エネルギー経済
IEEJ Energy Journal

Special Issue

October 2021

based on "The 6th IEEJ/APERC Joint International Energy Symposium 2021"

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,
The Institute of Energy Economics, Japan

Tatsuya Terazawa

This Joint International Energy Symposium, which the Institute of Energy Economics Japan launched jointly with the Asia Pacific Research Center (APERC) to commemorate its 50th anniversary in 2016, is celebrating its sixth year. As with last year, the event was held online this year due to the Covid-19 pandemic, on April 23.

The theme of the Symposium this year was “Carbon Neutral: What Does This Mean for the World?” The topic was extremely timely as the Symposium was held on the day after the Climate Leaders Summit, which US President Joe Biden hosted on April 22. Since last fall, the leaders of the world’s major countries including Japan have, one after another, declared the goal of reaching carbon neutrality by mid-century. Amid this major movement, there are calls to discuss methodologies for achieving the carbon neutrality targets. Moreover, the impact of carbon neutrality on developing countries and the Middle East, as well as developed countries, is becoming an increasingly important subject.

This IEEJ Energy Journal Special Issue focusing on the Sixth APERC/IEEJ International Energy Symposium is a collection of the presentations given by the Distinguished Fellows who spoke at the event, rendered into articles by the speakers themselves, as well as articles on the same themes authored by other Distinguished Fellows and IEEJ researchers.

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、今年で６回目を迎えました。コロナウイルス感染拡大のため、昨年同様、今年もオンライン形式で4月23日に開催されました。

今年の全体テーマは、「カーボンニュートラル：世界にとって何を意味するのか？」でしたが、ちょうど前日の4月22日から米国のバイデン大統領が主宰する気候サミットが開催され、まさに時宜を得たタイムリーなものとなりました。昨年秋以降、日本をはじめとする世界の主要国のリーダーが今世紀半ばでのカーボンニュートラルの目標を次々と表明して来ました。そうした大きな動きの中で、カーボンニュートラルの目標をどのように実現するのか、方法論についての議論が必要となっているとともに、先進国だけでなく、カーボンニュートラルが途上国や中東に及ぼす影響について議論して行くことの重要性が増しています。

本「エネルギー経済」特別号（合同シンポジウム連携版）は、登壇された弊所特別研究員に、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た論文を集大成したものです。

There were three subthemes, which we believe address the questions many people may have.

The first subtheme was “Can the World Achieve Carbon Neutrality?”

Are the carbon neutrality goals pledged by the leaders of major countries realistic and achievable? What bottlenecks might there be, and what actions must governments, companies, and other actors now take?

The second subtheme was “Can Developing Countries Pursue the Dual Goals of Carbon Neutrality and Economic Growth?”

Is carbon neutrality something that brings opportunities to developing countries, or are they just obstacles? What do they need for simultaneously achieving carbon neutrality and economic growth: longer timeframes or decarbonization technologies? What kind of support do they need from developed countries?

The third subtheme was “How Will the Middle East Respond to the Global Carbon Neutral Movement?”

How will the carbon neutrality movement impact the Middle East, which so far has relied heavily on oil and gas revenues? Under such circumstances, what are some of the challenges the Middle East will face in achieving prosperity and stability, most notably decarbonizing fossil fuels?

I succeeded Masakazu Toyoda as Chairman & CEO of IEEJ on July 1. How to address the carbon neutrality target is the priority issue for myself as well. It is a formidable challenge and there is still no clear, established path to solving it.

以下の３つのサブテーマがあり、多くの皆様が抱く疑問に対応したものになっています。

第一に、「世界はカーボンニュートラルを実現できるか？」というものです。

主要国のリーダー達が表明したカーボンニュートラルの目標は現実的にも実現できるものなのでしょうか？また、そのためにはどういうボトルネックがあって、政府、企業など各アクターは、今、何をしないといけないのでしょうか？

第二に、「途上国は、カーボンニュートラルと経済成長を両立できるのか？」というものです。

カーボンニュートラルは、途上国にとって単なる足かせなのか、あるいは機会をもたらすものなのでしょうか？途上国がカーボンニュートラルと経済成長を両立させるためには、何が必要なのでしょうか？より長い時間でしょうか、脱炭素技術でしょうか、先進国からのどういう支援なのでしょうか？

第三に、「中東は、世界のカーボンニュートラルにどう対応するのか？」というものです。

これまで石油・ガスからの収入に大きく依存してきた中東が、カーボンニュートラルに向けた流れの中でどういう影響を受けるのでしょうか？その中で中東の発展と安定のために、化石燃料の脱炭素化をはじめ、どのような課題があるのでしょうか？

私自身、本年７月１日に前任の豊田正和を引き継いで弊所の理事長に就任しました。まさにカーボンニュートラルにどう取り組んで行くのかが最大の課題となっています。極めて難しい課題であり、明確な道筋が確立されている訳ではありません。今後カーボンニュートラルに向

It is the mission of the IEEJ to do our utmost to identify the path and solutions to achieve carbon neutrality.

