction to reduce dependence on nuclear power. However, after she won the general elections the following year, Merkel formed a small coalition with the Free Democratic Party and revived the use of nuclear power. In 2011, the Fukushima Daiichi Nuclear Power Plant accident occurred, stirring strong public reactions against nuclear power. Merkel changed her policy once again, and decided to phase out nuclear power by the end of 2022. She is a wise politician rather than a good scientist. While this led her to retain political control for the period of 16 years, the choice to move away from coal and nuclear power and depend instead on gas from Russia brought about Germany’s over-reliance on Russia, which in turn gave President Putin too much confidence. Hence, we can probably say that Merkel’s decisions had brought about the Russia-Ukraine crisis today, which is the most severe geopolitical crisis in the postwar era.

Abendessen mit der Bundeskanzlerin am 29. September 2008 im Bundeskanzleramt

But the global energy crisis may subside in 10 years. The looming climate crisis and nuclear war could perhaps be more serious. According to Yuval Noah Harari, the author of *Sapiens: A Brief History of Humankind*, what wipes out humankind in the end will not be viruses, but a nuclear war, climate crisis, or algorithms. Harari says that all these crises are global and cannot be resolved through the efforts of any one country. On the other hand, in the current political climate around the world, populism and nationalism that puts the interests of one's own country above all, are taking great strides forward, while global values such as democracy and liberalism are in a state of crisis. This is a grave situation, says Harari, and politicians with a global identity are needed to address this crisis to humankind. Former Prime Minister Abe, who was killed by an assassin, was one of these rare politicians. The fact that his state funeral was attended by many world leaders attests to the relationships of trust that he had built. His death is truly regrettable. (Photograph of former Prime Minister Abe at ICEF 2019. He was the founder of ICEF.)

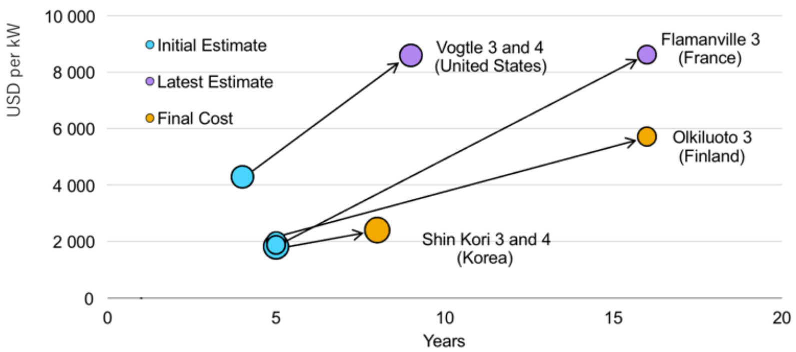
ICEF 2019 / Green Innovation Summit 2019-10-9

What should Japan do in the face of the current nuclear war crisis in Ukraine, the global energy crisis, and further, the climate crisis? I believe one of the answers is the peaceful use of nuclear power. If we were to look at Merkel's failure, it is clear how important nuclear power is to energy security. The operation of one nuclear power plant with a capacity of 1 Giga watts can help to save 1 million tons of LNG consumption per year. Putting 10 nuclear power plants back into operation, as Prime Minister Kishida declared, will then save 10 million tons. With that, Japan would not face any power shortage even if the gas supply from Russia to Japan were cut off. Germany would appreciate it if the surplus were passed on to them. It would be an international contribution that costs nothing. Furthermore, nuclear power plants, which do not emit carbon dioxide, also contribute to global warming measures. Restarting nuclear reactors that had been shut down is also cost-effective, so it would probably be the right choice to restart them after putting in place the strongest safety measures, followed by a review of the extension of their operating period from 40 years to 60 years, or even to 80 years as observed in the United States. Nevertheless, as the citizens have taken an extremely critical view of nuclear power after the Fukushima nuclear accident, the operation of nuclear power plants is a political issue. If an accident occurs at a nuclear power plant, it could cause serious damage as in the case of Fukushima. Even if the most stringent safety standards were applied after the accident, there is no absolute guarantee of safety. Particularly in the case of large-scale reactors, even if safety were enhanced, it would still be necessary to secure a large emergency evacuation area. Hence, the risks are still high in the event of an emergency. In comparison, for small modular reactors (SMRs), it could be possible to contain the evacuation area within the plant premises, depending on the design. In addition, it will reduce the initial construction costs and the passive safety design will further enhance the reduction of the risk. Since SMRs are flexible power generation and heating systems aimed at fulfilling local demand, it should be possible to incorporate the views of the local community from the design phase. Social acceptance should also increase significantly. Compared to large-scale light water reactors, SMRs may raise concerns of high unit cost for power generation. However, the cost of large-scale reactors to date have been double or triple that of the initial planned cost due to factors such as extended construction period and changes to safety specifications. Instead, building many reactors of the same type and standardizing them is a way to reduce costs. SMRs are an innovation that can achieve this. SMR can be operated as a backup to variable wind and solar power, during peak times when prices are high. This will be a paradigm shift from the current large-scale light water reactor systems, which operate large-scale reactors continuously as the base load. (Graph) The high-level radioactive waste site has not been determined so far. The back-end solution for nuclear power plants, such as spent fuel resulting from power generation activities at large-scale light water reactors including fuel debris from Fukushima, and the high-level waste after plutonium has been extracted through processing at the Rokkasho Reprocessing Plant from spent fuel, remains undetermined; this only serves to amplify the anxiety and unease among citizens. Moreover, there is the problem of proliferation risk of nuclear weapons. Ukraine has returned its nuclear weapons under the Budapest Memorandum, but if it had not, would Russia have carried out its aggression on the country? Under the circumstances, it is inevitable that an increasing number of countries, like North Korea and Iran, consider the possession of nuclear weapons the absolute security. It would not be an exaggeration to say that the nuclear nonproliferation regime is now in danger of collapsing. There is a need to develop technology to prevent diversion to nuclear weapons in countries that use nuclear power peacefully, and the security measures of IAEA, which monitors such diversion, should probably be reviewed.

For nuclear power to be sustainable, it is not sufficient for it to only be safe and to not emit CO_2. The nuclear power session at this year's Innovation for Cool Earth Forum (ICEF 2022) summarized the abovementioned problems as four conditions for the sustainability of nuclear power. The first is to minimize the risks of accident by introducing SMRs and passive safety design. The second is disposal plans for high-level radioactive waste, which countries such as Finland is materializing. This is also a condition for EU's taxonomy for sustainable investment. The third is technology with low proliferation risk of nuclear weapons. The fourth and last is social and

Delays and cost overruns have troubled the nuclear industry

Overnight cost and construction times for selected recent nuclear projects



Although advanced economies have nearly 70% of global nuclear capacity, investment stalled decades ago and the latest projects are running far over budget and behind schedule.

"NuclearPower and Secure Energy Transition" by IEA 2022-6-30

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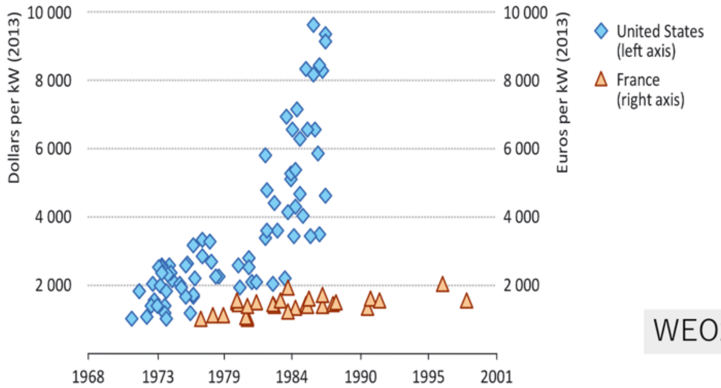
Standardization of reactors, NOT Size, that reduces unit construction costs.

Figure 10.6 ▷ Historical overnight cost of construction for nuclear power plants in France and the United States



WEO2014

Note: Overnight costs are shown for the year in which plants came online.

Sources: Cour des Comptes (2012), US CBO (2008) and US DOE/EIA (1986).

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political sustainability. In democratic countries in particular, there should be designs that make nuclear power acceptable to local communities. Assistant Professor Aditi Verma, one of the speakers at ICEF, called this "design justice." In the case of SMRs, it is possible to incorporate the demands of the community at the site of construction from the initial stages of design. In Wyoming, United States, the Natrium reactor that TerraPower is planning is a sodium cooling, metallic fuel fast reactor, but its aim is to replace the old coal power generator and keep locals employed. It also enables support at peak times through a heat storage system that uses molten salt. Canada's SMR is planned to be a heat source to melt down oil sand, and its use in the north-western part of the country is anticipated. Russia has moored a barge mounted with an SMR on the Arctic coast, which is already supplying electricity to arctic towns. The future of nuclear power lies in such flexible, locally distributed systems that fit well with renewable energy sources. Metallic fuel is ideal for enhancing flexibility, such as frequent output adjustments. Nuclear submarines and ice breakers use metallic fuel to facilitate frequent stops and goes. On the other hand, while oxide fuel is made easy to handle through solidification, it breaks easily during output adjustment, and is therefore suitable for large-scale light water reactors that operate continuously as base load. Nuclear power innovations lie in SMRs as well as the conversion to metallic fuels. Metallic fuels are also useful for advancing waste disposal. High-level radioactive waste needs to be stored in a stable manner for more than 100,000 years because it is mixed with what is known as minor actinides (MA), which are transuranic elements such as americium and curium with extremely long half-lives. Pyroprocessing is a dry processing method by which such elements are extracted from spent fuel along with plutonium, etc. and burnt in a fast reactor. The wet processing method (purex) used at Rokkasho extracts only plutonium, so it takes more than 100,000 years to detoxify the waste; pyroprocessing, on the other hand, requires 300 years. This is also a long time, but it makes it far easier to search for disposal sites. In the future, there is also potential for the development of nuclide transformation technologies that further reduces the detoxification time for nuclear waste to a hundred years or less. Burning the plutonium and MA extracted from fuel debris from Fukushima Nuclear Power Plant in an SMR through the pyroprocessing method, can convert it into 300-year waste. Debris cannot be transported anywhere even if it were extracted from a broken reactor, for example. No prefecture would accept it. There is no other option but to process it in Fukushima, convert it into 300-year waste, and store it in Fukushima. The Canon Institute for Global Studies convened the Study Group on Next-generation Nuclear Energy Utilization to discuss what sustainable nuclear power is, and summarized their recommendations in an interim report. (https://cigs.canon/article/20221006_7042.html) Chieko Nagayama, who participated in this study group as an observer, has commented at the symposium held by the same study group in the following video link, which I would highly recommend watching. (Photograph) (https://cigs.canon/videos/20220310_6639.html)

福島からのコメント｜次世代原子力を考えるシンポジウム⑤

While teaching in Fukushima in her 20s, she was afflicted with an incurable muscular disease. Without a cure, she had no choice but to give up everything, but she continues to spread various messages proudly today. Concerning the Fukushima accident, she says that despite the loss of beautiful Fukushima, if decommissioning efforts move forward by establishing a metallic-fuelled SMR and the pyroprocessing plant in Fukushima, it would help to restore trust in Japanese technology and contribute to the peaceful use of nuclear power in the world. This would transform Fukushima into “Fukushima for service.” Although there is no path to recovery for herself, she hopes that Fukushima can stand again by contributing to the future even if it is resigned to the outcomes of the accident.

There are also countries around Japan that are skeptical of Japan’s plutonium storage and use, and suspect that it has plans to possess nuclear weapons. In this case, Japan should place its surplus plutonium under IAEA’s management, formally accede to the Treaty on the Prohibition of Nuclear Weapons, and reaffirm its commitment to the peaceful use of nuclear power. There should be no opposition from the United States if the declaration were made by Prime Minister Kishida, who comes from Hiroshima. To strengthen the nuclear nonproliferation regime, non-nuclear-weapon states should be appointed as permanent members of the UN Security Council. Japan should commit fully to the peaceful use of nuclear power and develop diplomacy that is appropriate to its position as a leader in the peaceful use of nuclear power.

Politicians are likely to claim that it would be absurd to build nuclear power facilities such as pyroprocessing facilities and fast reactors in Fukushima, and that Japan cannot possibly engage in such diplomacy under the United States’ “nuclear umbrella.” However, there are no other ways to bring about the regeneration of nuclear power. Japan should draw lessons from Ms. Nagayama’s courage and the global identity of former Prime Minister Abe, and embark on its path to next-generation nuclear power starting with Fukushima.