This international symposium provided a wealth of insights as we strive to fulfill our mission. Likewise, the reports in this Journal provide clues for answering the questions many of us have. I sincerely hope they will contribute to discussions on policies and corporate strategies going forward.

We will continue our search for the path to and solutions for carbon neutrality with everyone. I ask for your support and collaboration in undertaking this mission.

October 2021

けた道筋とソリューションを全力で見出して行くことが弊所に課された使命であります。

こうした使命に取り組んで行く上では、今回の国際シンポジウムは様々な示唆を示すものです。また、本ジャーナルの各論文の中にも、沢山の示唆が含まれており、多くの皆様の疑問への答えのヒントが見出せるはずです。これからの政策論、企業戦略論に、お役に立つとしたら望外の喜びです。

今後カーボンニュートラルに向けた道筋とソリューションを皆様と一緒に見出して行きたいと考えていますので、何卒よろしくお願い申し上げます。

2021年10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.

執筆者紹介

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。

Contents
目　次

1.　Can the World Achieve Carbon Neutral?

世界は、カーボンニュートラルを実現できるか？

Energy Transitions and Carbon Neutrality by 2050?

Kenneth B Medlock III*

The world's economy has expanded considerably over the last three decades, underpinned by the rapid emergence of its most populous nations – China and India – as well as other developing economies. In fact, global GDP, in real terms, has more than doubled since 1990. This has driven substantial increases in global energy demand, with most of the growth over the last thirty years coming from developing economies. Notably, this has occurred concomitant with growing pressures to reduce CO_2 emissions, which is, to put it bluntly, challenging because fossil fuels make up the majority global energy use.

Economic growth, expanded access to energy services, and environmental sustainability are among the world's most pressing challenges. This has always been true to varying extents in different parts of the world, but international discourse has recently galvanized around environmental sustainability, with a particular emphasis on carbon neutrality, especially in the developed nations of the Organization of Economic Cooperation and Development (OECD). This begs two fundamental questions, "Is carbon neutrality by 2050 possible? And, if so, how can it be achieved?"

We do not portend to answer these questions herein. That story is still being written and there are likely to be multiple twists and turns in the plotlines that unfold. Rather, we will examine the current energy landscape in its context of recent history in order to identify some important vectors for consideration. This will allow a rationalization of what may be achievable, and obviously raise some important questions.

Energy Transitions – What Does Recent History Tell Us?

Make no mistake, energy systems are changing, and they will continue to do so with an inexorable inevitability. The *pace* of change, however, is an open question that will influenced by a multitude of factors – economics, policy, technology, regulatory and legal environment, etc. – that extend well beyond aspirations. That stated, the global energy system of 2050 will look very different than the global energy system of today. But that is not a particularly bold statement. The energy system of today looks different than it did in 1990, and the global energy system of 1990 looked very different than it did in 1960, which looked very different than it did 1930, and so on. The point? Energy is always in transition.