Writer’s Profile

Nobuo Tanaka

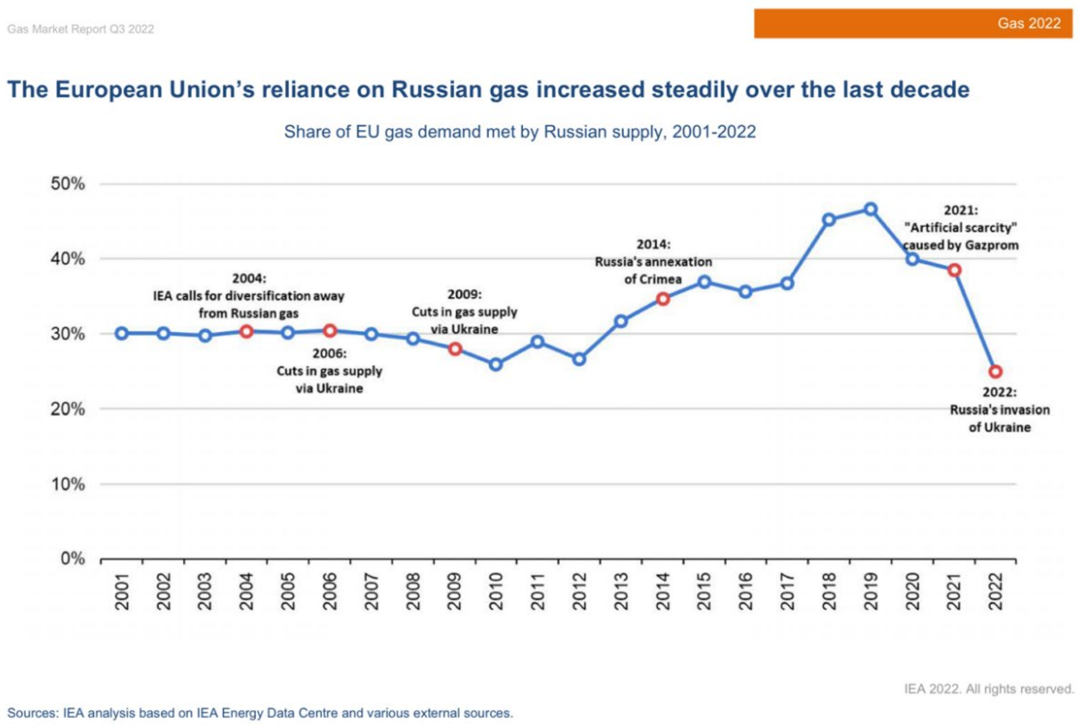
Mr. Tanaka is the Distinguished Fellow at the IEEJ. He is the chairman of the Steering Committee of Innovation for Cool Earth Forum (ICEF). As Executive Director of the International Energy Agency (IEA) from 2007 to 2011, he initiated a collective release of oil stocks in June 2011. He also played a crucial and personal role in the strengthening of ties with major non-Member energy players, including China and India. He began his career in 1973 in the Ministry of Economy, Trade and Industry (METI), and has served in a number of high-ranking positions, including Director-General of the Multilateral Trade System Department. He was deeply engaged in bilateral trade issues with the US as Minister for Industry, Trade and Energy at the Embassy of Japan, Washington DC. He has also served twice as Director for Science, Technology and Industry (DSTI) of the Paris-based international organization, OECD. He is currently CEO of Tanaka Global, Inc. He is also former Chairman of the Sasakawa Peace Foundation and serves as a Board member or an auditor at some corporations.

世界エネルギー危機と気候危機：日本は原子力の持続可能利用で貢献を

田中　伸男 *

国際エネルギー機関（IEA）のファティ・ビロル事務局長は世界はロシアという最大の化石燃料産出国がウクライナに侵攻したことで起った初めて経験するグローバルエネルギー危機の真っ只中にいるという。IEA が創立されたのは 1974 年の第一次石油危機だったが、現在石油に加えて天然ガス、石炭、電力全ての危機でありそれぞれの価格は歴史的な高さまで急上昇し、エネルギー安全保障が全ての国にとって最重要課題に浮上した。

欧州とロシアはエネルギー戦争と言ってもいい状態にある。欧州はロシアのウクライナ侵攻に対し制裁を強化、ロシアからの石油と石炭の輸入を禁止した。これに対抗してロシアは徐々に天然ガスの対欧州輸出を絞りつつある。欧州はロシアの化石燃料にとって最大の顧客である。特に天然ガスはパイプラインで大量に供給されその 75%が欧州向けだった。他方欧州はクリミア併合後もノルドストリーム 1 によって対露依存を増大させ一時は内需の 50%近くをロシアに依存し、さらにノルドストリーム 2 建設にも着手したがこれがプーチンロシア大統領を強気にしたと考えられる。（グラフ 1）これを押し進めたのがメルケル首相であり安いエネルギー源



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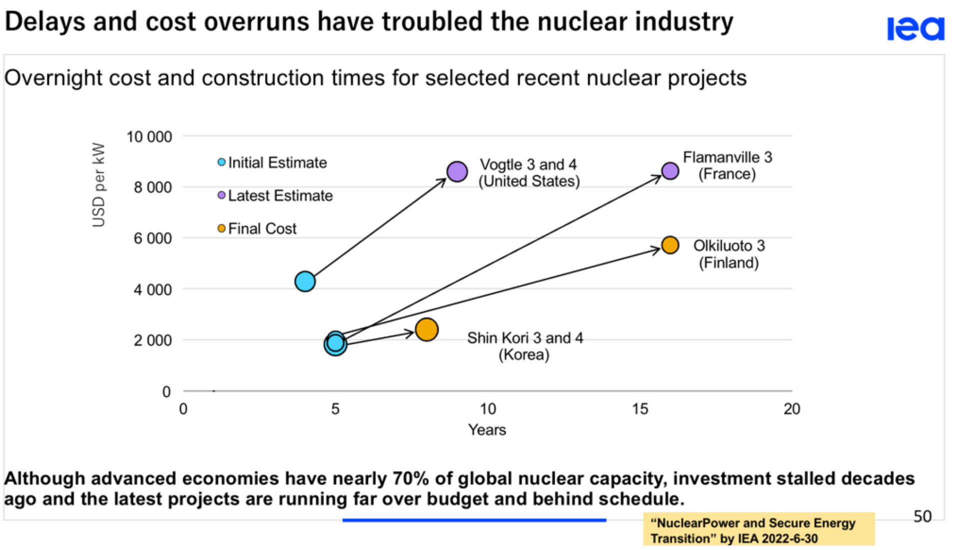
を 2020 年秋までは安定的に得てドイツ経済は欧州の中でも突出した成功をおさめた。他方ドイツ国民の多くが強い地球環境対策を求めたことに答え石炭利用を減らすことにコミットする。彼女は原子力利用も国民の反応によって政策を頻繁に変えた。2008 年にドイツ首相府で経済界のリーダーたちとのエネルギー政策に関する対話に参加したことがある。（写真）メルケル首相に「どうしてドイツは原子力を積極的に利用しないのですか」と質問したところ彼女は「田中さん、私は科学者です。原子力の重要性もどう利用するかもよくわかっています。しかし今のドイツでそうするためには票を頂戴。」と答えた。当時は反原発の社会民主党との大連立時代であり彼女は原子力縮小に舵を切っていた。しかし次の年の総選挙に勝利した彼女は自由民主党との小連立を組むと原発利用を復活させる。しかし 2011 年に福島第一原子力発電所の事故が起こり世論が大きく反原発に動くや彼女はまた政策を変更し 2022 年末までの原発廃止を決めた。彼女は良い科学者である前に賢い政治家なのだ。16 年の長きにわたる政権維持はその成果であるが、石炭と原子力をやめロシアからのガスに依存する選択をしたことでドイツの過度なロシア依存を招き、一方でプーチン大統領に過度の自信を与えたことで今のロシア・ウクライナ戦争という戦後最大の地政学的危機を招いたのも彼女の決断にあったと言えるだろう。

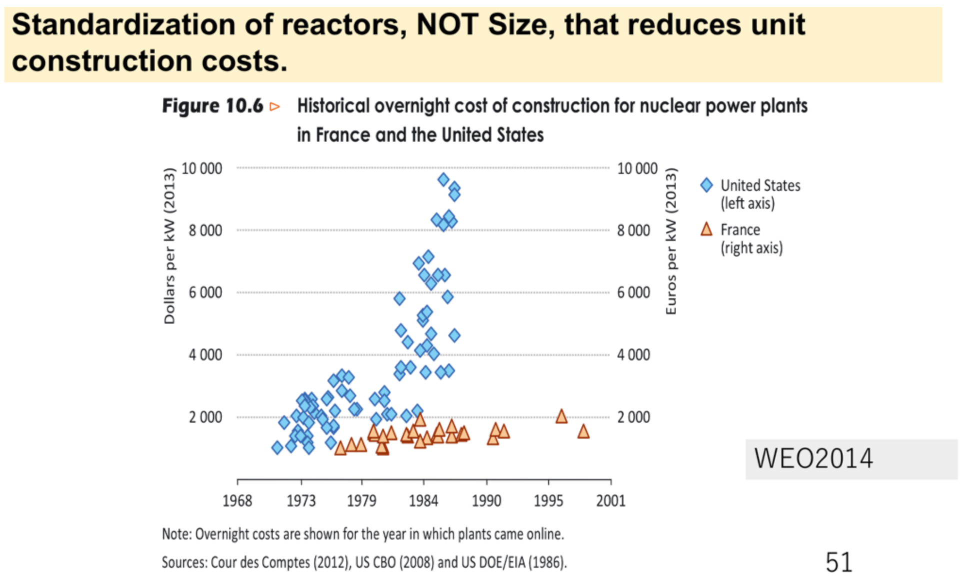
グローバルエネルギー危機はしかし 10 年経てば収まる。より深刻なのは迫り来る気候危機や核戦争かもしれない。人類を滅ぼすのはウイルスではなく核戦争か、気候危機、はたまたアルゴリズムだと言ったのは「サピエンス全史」の著者、ユヴァル・ノア・ハラリである。ハラリはこれらの危機は全てグローバルなものであり、一つの国単位では解決不能であるという。他方今の世界の政治状況はポピュリズム、自国優先のナショナリズムが闊歩しておりグローバルな価値である民主主義、自由主義は危機的状況にある。これは由々しき状態で人類の危機に対処するにはグローバルアイデンティティを持った政治家が必要とハラリはいう。テロリストの凶弾に倒れた安倍元総理は数少ないそんな政治家だった。国葬儀に多くの世界の首脳が集まったのも彼が作った信頼関係があったからだろう。本当に彼の死は惜しまれる。（写真はICEF2019 での安倍首相、彼は ICEF の創設者である）

ICEF 2019 / Green Innovation Summit 2019-10-9

現在のウクライナ核戦争危機、グローバルなエネルギー危機さらに気候危機にあたって日本は何をすべきなのか。一つの答えは原子力の平和利用にあるように思う。メルケルの失敗を見れば原子力がいかにエネルギー安全保障上重要かは明らかだ。百万キロワットの原発を一基稼働すれば年間百万トンの LNG 消費を節約することができる。岸田首相が宣言したように原発 10 基がさらに再稼働すれば一千万トンだ。これなら日本へのロシアからのガス供給が途絶えても電力不足にならないで済む。余った分はドイツに回せば喜ばれる。コストのかからない国際貢献である。また二酸化炭素を排出しない原発は温暖化対策にも貢献する。停止中の原子炉の再稼働はコスト的にも安く、安全に最大限の措置をとった上で再稼働し、さらに運転期間を 40 年から 60 年、さらに米国に見られるように 80 年への延長を検討することは正しい選択だろう。とはいうものの福島事故以後原子力に対する国民の意見は極めて厳しく、その稼働は政治問題である。原発は事故を起こせば福島のように甚大な被害をもたらす。事故後世界一厳しい安全基準をかけていると言っても絶対安全はない。特に大型炉は例え安全性を高めても緊急避難地域を大きくとらなければならないように万が一のリスクが高い。それに比べ小型炉（SMR）なら避難地域をプラント内に収めることもデザイン次第で可能だろう。また受動的安全装置も小型化によってコストが下がる。SMR は地元需要のための柔軟な発電、給熱システムなのだからデザイン段階から地元の意見を反映することができるだろう。社会的受容性も格段に高まるはずだ。大型軽水炉に比べ SMR は発電単価が高いとの懸念があるが、これまでの大型炉のコストは建設期間の延長や安全仕様の変更などで当初コストの 2 倍 3 倍となっており、むしろ同型炉をたくさん建てる標準化がコストを抑える方法である。SMR こそそれを実現するイノベーションである。変動する風力や太陽光のバックアップとしてピーク時に高い値段で運用するのが SMR であり、ベースロードとして大型炉を動かし続ける今の大型軽水炉システムとは違ったパラダイムになる。（グラフ）福島の燃料デブリをはじめこれまでの大型軽水炉による発電の結果としての使用済み燃料、それを六ヶ所村の再処理工場で処理しプルトニウムを取り出した後の高レベル廃棄物など原子力のバックエンドの処理方法も未確定でありこれが決まらないことが国民の不安を増幅している。さらに核兵器への技術転用問題がある。ウクライナがブダペスト合意でロシアに核兵器を返還したが、もししなければロシアはウクライナに侵攻し

たであろうか。北朝鮮やイラン以外にも核兵器を持つことが絶対的な安全保障になると考える国が増えても仕方ない状況がある。戦後の核不拡散体制は今や崩壊の危機にあると言っても過言ではない。原子力を平和利用する国で核兵器への転用を防ぐ技術の開発が必要だし、転用を監視する IAEA の保障措置も見直されるべきだろう。





原子力が持続可能であるためには単に安全性や二酸化炭素を出さないだけでは不十分である。今年のイノベーション・フォー・クール・アース・フォーラム（ICEF2022）の原子力セッションは上述のような問題点を四つの原子力の持続可能条件としてまとめた。すなわち第一が小型炉と受動的安全性によるリスクの最小化である。第二が高レベル放射性廃棄物処理計画がフィンランドのように具体化していること。EU の持続可能投資のタクソノミーもこれが条件だ。第三番目が核兵器への転用可能性が低い技術であることである。そして最後の第四番めが社会的政治的持続可能性である。民主主義国では特に原発の地元が受け入れるデザインであるべきだ。ICEF に登壇したアディティ・ベルマ教授はそれを「デザイン・ジャスティス」と呼

んだ。SMR ならデザイン当初から建設地のコミュニティの要望を取り入れることができる。米国ワイオミングでテラパワー社が計画しているナトリウム炉はナトリウム冷却、金属燃料の高速炉だが、古い石炭発電をリプレイスして地元雇用を守ることが目的だ。また溶融塩を利用した熱貯蔵システムでピーク時への対応を可能にしている。カナダの SMR はオイルサンドを溶かす熱源として北西部での利用が期待される。ロシアは北極海沿岸に小型炉を搭載したバージ船を係留することですでに電気を供給している。原子力の将来はこのような地方分散型で、自然エネルギーと食い合わせの良い柔軟なものになるだろう。頻繁に出力調整するなど柔軟性を増すためには金属燃料が最適である。原子力潜水艦や砕氷船は金属燃料を利用して頻繁に止めたり動かしたりしている。他方で酸化物燃料は硬くすることで扱いやすい燃料にしたが出力調整すれば壊れやすく、ベースロードとして動かし続けるのが良い大型軽水炉に適した燃料なのだ。原子力のイノベーションは SMR とともに金属燃料への転換でもある。廃棄物処理を進めるにも金属燃料は役に立つ。高レベル放射性廃棄物を十万年をこえて安定的に置いておく必要があるのはそれにマイナーアクチノイド（MA）と呼ばれる半減期の非常に長いアメリシウムやキュリウムなどの超ウラン元素が混ざるからである。これを使用済み燃料からプルトニウムなどと一緒に取り出し高速炉で燃やしてしまうのが乾式再処理法（pyroprocessing）である。六ヶ所村の湿式再処理法（Purex）はプルトニウムのみしか取り出せないために廃棄物が無害化するのに十万年を超える時間が必要だが、この方法なら三百年になる。三百年も長いがこれなら処分地を探すのはずっと楽だろう。さらに将来はこのゴミをさらに無害化して百年以下にする核種変換技術も開発可能である。またこの乾式再処理は福島原発の燃料デブリからプルトニウムと MA を取り出し小型高速炉で燃やすことで三百年のゴミにできる。デブリは例え壊れた炉から取り出せてもどこにも運んでいけないだろう。受け入れてくれる県があるとは思えない。福島の中で処理し三百年のゴミにして福島に置いておくしかない。キャノングローバル戦略研究所が次世代原子力研究会を開き持続可能な原子力とは何か、中間報告書をまとめた。（https://cigs.canon/article/20221006_7042.html）またこの研究会にオブザーバーとして参加している長山智恵子さんが同研究会が開いたシンポジウムについてコメントしているので是非聞いてもらいたい。（写真）（https://cigs.canon/videos/20220310_6639.html）

福島からのコメント｜次世代原子力を考えるシンポジウム⑤

彼女は福島で教諭をしていた 20 代で不治の筋肉の病にかかり治療法もなく全てを諦めるしかなかったが、今でも誇り高く色々発信されている。福島事故について彼女は「美しま、福島」は無くなってしまったが、この乾式再処理と金属燃料小型高速炉を福島に作って廃炉を進めればこれが日本の技術への信頼回復、世界の原子力平和利用に貢献できるということで「尽くす島、福島」になれるはずだという。自分には回復の道はないが、福島は事故の結果は諦めても将来への貢献で立ち直ってほしいと言う。

また日本がプルトニウムを貯蔵、利用していることに核保有への意図を疑う周辺国もある。この際日本は余剰プルトニウムを IAEA の管理のもとに置き、他方核兵器禁止条約に正式に加盟して、平和利用へのコミットを再確認すべきだろう。広島出身の岸田首相が宣言すれば米国が反対できるはずはない。核不拡散体制を強化するためにも非核兵器国を国連安保理の常任理事国とするべきだろう。日本は平和利用に徹し原子力平和利用のリーダーとしてその地位にふさわしい外交を展開すべきだ。

政治家は福島に乾式再処理や高速炉など原子力施設を建てるなんてとんでもない、米国の核の傘の下にある日本がそんな外交ができるはずがないと言うだろう。しかし原子力を再生するには他に道はない。長山さんの勇気と安倍元首相のグローバルアイデンティティに学び、次世代原子力への道を福島から始めてほしい。

執筆者紹介

田中　伸男（たなか のぶお）
“Innovation for Cool Earth Forum (ICEF)”における運営委員会の議長を務める。2007年から2011年の間、国際エネルギー機関（IEA）事務局長。IEA在任中2011年6月の石油備蓄放出を主導した。非加盟国である中国・インドとの関係強化に重要な役割を果たした。通商産業省（現経済産業省）では、通商政策局通商機構部長をはじめ、数々の要職を歴任。世界貿易機関（WTO）と二国間の自由貿易協定に向けた貿易交渉を主導。1982年から1985年の間は外務省在アメリカ合衆国日本国大使館（ワシントン駐在）で経済担当一等書記官を務め貿易摩擦問題などに取り組んだ他、1988年から2000年まで外務省在アメリカ合衆国日本国大使館公使。国際情勢に関する専門的な見識を活かし、経済開発協力機構（OECD）の科学技術産業（DSI）局長も務めた。現 Tanaka Global, Inc. CEO。

2. Asian Developing Countries' Pathways to Carbon Neutrality

アジア新興国のカーボンニュートラル実現への道筋

Energy Transformation and Sustainable Growth

Yukari Yamashita*

After COP26 in November 2021, actions on climate change countermeasures were expected to accelerate further in 2022. Unfortunately, the 2022 winter started with a concern for natural gas shortage around the world. Earlier in the 2021 summer/autumn season in Europe, demand for natural gas surged rapidly caused by a shortage of renewable electricity. Consequently, gas prices increased not only in Europe but around the world as well, raising concerns about the impact of fuel shortages on power supply. Meanwhile, Russia's invasion of Ukraine in February further increased the natural gas supply shortages, resulting in soaring energy prices. The 2022 shortage situation that suddenly emerged forced the world to realize the importance of energy security.

Natural gas, which is considered as the transitional energy source to future climate change countermeasures, is now becoming an issue as developing and emerging countries may continue to use cheap coal while the wealthier developed countries can secure the expensive gas (and lower their emissions). This may bring back the issue of divided world (i.e. North-South issue). To resolve climate change, it is essential for <u>all</u> countries to reduce emissions, including emerging and developing countries. Therefore, at this IEEJ/APERC symposium and as a follow up from the previous year, we discussed with Asian researchers the challenges of achieving carbon neutrality for the emerging and developing countries.

Introduction

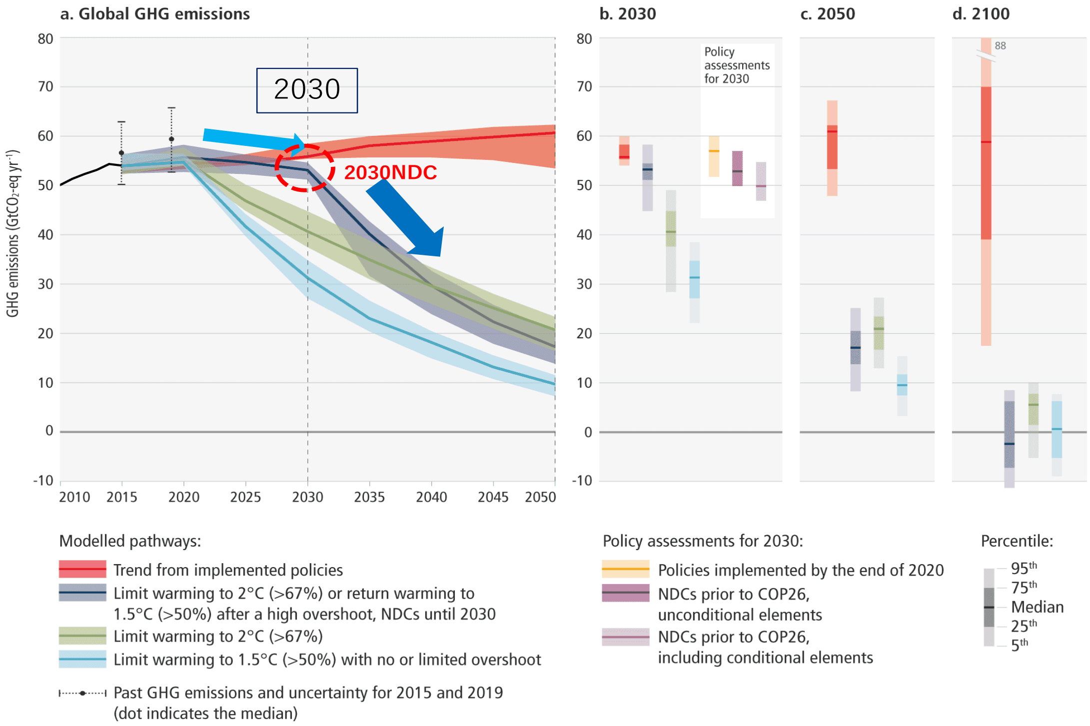
This is a summary of Session 2 of the IEEJ/APERC Symposium, held in Tokyo in April 2022. It was entitled; "The Path to Achieving Carbon Neutrality in Emerging Asian Countries". Climate change is a challenge faced by humanity and it cannot be solved by some or a few countries alone. The current crusade toward carbon neutrality (CN) for all is not perfect because of the insufficiency of concrete measures suitable for the developing world, even under a Sustainable Development Philosophy. The key is whether the entire world, emerging and developing as well as developed countries, can tackle climate change and move in the same direction.

In early April, the IPCC Working Group III report was released, and it was once again pointed out that the summation of the countries' Nationally Determined Contributions (NDCs), that are targeting 2030, are significantly insufficient to be on the paths of either the 1.5°C target or the 2°C target for 2050. Substantial emission reductions from 2030 onward will be necessary (Fig. 1).[1] The movement toward decarbonization by the financial community and companies is rapidly gaining momentum, but the perspective of how to support the transition to decarbonization in emerging and

* Managing Director, Charge of the Energy Data and Modelling Center, IEEJ
[1] IPCC AR6 WG3 SPM Figure SPM.4

developing countries is often overlooked. In this session, we continued from last year and discussed the importance of transition.

Fig. 1 Relationship between Emission Pathways and NDC Targets Depending on Future Temperature Rise Levels



(Source) IPCC AR6 WG3 SPM Figure SPM.4

What is Necessary for the Energy Transition of Emerging and Developing Countries

At the beginning of the session, Asian experts talked about their own perspectives on what would be required by the emerging and developing countries to transition towards carbon neutrality.

Dr. Han Phoumin, Senior Energy Economist, ASEAN-East Asian Research Centre (ERIA), collaborated with the Institute of Energy Economics, Japan (IEEJ) in a study on electrification toward decarbonization in ASEAN[2]. He emphasized that the strategy should first utilize as much as possible zero carbon power sources, including conventional hydropower, geothermal, biomass, etc. By 2060, ASEAN should achieve a well-balanced use of low-carbon technologies for various fossil fuels, including hydrogen, ammonia, CCS, etc., which would lead to effective CO_2 emissions reductions. He emphasized the importance of reducing the technology costs and increasing the

[2] ERIA and IEEJ, Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060 (July, 2022) Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060 (eria.org)

international cooperation in overcoming the economic challenges toward achieving carbon neutrality. A scenario based on carbon neutrality will result in higher costs for the emissions reductions and higher energy prices.

Dr. Leana Srivastava, then deputy director of the International Institute for Applied Systems Analysis (IIASA), pointed out that as of November 2021, countries that accounted for 90% of global greenhouse gas emissions had agreed to net-zero targets. Unfortunately, countries accounting for 73% of those emissions have not announced nor released their concrete plans to achieve such objective. She stressed the need to significantly reduce fossil fuel consumption if we want to achieve the goals of the Paris Agreement.

Based on various scenario analyses for carbon neutrality, it was pointed out that power demand will increase in the future due to electrification in the transport sector and population growth. The amount of power generated by renewable energy will increase significantly and become one of the major power sources. However, it is also estimated that in South and Southeast Asia, at least 50% of the electricity by 2030 and 100% by 2050 will need to be supplied by decarbonized power sources. Coal-fired power should decline sharply by 2030 and need to be phased out by 2040. Global coal-fired power generation doubled since 2000, primarily because of a rapid economic growth in China and India. As both countries are still planning for significant coal generation expansion in the future, various supports, such as investments in clean energy and infrastructure, the formulation of quantitative frameworks, and governance are needed.

Dr. Dina Azagalieva, Research Fellow at the Asian Development Bank Institute (ADBI), noted the potential of green bonds in Asia, which Europe and the United States introduced ahead of Asia. Green bonds, which surged since 2021, are a means of financing infrastructure investment in the Asia-Pacific region. She also stressed three related issues with green bonds. First, she cited the cost of certification, etc., to indicate that projects are “being green.” One solution to this is government support for green bonds, as has already been done in Hong Kong, China, Japan, Malaysia and Singapore. The second challenge is the risk of fluctuations in foreign exchange relative to local currencies that arises when green bonds are issued in foreign currencies. On the other hand, if the fluctuation is severe, repayment in local currency is one of the options, as has been the case in Malaysia. The third issue is related to the demand uncertainty for publishers with low credit rating (such as Moody’s). One solution to this is for government and pension funds to guarantee the purchase.

The Asian Development Bank’s (ADB) Energy Transition Mechanism (ETM) aims to accelerate the transition from fossil fuels to clean energy based on market forces. As a mechanism, she explained that pilot projects were being carried out in Indonesia, the Philippines, and Vietnam, and that these projects were contributing to the early phase-out of coal-fired power plants in the three countries. She emphasized that there was no single one-size-fits-all solution to long-term climate action, and that it was necessary to take multiple measures.

Energy Security and Asia

The panel discussion first addressed energy security and the dangers of dependence on a single energy source, which have become a concern around the world since the Ukraine crisis.

ADBI's Dr. Azagalieva pointed out the implications of a power supply shortage. such as the one that Japan faced in January 2022. The more important message is to first improve energy efficiency (lower demand) because supplies from renewable energy may not increase as fast as demand for electricity will increase in Asian countries. For example, in Malaysia and Singapore, there are examples of green buildings promoting cooling with low-carbon energy using green bonds.

Dr. Srivastava emphasized that achieving carbon neutrality by 2050 will not be easy. She also reminded the audience that each country's path would be different due to issues such as biodiversity, air pollution, as well as energy access in developing countries. Progress toward achieving the SDGs goals is also not rapid and she emphasized the importance of responding with a sense of urgency going forward.

Dr. Phoumin emphasized that carbon neutrality could not be achieved with a single energy source and that decarbonization needed to be considered across all sectors and a wide range of technologies. To achieve carbon neutrality, existing mature technologies that do not rely on fossil fuels such as solar, wind, and biomass must be first utilized, but it is important for government agencies and financial institutions to understand the need for each technology and invest in each of them. He also pointed out the energy transition must rely not only on important technologies such as renewable energy, but on CCS, ammonia, and DACS (direct air capture and storage) as well. In the medium term, he emphasized that the early phase-out of coal-fired power generation would be required, and that the formulation of policies (roadmaps) for the transition from coal-fired power generation to renewable energy would be a challenge in Southeast Asian countries.

It was emphasized that energy security is a top priority for Asian countries and that cooperation among countries is necessary. Amid the current high fossil fuel prices, the need for the immediate introduction and acceleration of renewable energy was pointed out. Dr. Srivastava emphasized that this required a shift in both our own mindset and behavior.