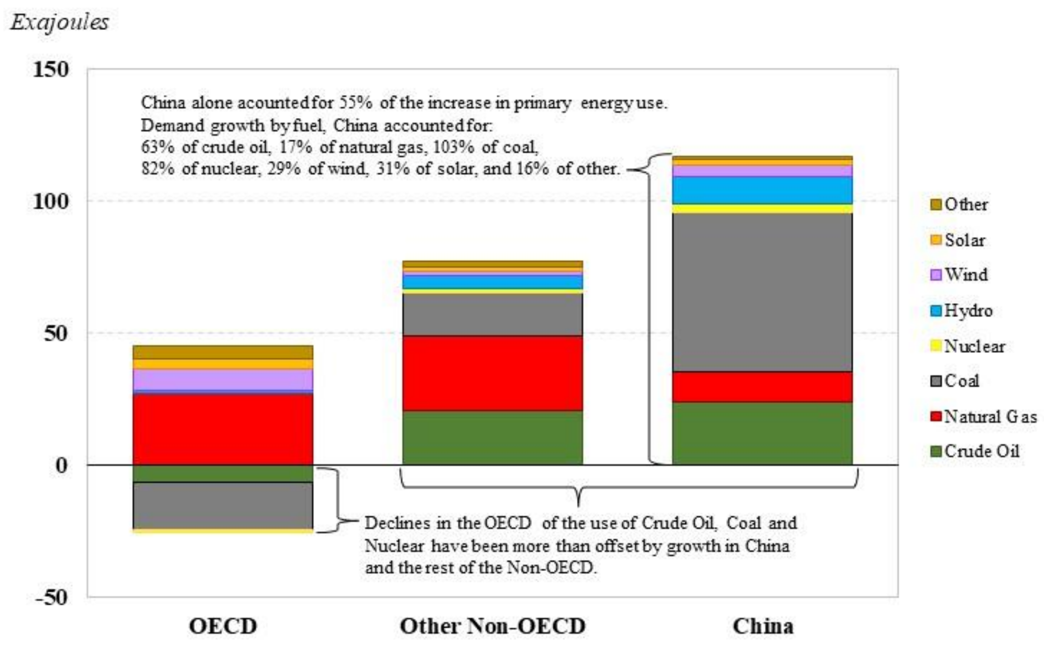
* Senior Director, Center for Energy Studies, Baker Institute for Public Policy, Rice University, US / Distinguished Fellow, IEEJ

Two primary factors have always driven this – economic growth and technological change. Consider the last 30 years and ponder the two largest drivers of change in the global energy system over that period: (1) energy demand growth in China and (2) the shale revolution in the U.S. Driver #1 is the result of rapid economic growth, and driver #2 is the result of innovation driving commerciality of a previously inaccessible oil and gas resource base.

From 1990 to 2020, China alone accounted for over half of the total increase in global energy demand. The impacts include a redirection of global energy trade, substantial investments in new energy resources (both fossil and renewable) and infrastructures to support expanded supply chains, and a shift in global geopolitics. Moreover, the observed growth in demand has been primarily fossil fuels (see Fig. 1).

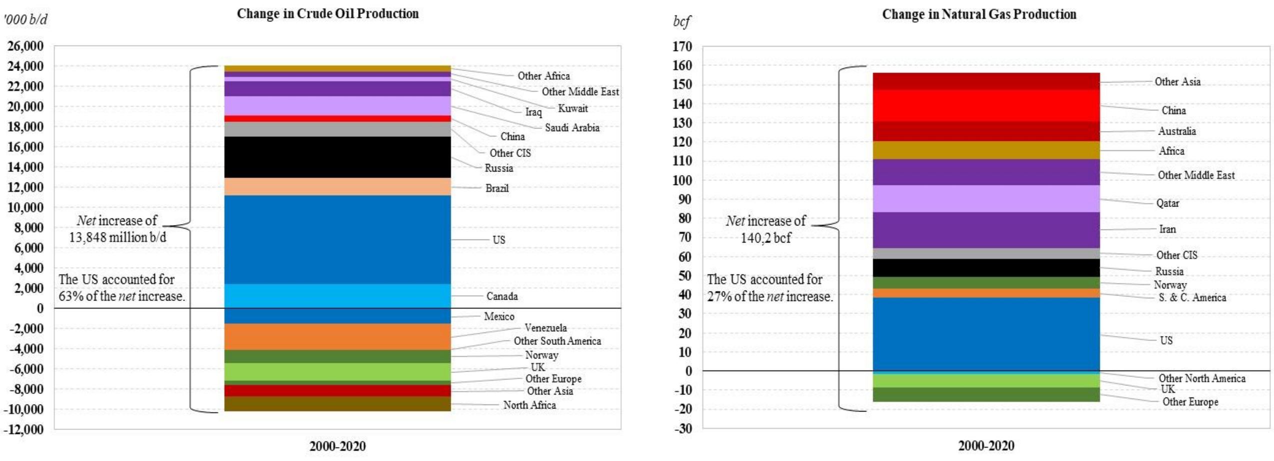
The shale revolution in the U.S. has driven equally dramatic shifts to global energy markets. As recently as 2000, the U.S. was the largest energy consumer on the planet, was positioned to become a major importer of LNG, was already a major importer of crude oil and petroleum products, and relied on coal for 24% of its energy mix. But the rapid growth of shale oil and gas production substantially altered the US contribution to global oil and gas balances over the last 20 years (see Fig. 2). Other regions also saw expansion to meet growing global demands, but the so-called shale revolution was transformational. In less than 20 years, the US became a net exporter of natural gas, a major player in the global LNG export market, a net exporter of crude oil and petroleum products, and saw a substantial reduction in the use of coal domestically. Altogether, this has held dramatic implications for global energy trade and geopolitics.