Expectations for Technologies for Carbon Neutrality

The government of Japan is providing for various assistance in technologies such as hydrogen, ammonia, and CCUS. According to Dr. Phoumin, it is important for Southeast Asia, which is currently highly dependent on fossil fuels, to combine and consider other options including hydrogen, ammonia and CCUS. He pointed out that there is a growing need for co-firing technologies and that hydrogen is particularly important for the transportation and power generation sectors, while ammonia is more for the power generation sector.

ADBI's Dr. Azagarjeva mentioned that the costs for hydrogen, CCUS and energy storage are rapidly declining, but they are still expensive. She expressed her hope that the use of these technologies would reduce the needs for fossil fuels. To attract investment, it is important to be green meaning that it is important to use renewable energy for hydrogen production and for storing energy. On the other hand, she said that fossil fuels could not attract investors unless they were used to produce hydrogen (with CCS). She emphasized the need for a “green” definition that was accepted by investors.

Dr. Srivastava, on the other hand, emphasized that technology was one solution, but not the only solution. Since many technologies are still in development and not readily available, the problem is to not get too caught up with high expectations for innovations. It is necessary to recognize that there are risks in new technologies.

Conclusion

Energy security has long been an important issue and often served as the basis of energy policies for countries that heavily rely on imports for most of their energy needs, such as Japan and emerging Asian economies. In the discussion on Japan’s Strategic Energy Plan, securing a stable supply of energy is as high a priority as simultaneously achieving economic efficiency and environmental compatibility (*and nuclear safety (S)*). Energy security is among the 3Es (stable supply, economic efficiency, and environmental compatibility). Since the entry into force of the Paris Agreement, response to climate change has been given top priority, mainly in Europe, and the importance of energy security has been set aside while declaring carbon neutrality captured the center of attention. Issues during the energy transition period have quickly become apparent, calling for the review of the role of nuclear power, the importance of ensuring a stable supply of electricity and the need for securing fuel despite a substantial increase in renewable electricity. The importance of sharing the challenges faced by emerging and developing countries is rising and an increasing international cooperation in energy and environmental measures is required.

Writer’s Profile

Yukari Yamashita

Ms. Yamashita is responsible for quantitative and qualitative analyses on energy policy issues. Her team’s analyses and recommendations contribute greatly to the debate and policy making for Japan and international communities such as ERIA, APEC and IEA. The annual IEEJ’s Outlook is globally recognized for its timely analyses and pragmatic approach towards climate change. She has been serving as a member of various government councils and committees in the fields of energy and science & technologies. She also led miscellaneous international and regional energy cooperation programs through IEA, APEC, ERIA and IPEEC. She served as the 2020 President of the International Association for Energy Economics (IAEE).

エネルギー変革と持続可能な成長

山下　ゆかり *

2021 年 11 月の COP26 開催を受けて、気候変動対策のさらなる加速が期待された 2022 年は、再エネ電力の不足から欧州で天然ガス需要が急増、ガス価格が世界中で高騰し、燃料不足による電力供給への影響が懸念される冬を迎えていた。その中、2 月のロシアによるウクライナ侵攻で世界はさらなるエネルギー価格の高騰と天然ガスの供給不足への対応を迫られ、エネルギー安全保障の重要性が急浮上した。

気候変動対策において移行期のエネルギーとして各国が利用を好む天然ガスの供給不足という事態は裕福な先進国が高価なガスを確保する一方で、途上国や新興国が安価な石炭利用を続ける可能性と、両者の分断化を招く危うさを抱える。気候変動問題の解決には途上国を含む全ての国による排出削減が欠かせない。そこで、今回の IEEJ/APERC シンポジウムでは昨年に続けて新興国や途上国のカーボンニュートラル実現に向けた課題についてアジアの研究者と議論した。

【はじめに】

本稿は 2022 年 4 月の IEEJ/APERC シンポジウムのセッション 2「アジア新興国のカーボンニュートラル実現への道筋」の議論に沿って整理する。気候変動は全人類の課題であり、一部の国だけでは解決できない。持続可能な成長理念と照らしても、途上国向けの具体的な対策が十分でない現在のカーボンニュートラル（以下、CN）の動きは完璧ではない。新興国や途上国を含む全世界が気候変動対策に取り組み、同じ方向に進めるかどうかがカギである。

4 月初旬には IPCC 第 3 作業部会の報告書が発表され、各国の 2030 年に向けた取組目標である NDC（Nationally Determined Contribution 国が決める貢献）の総計は 1.5 度目標だけでなく、2 度目標の達成にも大幅に不足していることから、2030 年以降の大幅な排出削減が必要であることが改めて指摘された（図 1）[1]。金融界や企業による脱炭素化の動きも活発化しているが、途上国や新興国の脱炭素化に向けた移行をどう支えるかという視点が見落とされがちである。本セッションでは昨年に続いて移行（トランジション）の重要性を取り上げた。

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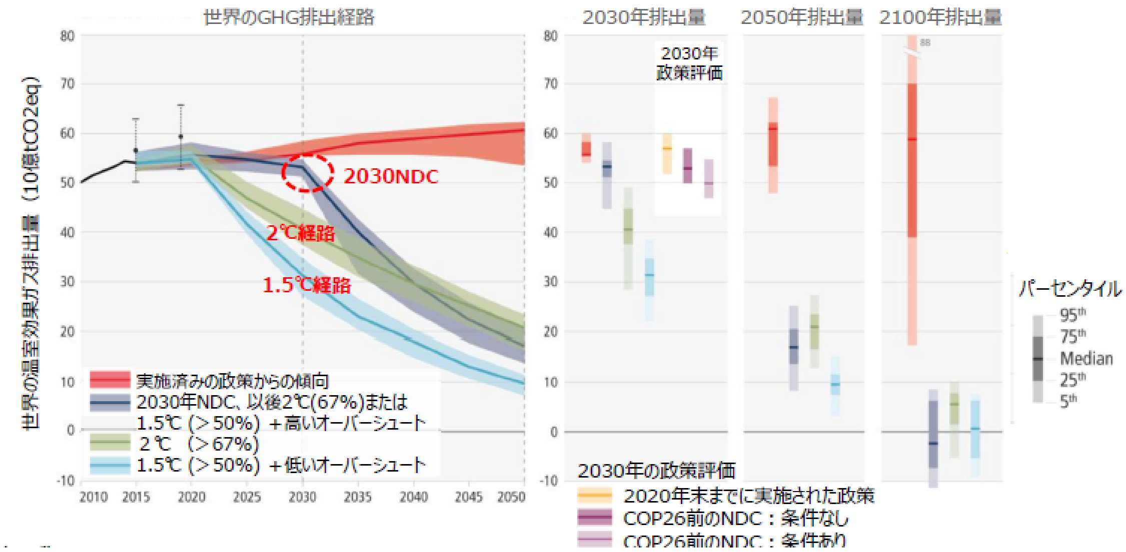
* （一財）日本エネルギー経済研究所　常務理事　計量分析ユニット担任
[1] IPCC AR6 WG3 SPM Figure SPM.4

図 1 将来の気温上昇水準に応じた排出経路と NDC 目標との関係



出所：環境省訳、「IPCC 第 6 次報告書第 3 作業部会報告書政策決定者向け要約解説資料」（2022.4.5）

【途上国・新興国の移行に必要なこと】

セッションの最初に、途上国や新興国のカーボンニュートラルに向けた移行に何が必要であるかについて、アジアの専門家から各自の視点から語ってもらった。

東アジア・アセアン研究センター（ERIA）シニアエネルギーエコノミストのハン・フーミン氏は弊所（日本エネルギー経済研究所、IEEJ）との共同研究[2]を引用して ASEAN の脱炭素化に向けた電化への対応として、まずは従来型の水力、地熱、バイオマス等を含む様々な低炭素電源の活用が重要な戦略となることを強調。さらに、2060 年に向けて水素、アンモニア、CCS 等を含む様々な化石燃料の低炭素化技術をバランス良く活用することが CO_2 の効率的な排出削減につながると指摘した。なお、カーボンニュートラルを前提としたシナリオでは排出削減コストやエネルギー価格は上昇する結果が得られるため、カーボンニュートラル達成に向けた経済的な課題克服には、エネルギー技術のコスト削減や国際的な協力が重要であることを強調した。

国際応用システム分析研究所（IIASA）のリーナ・スリバスタバ副所長（当時）は 2021 年 11 月時点で、世界の温室効果ガス排出の 9 割を占める国々がネットゼロ目標を掲げる中、排出量の 73%を占める国々では必ずしも目標達成に向けた計画が十分ではないことを指摘。パリ協定の目標達成に向けては化石燃料消費を大幅に削減する必要があることを強調した。

様々なシナリオ分析の結果から、運輸部門等の電化や人口増加によって将来の電力需要が増加する中、再生可能エネルギーによる発電量が大幅に増えて主力電源となり、南・東南アジアにおいても、2030 年までに少なくとも 5 割、さらに 2050 年までに 100%を脱炭素電源によって供給する必要があると指摘。石炭火力については 2030 年までに急激に減少させ、2040 年までにフェードアウトが必要とした。実際には、2000 年以降世界の石炭火力発電は中国とインド

[2] ERIA and IEEJ, Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060 (July, 2022) Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060 (eria.org)

での爆発的な導入で倍増、かつ、今後も両国で大幅な増設が計画されている中、クリーンエネルギーやインフラへの投資、計量的なフレームワークの策定、ガバナンス等、様々なサポートが必要だと指摘した。

アジア開発銀行研究所（ADBI）リサーチフェローのディナ・アザガリェバ氏は、アジア太平洋地域におけるインフラ投資の資金調達手段としてグリーンボンドが 2021 年以降急増してことから、欧米で先行したグリーンボンドのアジアでの可能性に言及した。関連して 3 つ課題があることも指摘した。第 1 に、“グリーンであること”を示す認証等のコストを挙げた。これに対しては、香港や中国、日本、マレーシア、シンガポールで既に行われているような政府によるグリーンボンドに対する支援が一つの解決策となる。第 2 の課題は、外国通貨でグリーンボンドを発行した場合に生じる現地通貨との為替リスクの変動リスクである。これに対しては、変動が激しい場合にはマレーシアで実績があるように現地通貨での返済も選択肢の一つとのこと。第 3 の課題は、ムーディーズ等による格付けの低い発行者に対する需要の不確実性を挙げた。これに対しては、政府や年金基金による買い取り保証が一つの解決策となるとのこと。

アジア開発銀行（ADB）の Energy Transition Mechanism（ETM）は、市場原理による化石燃料からクリーンエネルギーへの移行の加速化を目的としたメカニズムだとして、インドネシアやフィリピン、ベトナムではパイロットプロジェクトが行われており、3 か国においては石炭火力の早期廃止に貢献していると紹介した。その上で、長期的な気候変動対策に向けては、単一の万能な解決策はないため、複合的な対策をとることが必要であると強調した。

【エネルギー安全保障とアジア】

パネル討論では、ウクライナ危機後に世界中の懸念となっているエネルギー安全保障及び単一のエネルギー源に過多に異存する危険性について最初に取り上げた。

ADBI のアザガリェバ氏は日本が 2022 年 1 月に直面した電力の供給不足に関連して、アジア諸国でも急激に電力需要が増える中、再生可能エネルギーがすぐに大幅に供給を増やせるとも限らないため、エネルギー効率の向上が重要であると指摘。例えばマレーシアやシンガポールでは、グリーンボンドを活用した低炭素エネルギーによる冷房を利用するグリーンビルディングの推進事例があることを紹介した。

スリバスタバ氏は、2050 年のカーボンニュートラル達成が容易ではないことを強調。生物多様性や大気汚染などの課題や途上国のエネルギーアクセスの課題から各国の道筋が違うことや、SDG s 目標に向けた進捗が芳しくないことも指摘。今後スピード感をもって対応することが重要であるとした。

フーミン氏は単一のエネルギーのみでカーボンニュートラルは達成しえないことと、全てのセクターと幅広い技術で脱炭素化を考える必要がある点を強調。カーボンニュートラル達成に向けては、太陽光や風力、バイオマスなど化石燃料に依存しない既存の成熟した技術を活用しなければならないが、政府機関や金融機関が各技術の必要性を理解して投資していくことが重要とした。また、再エネだけでなく CCS、アンモニア、DAC（直接大気回収）などの技術を用いてエネルギー移行をする重要性も指摘。中期的には、石炭火力発電の早期廃止が必要となる中、東南アジアの国々では、石炭火力発電から再生可能エネルギーへの移行に向けた政策（ロードマップ）の策定が課題となっている点を強調した。

アジア各国にとってエネルギー安全保障が最優先課題であり、各国の協力が必要である点が強調された。化石燃料価格が高い中、再生可能エネルギーの早急な導入の必要性と加速化につ

いても指摘された。スリバスタバ氏はそのための我々自身のマインドセットと行動の両面の切り替えが必要だと強調した。

【カーボンニュートラルに向けた技術への期待】

日本政府は水素・アンモニア・CCUS などの様々な技術支援をしている。フーミン氏からは、東南アジアは化石燃料の依存度が高いため、水素、アンモニア、CCUS を組み合わせることが重要。水素は特に重要であり、輸送と発電用以外の活用を、また、アンモニアは発電用に混焼技術の必要性が高まっていると指摘した。

ADBI のアザガリェバ氏は、水素、CCUS、エネルギー貯蔵は、現状はまだ高コストだが急速に下がってきている点を指摘。これらの技術の活用によって、化石燃料の使用を減らすことへの期待を述べた。投資を引き寄せるには、グリーンかどうかが重要。水素の製造に再エネを使うこと、エネルギー貯蔵も再エネで行うことが重要。一方で、化石燃料については、水素の製造に使うのかどうか明確にしなければ投資家を引き寄せることできないと述べ、投資家に受容される“グリーン”の定義が必要となる点を強調した。

一方、スリバスタバ氏は技術は解決策の 1 つだが全てではないことを強調した。発展途上の技術は直ぐに利用可能ではないため、問われるのは我々のマインドセットだとした。イノベーションにとらわれすぎてしまうのは問題であり、新たな技術にはリスクがあることも認識することが必要であるとした。

【おわりに】

エネルギー安全保障はエネルギーの大宗を輸入に依存する日本やアジア新興国にとって従前からエネルギー政策の基本となる重要な課題である。日本のエネルギー基本計画の議論では原子力の安全性（S）を前提とした上で、3E（安定供給、経済効率性、環境適合）のうちエネルギーの安定供給の確保を優先課題としつつ経済効率性と環境適合の同時達成を念頭に置く。パリ協定の発効以来、欧州を中心に環境適合（気候変動への対応）を最優先課題とし、カーボンニュートラル宣言等多くの取組みがなされる中、エネルギー安全保障の大切さが忘れられていた。原子力の役割の見直しや再エネ電力が増える中での電力の安定供給と燃料確保の重要性など、エネルギー移行期の課題が顕在化している。新興国や途上国が直面する課題の共有とエネルギー・環境対策での国際協調の重要性が増している。

執筆者紹介

山下　ゆかり（やました ゆかり）
担任する計量分析ユニットは我が国のエネルギーミックスの議論に資する各種分析で貢献。毎年発表するIEEJアウトルックはタイムリーな分析と気候変動の実践的アプローチで世界に知られる。国際エネルギー機関（IEA）、APEC、ERIA、IPEECなど、エネルギー分野の国際協力で活躍し、国際会議等での講演・モデレーターの経験豊富。2020年国際エネルギー経済学会 会長。

Scenario Plausibility

Roger Pielke Jr.*

Scenarios are common in environmental research, and particularly so in climate research and policy. The climate research community uses scenarios to "provide plausible descriptions of how the future might unfold in several key areas – socioeconomic, technological and environmental conditions, emissions of greenhouse gases and aerosols, and climate" (Moss et al. 2010). Such scenarios "play a fundamental role in improving understanding of the climate system as well as characterizing societal risks and response options" (O'Neill et al. 2016). Climate scenarios thus make important contributions to the development and evaluation of climate policy options.