Fig. 1 The Impact of China on Global Energy, 1990-2020



Source: Data obtained from the BP Statistical Review of World Energy 2021

Fig. 2 The Impact of the US on Global Oil and Gas Production, 2000-2020



Source: Data obtained from the BP Statistical Review of World Energy 2021

What does this mean? To begin, the changes themselves, while impactful on the global energy ecosystem, are not the main point. Rather, the *drivers* of change are. The notable shifts in global energy demand toward China and the rest of the developing world are being driven by *economic growth*. And, the dramatic production increases of oil and gas in the US, a result of shale development, have been driven by *innovation* in the upstream. Regardless of one's view of the next 30 years, it can almost certainly be stated that economic growth and innovation will drive the future of global energy!

Energy Transitions – Carbon Neutrality by 2050?

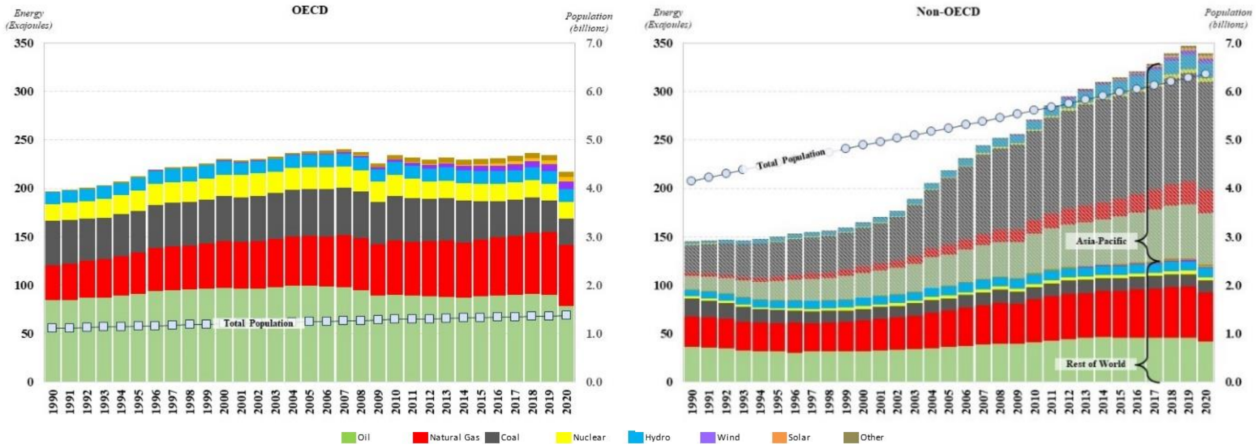
Despite the rapid growth in energy demand in developing countries over the past 20-30 years – which has triggered a shift in global center of gravity in energy toward developing nations in the Asia-Pacific region (see Fig. 3) – the world of energy remains a world of 'haves' and 'have-nots'. This is particularly noticeable when one compares the per capita energy use across regions – the populations across the OECD, on average, consume roughly 3 times the amount of energy per person than populations of non-OECD nations, with some differences even more striking on a country-by-country basis.

The nations of the OECD are home to about 1.3 billion people and generally enjoy reliable and consistent access to modern energy services. In contrast, the nations of the non-OECD collectively represent about 6.4 billion people, about half of whom still lack *reliable* access to modern energy services.[1] Of course, each non-OECD nation is different, with some having rapidly ascended over the last 30 years (especially those in the Asia-Pacific region) and others still lagging far behind. Any status quo paradigm that leaves such a sizeable portion of the world's population in

[1] See J. Ayaburi, M. Bazilian, J. Kincer, T. Moss, "Measuring "Reasonably Reliable" access to electricity services," *The Electricity Journal*, Volume 33, Issue 7, 2020, https://doi.org/10.1016/j.tej.2020.106828.

the dark is neither sustainable nor acceptable, and meeting energy demands for such a large, and growing, fraction of the world's population presents a non-trivial challenge to global carbon neutrality.

Fig. 3 Energy Demand by Primary Source and Population by Region, 1990-2020



Source: Data obtained from the BP Statistical Review of World Energy 2021 and World Bank

The widespread access to energy services in the OECD is a product of massive capital investments in energy infrastructure over multiple decades. Therein lies a fundamental challenge. Namely, the *scale* of energy infrastructure required to support modern economies is enormous, and once in place it establishes a *legacy* of infrastructure and fuel choices that do not change rapidly. In well-developed economies, such as those in the OECD, new energy technologies – such as wind, solar and batteries – must compete for market share against well-entrenched incumbents. And, they must do so against a backdrop of little to no growth in total energy demand (see Fig. 3).

In order to deliver reliable access to modern energy services to populations in developing non-OECD nations, a scale of capital investment in energy infrastructure never before seen must occur. This means that the size of the global energy system will certainly expand. Not only must *existing* energy systems see a significant reduction in the use of fossil fuels while also continuing to deliver energy services reliably, *new* energy demands must be met primarily with low carbon energy sources, a trend that has yet to be seen in developing nations (see Fig. 3). Consider a case where global energy use rises by one-third from 2020 to 2050, representing a 0.96% average annual growth rate, which is well below the 1.64% rate seen from 1990 through 2020.[2] Simply holding the use of fossil fuels constant at their 2020 levels requires the fossil share to fall from 83.1% to 62.4%. While this may not be insurmountable, it translates to a three-fold increase in all other energy sources globally. If we assume all non-fossil demand will be met by wind and solar,

[2] Note this simple exercise does not account for the fact that energy use declined in 2020 due to the economic malaise triggered by responses to the COVID-19 pandemic. Arguably, demand will rebound in line with 2019 as the pandemic subsides, but, for simplicity, we construct this example using 2020 as the reference year.

an almost 13-fold increase in wind and solar energy must occur over the next three decades, just to keep fossil energy use flat. To achieve a much more ambitious carbon-free energy portfolio, such increases would have to be significantly larger, unless, of course, we significantly reduce the growth of energy demand. But that would complicate, to say the least, efforts to increase reliable access to modern energy services outside the OECD.

Closing Remarks

The above discussion is not meant to downplay efforts to transition the global energy system. Energy will transition. It always has and always will, but the pace of change is uncertain. In the end, the future of energy is NOT an OECD story; it is about developing economies. It will be challenging to meet the expanding energy needs of a growing population in the developing world, while also decarbonizing energy systems in the developed world. Any movement to achieve carbon neutrality by 2050 must be facilitated by a full portfolio of potential solutions – from carbon capture, to nature-based solutions, to expansion of renewables and hydrogen, to rethinking the role of nuclear and hydro power, to technologies that have not yet been fully developed, including potential advances in material science that create a "carbon-to-value" proposition through the development of advanced carbon materials.[3] Nothing can be left off the table. If policy attempts to define a subset of the potential portfolio through various measures, failure is inevitable.

Writer's Profile

Kenneth B Medlock III

Dr. Medlock, III is the James A. Baker, III and Susan G. Baker Fellow in Energy and Resource Economics and senior director of the Center for Energy Studies at Rice University's Baker Institute, co-director of the Master of Energy Economics program, and adjunct professor in Economics and Civil and Environmental Engineering. He is Distinguished Fellow at IEEJ and on the Advisory Board of the Payne Institute at Colorado School of Mines. He has published numerous articles, has testified multiple times on Capitol Hill, has spoken at OPEC, and frequently speaks at venues around the world. He has received several awards for scholarly achievements, most recently the 2019 Lifetime Achievement Award for the Advancement of Education for Future Energy Leaders from the Abdullah Bin Hamad Al-Attiyah Foundation. He is a member of the AEA and NPC. He received his Ph.D. in economics from Rice University in May 2000.

[3] See, for example, K. Medlock and R. Meidl, "The Advanced Carbon Economy: A Sustainable Hydrogen Pathway," available at https://doi.org/10.25613/v58t-pm38.

Can the World Realize Carbon Neutrality?