In this short paper I summarize recent work I and colleagues have conducted on the plausibility of the scenarios of the Intergovernmental Panel on Climate Change (drawing from Burgess et al. 2020, Pielke and Ritchie 2021, Burgess et al. 2022, Pielke et al. 2022). The IPCC and much of the climate research community uses carbon dioxide (CO_2) emissions scenarios to imagine and evaluate "a range of plausible futures, because human development is determined by a myriad of factors including human decision making" (IPCC WGIII 2014).

Scenarios used in the IPCC 5th Assessment Reports (AR5) and 6th Assessment Reports (AR6) include the 'Representative Concentration Pathways' (RCPs) and the 'Shared Socioeconomic Pathways' (SSPs) (see Pielke et al. 2022). The high-emissions end of the RCP/SSP range is consistent with 8.5 W/m^2 radiative forcing and 4°C–5°C of warming relative to pre-industrial levels by 2100 (e.g. SSP5-8.5, RCP8.5). At the low end, scenarios project emissions consistent with 1.9 W/m^2 radiative forcing and 1.5°C of warming or slightly less by 2100 (e.g. SSP1-1.9).

The report of Working Group 1 of the IPCC AR6 observes that "No likelihood is attached to the scenarios assessed in this Report." Yet, at the same time the IPCC AR6 recognizes that "the likelihood of high emissions scenarios such as RCP8.5 or SSP5-8.5 is considered low" and recent 'stated policy' scenarios of groups such as the International Energy Agency (IEA) are "approximately in line with the medium RCP4.5, RCP6.0 and SSP2-4.5 scenarios." The IPCC's recent recognition of scenario likelihood is part of a broader and fast-moving discussion of scenario plausibility and implications for research and policy (sources can be found in Pielke et al. 2022).

Scenario 'plausibility' has been discussed for many years, but the IPCC has not evaluated the plausibility of scenarios central to much of climate research and assessment (Pielke and Ritchie 2021). Our recent analysis defines a 'plausible' scenario as one in which future fossil-fuel-and-industry (FFI) CO_2 emission growth rates of the scenario show a consistency with historical observations and IEA Stated Policies Scenario (STEPS) near-term projections (see Pielke et al. 2022 for details on our methodology). A scenario that has already diverged from reality is, by

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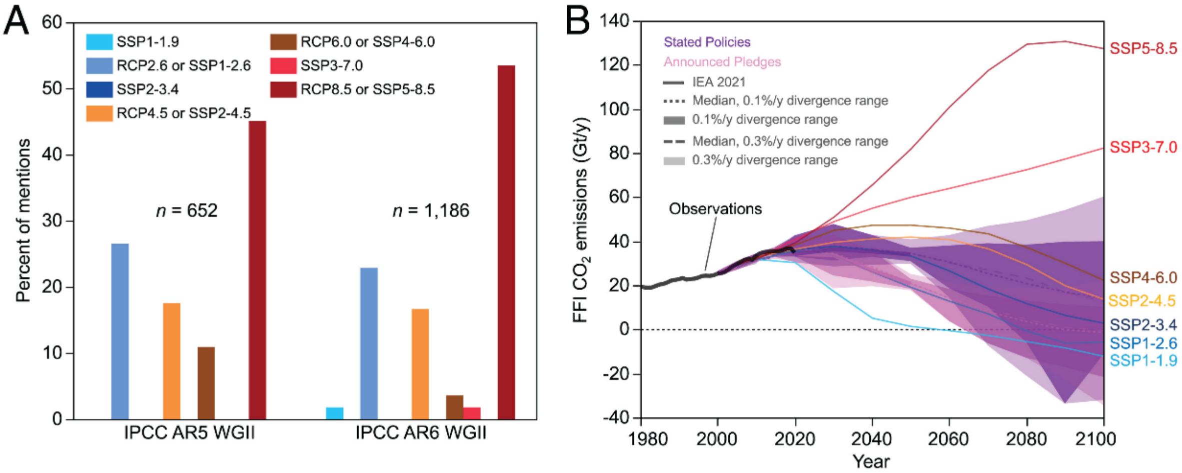
definition, not plausible. It is theoretically possible for a scenario that has already diverged significantly from observations to later return to the same projected future emissions level, though for this to occur would imply opposite divergences in the future, which would require a major departure from the trajectory of the original scenario, thus also making that scenario implausible, even if it were to arrive at the same final level of emissions (see Burgess et al 2021).

The figures below show (A, left) the prevalence of scenario mentions in the IPCC AR6 (Working Group 2 report) and (B, right) our results for all scenarios of the IPCC AR6 in terms of plausibility (the figures were originally published in Burgess et al. 2022). The detailed methodology for the quantitative evaluation of plausibility is described in Pielke et al. (2022).



The figure shows that plausible scenarios span a 2100 range below and above the SSP1-1.9 and SSP4-6.0 scenarios, centered on a median of a SSP2-3.4 scenario. The SSP3-7.0 and SSP5-8.5 scenarios reside far from the zone of plausibility. However, as the left panel shows the SSP5-8.5 (and RCP8.5) scenarios dominate the mentions in the IPCC report (which follows the same practice of the IPCC AR5, see Pielke and Ritchie 2021). Unfortunately, the climate research and assessment communities emphasize implausible scenarios.

In our work, we have made several recommendations on how the climate research community can correct course away from implausible scenarios and toward those with greater plausibility.

First, and obviously, the climate community could recognize the over-reliance on implausible scenarios, and take steps to immediately address it to avoid a growing credibility crisis. As common sense as this may seem, there are countless academic papers, research grants, the scenario architecture developed over 17+ years, and the ongoing Sixth Assessment of the IPCC – all of which has created an enormous momentum that may prove difficult to change.

Second, serious consideration should be given to either (a) terminating the role of the IPCC in orchestrating the content of climate science, or (b) transferring the mandate of the IPCC to assess climate science research to an organization independent of scenario development that plays no role in shaping how climate research is produced. With respect to scenarios of the future, the hegemony of the IPCC has become a source of myopia, rather than enlightenment.

Third, despite the presence of thousands of scenarios in the community, more regular attention needs to be given to a much simplified set of near-term, policy relevant scenarios, similar to how the International Energy Agency issues scenarios on an annual basis.

Fourth, more work is needed to reconcile long-term narrative pathways based on an idealized year 2100 end-point with what policy makers need to know about the next years and decades. While there are an increasing number of scenarios focused on the role of Paris Agreement NDCs through 2030, there is a significant gap in the IPCC assessments for scenarios that address developments before 2050 in the context of today's policy environment. This gap is created by an excessive focus on long-run, full century scenarios, driven in large part by the needs of the physical science modeling community.

Finally, climate research and assessment would benefit from a more ecumenical and expansive view on relevant knowledge. The IPCC scenario process has been led by a small group of academics for more than a decade, and decisions made by this small community have profoundly shaped the scientific literature and correspondingly, how the media and policy communities interpret the issue of climate change. The dominant role of this small community might be challenged in order to legitimize a broader perspective of views, approaches and methods.

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Writer's Profile

Roger Pielke Jr.
Professor Pielke founded and served as Director of the Center for Science and Technology Policy Research at the University of Colorado Boulder from 2001 to 2007 and from 2013 to 2016. He was a visiting scholar at Oxford University's Saïd Business School in the 2007-2008 academic year. His interests include understanding the use and misuse of science in areas such as the Covid-19 response, climate change, disaster mitigation, energy policy; and sports governance. If 2022, he was on sabbatical in residence at the University of Oslo.

3. Stabilization of Energy Prices and Supply/Demand Balance During the Transition Period to Carbon Neutrality

カーボンニュートラル実現に到る移行期間でのエネルギー価格及び需給の安定化

The Ukraine Crisis and Global Energy Transition

Ken Koyama*

Introduction

The global energy situation is rapidly becoming fluid as a result of the deepening Ukraine crisis, and the world is on the brink of an energy crisis. Stable energy supply and energy security have become issues of top priority around the world, particularly in Europe where there is heavy reliance on Russia for energy, and we face the urgent task of strengthening energy security measures.

Under these circumstances, initiatives toward reducing reliance on Russia, which are increasingly being implemented as the pillar of energy security measures, have become an important concern worldwide. This is because one of the important measures for reducing reliance on Russia is to reduce dependence on fossil fuels, and that could lead directly to promoting decarbonization.

Based on this global energy situation, this paper first discusses the current situation of Ukraine crisis and the associated issues, followed by a discussion on the emphasis on energy security and strengthening of measures emerging from that situation. Thirdly, it discusses the impact that these strengthened energy security measures has on global energy transition, particularly the impact on energy transition toward decarbonization, and finally, examines the future pathway for energy transition.

1. The Ukraine Crisis and Global Energy Situation

The price hikes that occurred simultaneously in the crude oil, natural gas, LNG, coal, and electricity markets from the second half of 2021 were accelerated all at once when Russia launched its military invasion in Ukraine on February 24, 2022, further destabilizing the global energy markets.

All the energy markets saw significant price rises, and historical high prices were recorded across the overall global energy market with the exception of crude oil, which registered its highest prices after the global financial crisis in 2008. Among these, the most dramatic price hikes were observed in European gas prices. Prices on Europe's major trading hub, TTF, hit approximately US$100 per million BTU in August 2022; this was an abnormally high price at the crude oil equivalent of close to about US$600 per barrel. This was caused by a significant drop in supply from Russia through major gas pipelines and a sudden surge in concerns about gas shortage in Europe, amidst the heavy reliance on Russia in the European gas market and difficulty of finding

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alternative gas supplies. Thereafter, Europe strongly advanced various measures to stabilize energy supplies, as described later in this paper, even expanding gas storage to over 90% of its storage capacity under the mild weather conditions and gas consumption reduction coupled with efforts to secure addition supplies including procurement of LNG from the United States and other countries. As a result, gas prices dropped significantly, and calm was restored. Moreover, heightened concerns over a global economic slowdown contributed to widespread expectations of a slowdown in oil demand, manifesting in unstable trends such as the significant decline of crude oil prices in September.

However, despite the decline, crude oil prices remain high at around $80, while European gas prices are also maintaining a high price level at around US$30-40 per million BTU (crude oil equivalent of around US$200). Prices may rise significantly again in 2022 as a result of winter temperatures, or other factors such as whether there are unexpected supply disruptions, depending on the scale of such disruptions.

In the event of a large-scale supply disruption, there is also the possibility of major consumer nations competing over the limited “supply pie” to secure their own supplies. Under such conditions, the potential for chaos and instability in the global energy markets remains; depending on the situation, it may become difficult to procure energy (emergence of physical shortage). Even if the seriously troubled gas market manages to ride over this winter in Europe, the gas market will see very low stock conditions at the start of the year 2023. As additional supplies may be limited after 2023 in the global gas/LNG market, it has been pointed out that the tight demand-supply environment may continue for some time.

2. The Shift to the Emphasis on Energy Security

Soaring energy prices and market instability have emerged as one of the most important issues for the global economy. Even developed region/country such as EU and Japan are increasingly strengthening measures to counter the price increases by introducing various forms of energy subsidies. Rising energy prices have accelerated inflation rapidly particularly in the United States and Europe, and the implementation of raising interest rate policies to counter inflation is having a major impact on global economic growth.

In addition to energy subsidies to cover the price increases, countries are moving forward swiftly on the implementation of more fundamental policies to secure stable supplies of energy and strengthen energy security. This can be seen most symbolically in Europe, which is heavily reliant on Russian energy and is bearing the brunt of this energy crisis. At the same time, however, the emphasis on energy security is an important issue shared by countries around the world. This is because energy is an indispensable good to all countries. Furthermore, in a certain sense, precisely because of the indispensable nature of energy, increases in energy prices have a “regressivity” that hits low-income countries and populations more severely. Hence, we cannot overlook the fact that it is becoming an even more serious issue for emerging and developing countries.

Amidst the current Ukraine crisis, countries are focusing on the following four pillars of energy security policies: (1) Reducing reliance on Russian energy; (2) Strengthening emergency response capability; (3) Implementing and securing appropriate investments for securing supply and surplus supply capacity, and (4) Strengthening stable base load power sources.

Firstly, (1) comprises of two elements: measures to reduce dependence on fossil fuels by accelerating the promotion of renewable energy and energy conservation, expanding nuclear power, etc., and measures to procure alternative fossil fuel supplies produced by countries other than Russia. As for (2), in addition to measures by each country to strengthen domestic resilience, the basic measure is to engage in international cooperation between consumer nations and producer-consumer nations to address the instability in energy markets. (3) is an important pillar to ensure the functioning of (1) and (2), and holds the key to success or failure in promoting investments in the fossil fuel sector, particularly natural gas and LNG. (4) involves initiatives to utilize nuclear power, which is a stable base load power source as well as a zero-emissions power supply.

In Europe, where the energy crisis situation is most severe, various policies are being promoted strongly, as represented by the "REPowerEU" plan. In particular, EU and each country are promoting initiatives as a form of crisis response to the aforementioned soaring gas prices and concerns over gas shortage. Strong energy conservation plans have also been drawn up, and coal-fired power generation is being utilized with the acceptance that CO_2 emissions will increase as a result.

With regard to nuclear power, while moves to utilize nuclear power had been observed within the EU before the deepening of the Ukraine crisis, we are now seeing major moves such as moves by France, the United Kingdom, and Eastern European countries to formulate new nuclear power construction plans, extension of the operation of existing nuclear power plants in Belgium, as well as the decision to maintain nuclear power plants in Germany that had been earmarked for decommissioning within 2022, until the spring of 2023 in order to get through this winter.

Prior to the occurrence and deepening of the Ukraine crisis, debates over global energy issues had focused almost solely on the problem of decarbonization and carbon neutrality. However, we can say that the situation has changed dramatically. Serious problems have occurred with the stable supply of energy, which is indispensable to our daily lives, economic activities, and the operation of nations, and this has in turn given rise to the divide of the world and heightened geopolitical tensions. The recognition of this as an important structural problem has changed the situation completely. We can say that the energy security problem has truly become the most pressing issue for the whole world.

3. The Emphasis on Energy Security and Its Impact on Global Energy Transition

The emphasis on energy security as a result of the deepening Ukraine crisis will have diverse and significant impacts on international politics, the global economy, the global energy situation, and many other areas. How various impacts and changes arise will become an important focus for the world in the future, but amidst that, we cannot overlook the impact that this emphasis on energy security will have on energy transition in a world that is aiming toward decarbonization.

With regard to decarbonization efforts, most countries around the world have already announced policies aimed at achieving net zero emissions around the mid-21st century, and strengthening future measures is vital toward preventing climate change and securing global interests. We can say that the importance of decarbonization remains unchanged regardless of the deepening of the Ukraine crisis.

At the same time, however, in the real world, an emphasis on stable energy supply and energy security is highly likely to impact decarbonization in various ways. The first is, under the present circumstances or from the perspective of crisis measures, securing a stable supply of energy has become the top priority, and depending on the situation, it is very possible for such measures to be incompatible with decarbonization. For example, even in Europe, which is leading the world in its decarbonization initiatives, has not hesitated to utilize coal-fired power generation as a crisis countermeasure. This is because it has no choice but to use all options to secure stable energy supplies. Moreover, many emerging and developing countries are observed to be regressing to coal as a cheaper form of energy, in order to cope with the soaring energy prices. In the short term, the current energy situation could work as an opposing force to decarbonization.

On the other hand, there could be different impacts in the medium- to long-term. This is typically observed in regions such as the EU, where the current policy of reducing dependence on Russian energy takes the form of promoting renewable energy, energy conservation, and the shift to hydrogen and electrification, and the utilization of nuclear power that each country is promoting basically serves to accelerate decarbonization. In light of this crisis, we can take the view that the trend of reducing dependence on fossil fuels as far as possible could strengthen the impact over the medium- to long-term. Of course, this does not apply only to Europe; it could be explored by various countries around the world.

However, there are some uncertainties as to whether efforts to reduce reliance on Russian energy and fossil fuels, equated with efforts to accelerate decarbonization, will go as smoothly as anticipated. This is because when such initiatives and energy transition become too expensive, and especially when coupled with the negative economic situation at that point, it could significantly heighten political and social dissatisfaction. In this crisis, we can already clearly see, even in developed countries, the social impact that soaring energy prices could bring. Thus, this poses a much more formidable challenge to low-income countries. Rather, the question of how to reduce the overall necessary costs for implementing energy transition, has become an extremely important issue. This is another lesson drawn from the Ukraine crisis. To that end, rather than attempting to take an extremely challenging "a leap-flog approach," it has become more important to take gradual and steady steps through an inclusive approach that corresponds to the economic situation, resource reserves, and technological level of each country. Stabilizing the fossil fuel market is the first pressing issue; once the market has become more stabilized, it will be important to explore and implement pragmatic approaches to decarbonization, in order to strike a balance between decarbonization and energy security in the world.

Conclusion

Efforts aimed at striking a balance between energy security and decarbonization will be the most important energy policy issue worldwide in the future. In Japan, too, future energy policies will be based on domestic and foreign strategies aimed at achieving this balance. In addition to strengthening initiatives to achieve the targets set out in its Strategic Energy Plan, Japan will need to advance the review of policies and strategies based on the new situation, toward the formulation of the next Strategic Energy Plan.

Writer’s Profile

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Dr. Koyama joined IEEJ in 1986. He got his PhD in 2001 from University of Dundee, Scotland. He has held many senior positions in IEEJ, including Head of the World Oil & Energy Group, Senior Research Fellow, Energy Strategy Unit. He has served as a committee member of energy policy related councils and advisory committees of Japanese government in many occasion. His specialized field of research is: energy security issues and geopolitics of energy; and analysis for global energy market and policy development with emphasis on the Asia-Pacific region. He has authored numerous publications in the area of energy economics.

ウクライナ危機と世界のエネルギー転換

小山　堅 *

はじめに

ウクライナ危機深刻化で国際エネルギー情勢は一気に流動化し、「エネルギー危機」の状況を迎えることになった。エネルギーのロシア依存度が高い欧州を中心に世界でエネルギー安定供給とエネルギー安全保障が最重要課題となり、その対策強化が急務となっている。

この状況下、エネルギー安全保障対策の柱として実施されつつある、ロシア依存度低減に向けた取組みが世界の重要関心事項となっている。ロシア依存度低減のための重要な方策の一つが、化石燃料への依存を引き下げることであり、それはそのまま脱炭素化推進に直結することにもなりうるからである。

本稿では、こうした国際エネルギー情勢を踏まえ、第 1 にウクライナ危機の現状とそこから生じている課題を論じ、第 2 にその中で浮上しているエネルギー安全保障の重視と対策強化を議論する。次いで、第 3 にそのエネルギー安全保障対策強化が、世界のエネルギー転換にどのような影響を及ぼすのか、とりわけ脱炭素化に向けたエネルギー転換にどのようなインパクトを持つのか、を論じた上で、今後のエネルギー転換の道筋について考察する。

1.　ウクライナ危機と国際エネルギー情勢

2021 年後半から発生していた原油・天然ガス・LNG・石炭・電力市場における同時多発的な価格高騰は、2022 年 2 月 24 日のロシアによるウクライナへの軍事侵攻を機に一気に加速し、国際エネルギー市場不安定化が深刻化した。

いずれのエネルギー市場でも、著しい価格高騰が発生し、「リーマンショック後の最高値」となった原油を除く国際エネルギー市場全体で「過去最高値」を記録することとなった。その中でも最も著しい価格高騰が見られたのは欧州ガス価格である。欧州の主要な取引ハブ価格（TTF）は、2022 年 8 月には 100 万 BTU 当たり約 100 ドル、原油換算で 1 バレル 600 ドル近い異常な高価格となった。これは欧州ガス市場のロシア依存度が高く、ガスにおける脱ロシアが困難な状況下において、ロシアからの主要なガスパイプラインによる供給が大きく低下し、欧州でのガス不足懸念が一気に高まったことによる。その後、欧州では後述する様々なエネルギー安定供給対策が強力に進められ、米国等からの LNG 調達の下でガス貯蔵が貯蔵容量の 9 割超にまで拡大するなどの展開があったため、ガス価格は大きく下落、落ち着きを取り戻すこととなった。また、世界経済減速懸念の高まりで石油需要が鈍化するとの見込みが広がり、原油価格も大きく低下する、など不安定な動きを示している。

しかし、低下したとはいえ、原油価格は 80 ドル前後、欧州ガス価格も 100 万 BTU30～40 ドル（原油換算で 200 ドル前後）と高価格水準であることには変わりない。そして 2022 年の冬季の気温によって、あるいは想定外の供給支障発生の有無や規模などによっては、再び価格が大きく上昇する可能性もある。

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また、大規模な供給支障発生の際には、限られた「供給のパイ」を巡って、主要消費国が供給確保競争に向かう可能性もある。こうした状況下、国際エネルギー市場の混乱・不安定化の可能性は残り続けており、場合によっては、エネルギーの入手困難な事態（物理的不足）の発生の可能性もありうる。状況が深刻なガス市場では、今冬を乗り切っても、2023 年は当初から低在庫状況でスタートすることになり、2023 年以降の追加的な供給拡大が限定的となる可能性があることから、しばらくは厳しい需給環境が続く可能性も指摘されている。

2.　エネルギー安全保障重視へのシフトと対策強化

エネルギー価格高騰と市場不安定化は、世界経済の最重要課題の一つとして浮上することとなった。欧州や日本などの先進国においても、価格高騰対策でエネルギー補助金制度が様々な形で導入され強化されつつある。エネルギー価格高騰の下で特に米国・欧州では一気にインフレが加速し、その対応で強力な利上げ政策が実施されるなどマクロ経済政策にも大きな影響が及んでいる。

価格高騰への直接的な補助金制度などに加えて、より根本的なエネルギー安定供給確保およびエネルギー安全保障強化の政策の実施・強化が急速に進められている。これは、ロシア依存度が高く、今回のエネルギー危機の矢面に立っている欧州で最も明確に顕在化しているが、エネルギー安全保障の重視は世界共通の重要課題となっている。それは、エネルギーがどのような国にとっても必要不可欠の物資だからである。さらに、ある意味では、必要不可欠だからこそ、エネルギー価格高騰は「逆進性」を有しており、所得の低い国・層ほどより厳しい状況に直面するため、新興国・途上国にとってより重大な問題となっている点も見逃せない。

現在、ウクライナ危機の下で、重視されているエネルギー安全保障政策としては、①ロシア依存度の低減、②緊急時対応能力の強化、③供給力・供給余力確保のための適切な投資実施・確保、④安定的ベースロード電源の強化、の 4 本柱がある。

まず、①は、再エネや省エネの推進加速や原子力の拡大などによって化石燃料への依存を下げる方策と、ロシア産以外の化石燃料の代替調達という方策の２つから構成される。②については、各国での国内レジリエンス強化対策に加え、基本的にはエネルギー市場不安定化に対処するための消費国間および産消国間の国際協力である。③については、①と②が機能するためにも重要な柱であり、化石燃料分野特に天然ガスや LNG における投資促進が成否のカギを握ることになる。④は、安定的なベースロード電源で、かつゼロエミッション電源でもある原子力の利活用を図る取組みとなる。

最も状況が深刻な欧州では、「REPowerEU」計画に代表される、様々な政策が強力に推進されている。とりわけ、前述のガス価格高騰とガス不足懸念を受けて、欧州ではまさに危機対応として、EU・各国で、取組みが進められている。強力な省エネが計画され、CO_2 排出が増えることを覚悟で石炭火力発電の活用も実行されている。

原子力については、ウクライナ危機深刻化以前から EU 内で利活用に向けた動きが見られたが、フランス・英国・東欧諸国などでの新設計画に向けた動き、ベルギーでの既存原子力発電所の運転延長、さらには、2022 年内に廃止を決定していたドイツの原子力発電所が今冬を乗り切るため 2023 年春まで予備電源として温存されることが決まるなど、大きな動きが見られている。

ウクライナ危機発生と深刻化の前は、世界のエネルギー問題を巡る論壇が、脱炭素化・カーボンニュートラル問題一色に染まっていたことを思えば、状況はまさに劇的に変化したといっ

ても良い。日々の暮らし、経済活動、国家運営にとって不可欠なエネルギーの安定供給に大きな問題が発生し、それが世界の分断や地政学的緊張の高まりを生み出すことで、いわば構造的な重要問題と認識されることで、様相が一変したのである。エネルギー安全保障問題は、世界にとって、まさに喫緊の最重要課題となったといってよいであろう。

3.　エネルギー安全保障重視による世界のエネルギー転換への影響

ウクライナ危機の深刻化によるエネルギー安全保障の重視は、国際政治・世界経済・国際エネルギー情勢などに、多様かつ多大な影響を及ぼしていくことになる。様々な影響や変化がどのように生じていくか、は今後の世界にとっての重要な注目点となるが、その中で、そもそもエネルギー安全保障の重視が、脱炭素化を目指す世界のエネルギー転換にどのような影響・インパクトをもたらすかも見逃せない問題である。

脱炭素化への取組みは、世界の大多数の国々が 21 世紀の中頃を目途として排出ネットゼロを目指す方針をすでに発表しており、気候変動防止という「地球益」のためにも今後の取組み強化が必須の課題である。ウクライナ危機が深刻化したからと言って、脱炭素化の重要性が変わることは全くない、と言っても良いであろう。

しかし、同時に、現実的な世界においては、エネルギー安定供給とエネルギー安全保障の重視が、脱炭素化にとって様々な影響を及ぼしていく可能性は十分に考えられる。その第 1 は、当面の状況下、あるいは危機対策という観点では、エネルギー安定供給確保が最優先となり、場合によってはその対策が脱炭素化に即しないものとなる可能性が大いに考えられる。例えば、脱炭素化への取組みで世界を主導する欧州でも、危機対応のためには石炭火力発電の活用も躊躇っていない。エネルギー安定供給確保のためには全てのオプションを活用せざるを得ないからである。また、多くの新興国・途上国では、エネルギー価格の高騰に対応して、少しでも価格の安価なエネルギーとしての石炭への回帰の動きも見られている。短期的には、現在のエネルギー情勢は脱炭素化とは逆方向に力を働かせる可能性がある。

他方、中長期的には異なる影響が考えられる。これは、EU 等に典型的に見られるもので、現在の「脱ロシア」政策は、再エネ・省エネ・水素・電力化の推進であり、各国で進む原子力利活用は、基本的に「脱炭素」を加速化するものでもある。今回の危機を踏まえ、化石燃料依存をできるだけ低減させよう、という流れが中長期的に影響力を強めていく可能性がある、と見ることができよう。この点はもちろん欧州だけでなく、世界の様々な国で模索されていくことになると考えられる。

しかし、脱ロシア・脱化石燃料イコール脱炭素化の加速の取組みが、想定している通り順調に進むかについては不透明な部分もある。その取組みとエネルギー転換の移行があまりに高コストになる場合、特にその時の経済状況とも相まって、政治的・社会的な不満が大きく高まる可能性があるからである。今回の危機で、エネルギー価格の高騰が如何に社会的なインパクトを持ちうるかは、先進国でも明らかになった。ましてや所得水準の低い国では、これは容易ならざる挑戦となる。むしろ、エネルギー転換を実行していく際の総合的な移行コストを如何に引き下げるか、が極めて重要な課題になったことこそがウクライナ危機の教訓でもある。そのためには、それぞれの国の経済状況、資源賦存、技術水準などの際に応じた、包摂的なアプローチで、無理な「一足飛び」を図るのでなく、段階的で着実なステップを踏んだ取組みが一層重要になると考えられる。化石燃料市場の安定化を図ることがまずは喫緊の課題であり、その安定化の下で、脱炭素化に向けたプラグマティックなアプローチを模索し、実施していくこと

が世界の脱炭素化とエネルギー安全保障の両立のために重要となろう。

おわりに

エネルギー安全保障と脱炭素化の両立を目指す取組みは今後の世界のエネルギー政策の最重要課題となる。日本においても今後のエネルギー政策は、この両立のための内外戦略に基づくものとなる。現行のエネルギー基本計画の目標達成を目指す取組みを強化するとともに、次期エネルギー基本計画の策定に向け、新情勢を踏まえた政策・戦略検討を進めていくことが求められよう。

執筆者紹介

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Stabilization of Natural Gas and LNG Prices and the Supply/Demand Balance During the Transition to Net Zero Emissions

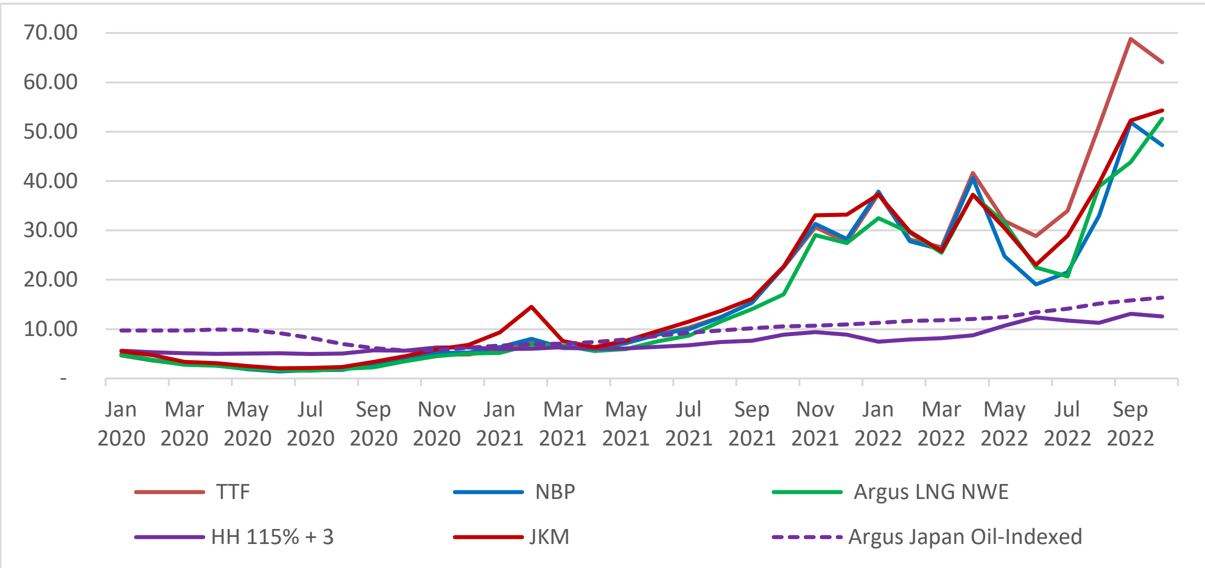
Jonathan Stern*

Natural Gas and LNG Prices 2020-22

After the decade of the 2010s when internationally traded gas and LNG prices were largely in the range of $5-10/mmbtu, the past three years have seen prices move through two extreme market cycles. Fig. 1 shows a range of widely reported internationally traded gas and LNG prices in the US, Europe and Asia:

- TTF – month ahead prices at the Dutch TTF hub
- NBP – month ahead prices at the British NBP
- Argus LNG NWE – LNG prices in north west Europe reported by Argus
- HH 115% +3 – 115% of US Henry Hub prices plus a $3/mmbtu liquefaction fee (to which shipping costs would need to be added to provide a delivered cost)
- JKM – Platts Japan/Korea Marker spot LNG prices
- Argus Japan Oil-Indexed - equivalent to Japan JCC LNG price

Fig. 1 European Hub and Asian LNG Prices 2020-22 ($/mmbtu)



Sources: Argus, Platts and OIES analysis.

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During 2020, natural gas and LNG prices reached historical lows due (largely) to a combination of the Covid-19 recession and global oversupply of gas and LNG. For most of 2020, the JCC oil-linked price was significantly above European levels (as it had been for much of the 2010s). Similarly, the Henry Hub-related price for LNG delivered to Europe was significantly above the European hubs and around 200 US LNG cargos were not dispatched to Europe because exporters could not cover their operating costs. Price levels and differentials changed at the end of 2020 as European and Asian economies recovered from recession, and Gazprom first reduced and then eliminated spot and short term gas sales by the end of 2021. In the second half of 2021 and into 2022, European prices and the JKM spot price spiralled upwards to historically high levels, while JCC and Henry Hub-related prices also rose but much more slowly and a substantial gap opened up between these two groups.

The 2022-23 Crisis

At the end of February 2022, Russia invaded Ukraine causing European gas prices to spike again and from June a progressive reduction of pipeline exports to Europe, and intense government-directed purchasing of gas to ensure high storage levels for the coming winter, caused prices (particularly at TTF) to increase to even more extreme high levels. In the second half of 2022, JKM and NWE LNG prices became strongly correlated below the TTF level as the latter increasingly represented Continental European pipeline gas (rather than LNG) price supply/demand dynamics. Similarly for much of 2022, NBP traded at a substantial discount to TTF as the UK was able to import very large quantities of LNG and (re)export much of this as pipeline gas to Continental Europe (which had never previously been seen as such high levels).

European Supply/Demand and Prices over the Next Two Years

European gas supply and demand over the next two years will be dependent on a number of factors. Most immediately it will be important how cold winter temperatures will be, not just in Europe but, in the north hemisphere as a whole. Broadly speaking the colder the temperatures the higher will be gas demand in countries which are strongly dependent on gas for heating. In July 2022, the EU issued a Regulation calling for a voluntary 15% cut in gas demand between August 2022 and March 2023.[1] If levels of supply fall, or voluntary measures fail to sufficiently reduce demand, the Commission would declare a 'crisis alert' and the 15% cut would be made compulsory. But the 15% figure is misleading because for the August-October period many countries had already achieved this reduction due to high prices and mild weather. The EU has also proposed a 5% reduction in peak electricity demand a general reduction in power demand in order to reduce gas demand in the power sector.

[1] Proposal for a Council Regulation on 'Coordinated demand reduction measures for gas', COM(2022) 361 final. There are a list of derogations (exceptions) for individual countries.

Russian gas, FSRUs and storage

An important question is how much Russian gas, Europe will continue to receive. In November 2022, the only pipeline flows which were operational were around 35-40 mmcm/d through Ukraine and 30 mmcm/d volumes via Turk Stream to Greece and non-EU Balkan countries, around 15% of Russian pipeline export levels. The ongoing conflict means that flows through Ukraine could be interrupted at any time. Flows to Turkey through the both Turk Stream and Blue Stream have remained unaffected. Russian LNG has continued to flow to EU countries (but not to the UK) and although this could also be impacted – either by EU or Russian sanctions – the consequences would not be as serious as the loss of pipeline supplies.

To compensate for the loss of Russian gas, many countries are rushing to install new floating storage and regasification units (FSRUs) in time for the winter season. The key country here is Germany where six FSRUs have been ordered and the first three should be operational around the end of this year or the beginning of 2023. In the Netherlands, two FSRUs began operating in September, and others in France, Poland, Greece, and Finland/Estonia should be in operation by the end of 2023.

The EU also introduced a new gas storage regulation requiring member states to fill their storage to 80% of capacity by November 1, 2022.[2] In reality by November, due to mild temperatures, EU storage levels were already at 95% (a higher level than the previous year). However, Europeans are already asking how much gas will remain in storage in March 2023, particularly if the winter is cold, and if Russian pipeline supplies are completely interrupted. This is a critical issue because, as long as winter 2022-23 is not too cold, Europe may have sufficient storage to maintain gas supplies without exceptional measures such as power outages and rationing. However, with the likelihood that Russian pipeline gas supply to EU countries will not increase from current levels (and may decline to near-zero), very low storage levels in Spring 2023 would create major difficulties. A general view is that if storages are more than 40% full by April 1, 2023 (the end of the European winter), it will be possible to refill storages in time for winter 2023-24.

Gas/electricity price linkages and 'price caps

In relation to prices, there is a specific EU (and UK) proposal to change the current situation where in many European countries electricity prices are linked to the cost of the marginal incremental unit of generation, which is gas when renewables are unavailable or insufficient, and are therefore extremely high. This is a long-standing practice dating back to before renewables comprised such a large share of power generation, and demand-side management was not a significant factor in electricity systems. Delinking power prices from those of natural gas is intended to correct the current situation where:

- gas-fired generation may be a relatively small share of overall power generation for the majority of operating hours but is setting the gas price for the entire power market;
- renewable and nuclear generators are making very high profits as their costs remain

[2] Regulation (EU) 2022/1032, 29 June 2022.

constant, while the prices which they receive (and hence their profits) have increased enormously.

There are a number of proposals for delinking gas and power prices, all of which are relatively complex and could take up to three years to implement. In the short term, Spain and Portugal have placed caps on price of natural gas supplied to power generation and there is a wider discussion about whether similar measures should be introduced more widely in the EU. There has also been a debate as to whether a cap should be placed on wholesale gas prices, principally the price at the TTF hub in the Netherlands. The proposed EU Regulation describes this as, 'a last resort measure... to establish a maximum dynamic price at which natural gas transactions can take place in the TTF spot markets under specific conditions'.[3] Fifteen member states are in favour of such action but there are many problems associated with it.[4]

When could We see a Stabilisation of Prices?

In November, several weeks into the northern hemisphere winter it is very difficult to be optimistic about a stabilisation of European gas prices and also global LNG prices. Very surprisingly, European day-ahead prices (at TTF and NBP) at the end of October briefly fell below $10/mmbtu but then rebounded at the first sign of colder weather. The November 2022 forward price curve shows TTF prices around $40/mmbtu for most of next year and into 2024, falling progressively to around $20/mmbtu by 2025 and further to $10/mmbtu in 2026.

To compensate for the loss of Russian pipeline gas Europe has maximised imports of LNG which has created a global supply shortage. On the supply side, this will not change significantly until major new LNG projects – from Qatar, the US and East Africa – are brought onstream in 2026-27. However, it is possible that demand reduction caused by a combination of recession and very high gas (and electricity) prices will bring global supply and demand into balance in a shorter period of time. Depending on the severity of the demand reduction, the wave of new LNG could cause the global market to tip into oversupply and low prices before the end of the 2020s. Much will depend on how much LNG Asia – but especially China – will need to import and, aside from general economic conditions, this will also be impacted by Russian pipeline exports to China which may exceed 50 bcm/year by the late 2020s. This suggests that we may not see a 'stabilisation' of prices, but a continuation of the extreme price cycles witnessed since 2018 with low price levels as the next cycle.

While this analysis suggests that the forward curve is directionally correct up to 2026, the hallmark of the past two years has been much more extreme short term price volatility than previously experienced as the market reacts much more violently to daily events. We should therefore expect periods of much lower and much higher prices with no stabilisation over the next 3-4 years.

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[3] COM (2022), 549 final, 18.10.2022, p.8.

[4] For a discussion of these problems see the Annex to: EU 'Non-Paper on Emergency Gas Market Interventions', September 28, 2022. Fulwood M. 'The Consequences of Capping the TTF Price', OIES Energy Comment, October 2022.

Beyond the 2022 Crisis – a refocus on transition and net zero targets

The next price cycle will coincide with a refocus on energy transition and the progress which countries have made towards meeting their net zero targets. The chief uncertainty will be how much gas (and energy) demand has been ‘destroyed’. In Europe there are fears of ‘de-industrialisation’ ie that energy intensive plants producing steel, fertiliser and cement may move to lower price countries in the Middle East and North America and may not return even when prices fall. More generally, this period of very high gas prices – even in those regions not dependent on spot prices – is likely to result in a significant decline in longer term European gas demand, a decline which will need to accelerate post-2030 if greenhouse gas reduction targets are to be met.

Writer’s Profile

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Professor Stern is a Distinguished Research Fellow and founder of the Natural Gas Research Programme at the Oxford Institute for Energy Studies (OIES). He holds professorships at the University of Dundee; and fellowships at the Energy Delta Institute and the Institute of Energy Economics, Japan.

The Impact of Covid and the War in Ukraine on the Energy Transition

Paul Stevens*

Recent events – the covid pandemic and the Russian invasion of Ukraine - have had a significant impact on the current "energy transition": a switch from hydrocarbon molecules (fossil fuels) to electrons. Before these events, which kicked off in 2020 and 2022, the speed of this transition had generally been underestimated by the "energy establishment" i.e. the IEA, the OPEC Secretariat, the major oil companies and many other players in the energy markets. This underestimation was in large part due to a degree of intellectual inertia amongst the analysts and strong vested interests from those involved in fossil fuels. However, once these two events began, views began to change and there was a growing consensus that ultimately the transition might speed up. The impact of both events on the transition is outlined below.

The Covid Pandemic

The pandemic began at the start of 2020 and the initial impact, as a result of the lockdowns, was a global economic recession. This led to a collapse in oil and gas demand and a dramatic fall in the price of oil and gas. In April 2020 the price of WTI actually went negative to -$30 per barrel! These lower prices meant there was a major fall in upstream oil investment and maintenance affecting producing capacity. For example, OPEC+ found it increasingly difficult to meet their production targets. In the summer of 2022, they were 3 million barrels per day below the overall target. However, as will be seen below, of even greater impact was a significant impact on popular expectations. There was growing concern over the reliability of supply chains and over the role of government in managing the economy. The "Washington Consensus" view of the world that argued you simply left everything to the market was seriously undermined. Increasingly, people felt governments needed to intervene more. As the pandemic appeared to recede some economies recovered and oil and gas demand began to rise. But as capacity constraints from underinvestment rose and spare capacity appeared to decline, oil prices began to rise. Into this mix came Russia's invasion of Ukraine.

Russia's Invasion of Ukraine

The immediate impact came from the imposition of sanctions as a counter to Russian aggression. These were aimed very much at Russian oil and gas exports. This not only created

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immediately higher oil and gas prices but also fuelled expectations of even further rises to come. This was particularly relevant in Europe which relied on Russia for around one third of its gas supplies. At the same time there was a scramble for alternative sources of oil and gas which reinforced the rapidly rising prices. This was particularly true for LNG which represented the only short term solution to consumers faced with shortages of pipelined gas. The result was that energy security of supply moved rapidly up the agenda in most oil and gas importing consuming countries especially in Europe. This was very reminiscent of the impact of the oil price shocks of the 1970s driven by political interventions in the global oil market when such energy security issues rapidly dominated government policies in consuming countries. This prompted many highly interventionist policies to save energy and use it more efficiently and to try and move away from oil. These security of supply concerns were very much reinforced by the fallout from the covid pandemic creating popular expectations that governments "should do something" about energy. Meanwhile, the scramble for alternative energy prompted a move towards greater use of coal together with delays to the reduction in the use of nuclear, notably in Europe.

At the same time, there were a number of related developments. Europe suffered massive droughts over the summer coupled with serious forest fires. The droughts in Europe had significant impacts on nuclear production highly dependent on water for cooling. Elsewhere, globally there were devastating floods leading to massive disruption and loss of life. This meant that climate change began to move back up the popular policy agenda after it had been somewhat overshadowed by the covid pandemic. This trend of concern over climate change was reinforced as the COP27 meeting in Egypt failed to produce much by way of progress. The industrialized countries continued to stall on taking serious action to address the climate emergency especially over giving serious financial assistance to vulnerable countries in terms of the "damage and cost" issues raised. At the same time, most oil companies continued to wallow in what can only be described as "greenwash" i.e. claiming to take action to reduce carbon emissions while pursuing a "business as usual" commercial strategy. This climate concern was further reinforced by growing evidence that the 1.5 degree target agreed in Glasgow was way off track.

What Next?

The covid pandemic, while receding, is far from being over. One only has to consider recent events in China where there appears to be something of a resurgence in cases. Also, to be really gloomy, it may only be a matter of time before the Omicron variant of covid is superseded by the Pi variant.

However, in the immediate term, much will depend upon what happens in Ukraine. Currently, it looks as though the war will continue for some time with no obvious winner or loser. Much will depend upon whether Western support for the Ukrainian military effort remains strong and further sanctions on Russian energy exports are imposed or whether such support begins to suffer from fatigue. It also depends upon whether the global economy suffers a major recession which looks increasingly likely. If sanctions remain strong or become even stronger this will maintain increased pressure on oil and gas prices but if a major recession hits this should reduce prices. Higher fossil fuel price will speed the energy transition while lower prices might slow its progress. However, there will inevitably be a blip slowing the transition for a few years as energy consumers adjust to the loss of Russian oil and gas by moving to other fossil fuels. Even if sanctions on Russian energy exports fail to be effective, which would be very much in line with the history of such sanctions, consumers will be very unwilling to depend in the future upon Russian energy supplies. While the Putin regime remains in power, such supplies will always look very vulnerable in a world where, as already outlined, energy security of supply is very much back on the agenda. Renewables represent secure domestic sources of energy, especially in Europe where interconnection reduces the problems created by intermittency. The drive to greater use of renewables will be strongly reinforced as climate change continues to move back up the policy agenda following evidence of a growing climate emergency. Thus the balance of probability is that the energy transition will significantly speed up in the future after a short hiatus.

Writer's Profile

Paul Stevens

Professor Stevens was educated as an economist and as a specialist on the Middle East at Cambridge and SOAS; 1973-1979 teaching at the American University of Beirut in Lebanon; 1979-93 at the University of Surrey. Between 1993 and 2008, he was Professor of Petroleum Policy and Economics at the University of Dundee, Scotland, a chair created by BP. He is an expert in the international petroleum industry, economic development in the Gulf and energy economics.

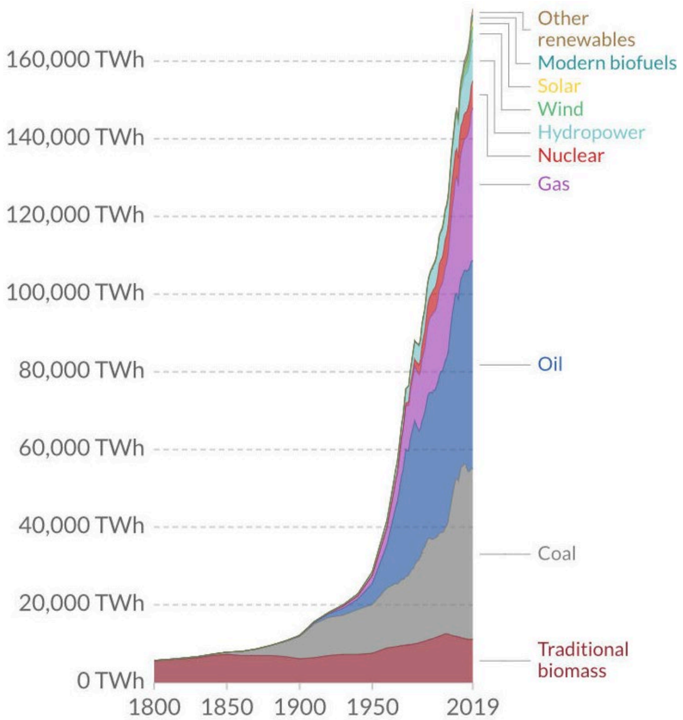
Stabilization of Energy Prices and Supply/Demand Balance During the Transition Period to Carbon Neutrality

Tatiana Mitrova*

Decarbonization is the main driver of energy transition globally. Addressing climate change requires that emissions peak during this decade, followed by a rapid reduction in fossil fuel consumption. The latter is driven by the falling cost of renewable power generation, and polices that aim to tackle urban air pollution, improve energy efficiency, and accelerate decarbonization.

The laws of economics suggest that in the long term, the development of green technologies and the energy transition should reduce the demand for fossil fuels, or at least stabilize it - as it was happening during the previous energy transitions from wooden biomass to coal, from coal to oil, etc. (see Fig. 1). Accordingly, this demand destruction (or stabilization) should lead to a decrease of the fossil fuel prices. Sounds reasonable in the long run, as a destination, but achieving this long-term goal might be accompanied by serious shocks for the world energy system.

Fig. 1　Two Centuries of Global Primary Energy Consumption



Sources: Vaclav Smil (2017), BP Statistical Review of World Energy, OurWorldinData.org/energy

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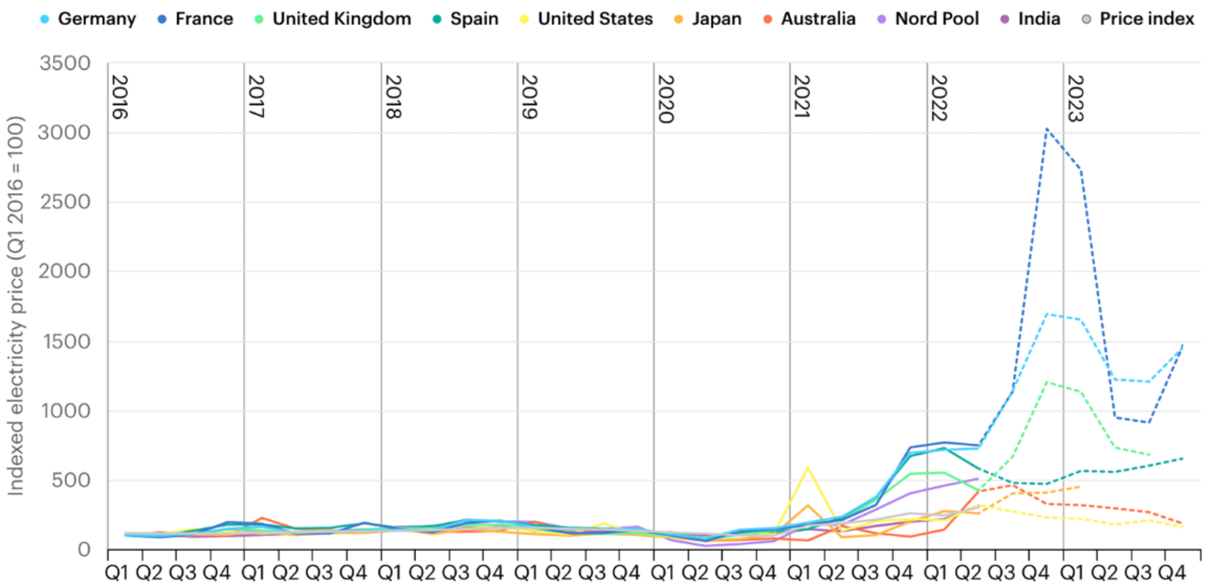
The most important question for the entire transition period is how to ensure that it will go smoothly and will not lead to a significant imbalance between supply and demand in the market and to sharp price spikes? How manageable will this development be and what volatility will the markets face in the process of transition?

Energy transition is a nonlinear, difficult to predict process that can face many challenges. Will the technologies and materials needed for the green technologies scaling up be available in all regions of the world, or will we witness new global and regional shortages (for example, deficit of rare earth metals)? Will the investments required for the large-scale implementation of renewable energy be available at the same time as the investments needed to sustain operations of the fossil fuel industries, which are anyway required at certain volumes until the transition is over? Will the regulators and the businesses be smart enough to ensure proper institutional framework and proper strategies to be able to cope with the climate change in a timely manner or would the transition be further weighed down by the climate damage factors and related economic losses? And of course, how will the current geopolitical realities affect the situation?

So far, unfortunately, it can be stated that the answers to most of these questions are negative. The existing technological, regulatory, commercial, and geopolitical conditions can hardly be called favorable for a quick and smooth global energy transition. And, as practical evidence, despite visible growth of the RES share in the energy balances of many countries, during the last few years volatility of the energy prices was reaching record heights (see Fig. 2).

Fig. 2 Quarterly Average Wholesale Prices and Futures Prices Estimates for Selected Regions, 2016-2023



Source: IEA Electricity Market Report – July 2022. https://www.iea.org/reports/electricity-market-report-july-2022

Does it mean that the economic laws are not working? Not at all: the main reason for the price rise is a noticeable underinvestment in hydrocarbon production in recent years, a reduction in the supply of oil and gas due to the introduction of tough sanctions against Russia, the resulting temporary shortage of fossil fuels and the associated speculative expectations.

Is it possible to guarantee that after the stabilization of the geopolitical situation and the time lag necessary for the commissioning of the missing hydrocarbon production capacities, the situation will normalize? Also not, unfortunately: the global energy system is currently too destabilized, and the almost inevitable further reduction in the supply of Russian energy resources in the coming years will aggravate the situation, so further price jumps are highly likely. The imbalances caused by the post-Covid recovery, and other “black swans” should not be ruled out: the world has entered a period of high economic and political instability. Moreover, the problems may concern not only Russia, but also other hydrocarbon-exporting countries. Many hydrocarbon-rich countries face an energy paradox: investment in green growth requires financial resources that can only really be earned by the export of hydrocarbons. But once again, these revenues are threatened by the energy transition.

At the same time, the global community has no other choice: the urgency of the climate challenge simply leaves no other opportunity than to accelerate the energy transition, even if it is accompanied by price jumps and other problems. The existential challenge now facing humanity requires swift and decisive action on the part of all stakeholders.

With a favorable combination of circumstances, it is quite possible that energy prices will normalize already before 2030, but negative price scenarios cannot be completely ruled out. However, these price risks are not comparable to climate risks and can be considered as “acceptable damage”. Of course, the most important task for epy governments is to minimize these risks through regulatory measures. However, this is a real challenge of finding the right balance between market interventions and their ability to self-regulate. Perhaps there will be mistakes and failures on this path, but, anyway, humankind has no other way forward than accelerating energy transition.

Writer’s Profile

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Dr. Mitrova has twenty five years of experience in dealing with Russian, FSU and global energy markets, including production, transportation, demand, energy policy, pricing and market restructuring. From February 2017 to December 2020, she was the Executive Director of the Energy Centre of the Moscow School of Management SKOLKOVO, a graduate business-school. From 2006-2011 she has also been the Head of Research in the Oil and Gas Department in the Energy Research Institute of the Russian Academy of Sciences. She is a graduate of Moscow State University’s Economics Department. She is a Visiting Professor at the Institut d’Etudes Politiques de Paris (Sciences Po). She is a member of the board of directors of the global oil service company Schlumberger since July 2018. She has more than 200 publications in scientific and business journals and co-authors10 scientific books as well as best-seller “The 8 and 1/2 Steps: How to Live, Love And Work At Full Capacity” (stories of women leaders).

エネルギー経済 IEEJ Energy Journal
Special Issue　January 2023

Editor : Yoshihiko Omori

Publisher : The Institute of Energy Economics, Japan
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