Hiroki Kudo*

Introduction

The Paris Agreement, which was adopted in 2015 and ratified in 2016, aims to limit the rise in global average temperatures to well below 2°C above pre-industrial levels by the end of this century and for pursuing efforts to limit global warming to 1.5°C. It also sets out a target of reaching net-zero greenhouse gas (GHG) emissions, or carbon neutrality, in the second half of this century to achieve the temperature target. Under the Paris Agreement, parties to the pact are bound to set their respective long-term targets and policy measures. After the ratification of the Paris Agreement, the Intergovernmental Panel on Climate Change (IPCC) released the Special Report on Global Warming of 1.5ºC and various stakeholders including the United Nations encouraged all countries to enhance global warming countermeasures. As a result, more than 100 countries in the world have vowed to pursue carbon neutrality. Particularly, major advanced countries including Europe, the United States under the new Biden administration and Japan have made political declarations to achieve carbon neutrality by 2050 and enhanced their GHG emission reduction targets for 2030 in consideration of the 2050 carbon neutrality target. China, the world's largest GHG emitting country, released a target of achieving carbon neutrality by 2060. The feasibility of and specific initiatives for the Chinese target have attracted global attention.

The carbon neutrality target has been set to avoid the serious impacts of climate change. It is not a quantitative target set through the accumulation of feasible measures. The challenging target requires innovative technologies to be commercialized and diffused globally through innovations. The achievement of the target includes numerous uncertainties including progress in the development of various technologies and the realization of their sufficient economic efficiency for commercialization. While scrutinizing the feasibility of the carbon neutrality target, technology development trends over time and the effects of policy measures, each country will be required to continuously take measures to improve the effectiveness of relevant initiatives.

At the 6th International Energy Symposium sponsored by the Institute of Energy Economics, Japan (IEEJ) and the Asia Pacific Energy Research Center (APERC), U.S., Canadian, Chinese and Japanese experts discussed two issues: "How much is the seeming probability of achieving Carbon Neutral by mid-century?" and "What urgent actions are now required for key actors such as government and business to untangle bottlenecks on the way to Carbon Neutral?" Global carbon neutrality is a challenge that requires a dramatic structural transition from the present energy supply and demand system. These experts provided their respective views about the feasibility of the carbon neutrality target and government and business initiatives to realize the target. At a time

* Board Member, Director, Charge of Electric Power Industry & New and Renewable Energy Unit, IEEJ

when less than 30 years remain until 2050, I would like to consider challenges to realize carbon neutrality in the future through discussions between the experts.

Key Points towards Realizing Carbon Neutrality

Kenneth Medlock, senior director of the Center for Energy Studies at the U.S. Rice University's Baker Institute, pointed out that carbon neutrality initiatives should consider differences between economic, social and other national fundamentals. This means that as each country faces multiple turning points regarding economy, society or energy supply and demand, appropriate carbon neutrality initiatives differ by region or situation. While 1.3 billion people out of the global population at 7.8 billion live in advanced economies belonging to the Organization for Economic Cooperation and Development (OECD), 3.4 billion people reside in China, India and the members of the Association of Southeast Asian Nations (ASEAN) where energy consumption is increasing in line with economic growth. In Latin America, Africa and the Middle East where 3 billion people live, access to modern energy services has yet to be secured in the presence of haves and have-nots. Medlock noted that the facts should be recognized.

In non-OECD countries, particularly, economic and population expansion are leading energy demand to increase faster than in OECD countries. Non-OECD countries depend heavily on fossil fuels due to their economic efficiency and easy accessibility, resulting in a rapid increase in their CO_2 emissions. Therefore, Medlock pointed out that carbon dioxide capture and storage (CCS) technologies as well as hydrogen technologies would be important for realizing carbon neutrality in these countries, given that their dependence on fossil fuels is likely to remain heavy. He also noted that while renewable energy technologies attract attention as a key to decarbonization in non-OECD countries, power transmission networks and other infrastructure must be developed to meet an increase in solar and wind power generation capacity from the current levels.

Approaches to Carbon Neutrality

Allan Fogwill, president and CEO of the Canadian Energy Research Institute, discussed current challenges and future approaches regarding global carbon neutrality initiatives.

While being optimistic that carbon neutrality would be technologically feasible, Fogwill pointed out a cost challenge. While GHG emission reduction initiatives are currently implemented under the jurisdiction of national government agencies, it is important that countries at an international level share what they pursue under their respective jurisdictions, according to Fogwill. The energy sector accounts for 73% of global GHG emissions. It must be recognized that not only energy supply-side emission sources, but also various demand-side sources should be subjected to emission reduction initiatives, with consideration given to complex economic and environmental spillover processes. Fogwill noted that the biggest challenge would be that economic growth, trade balance and social infrastructure should all be considered to reduce overall emissions.

The government sector's engagement in GHG emission cuts and its cooperation with the business sector would be the key to realizing carbon neutrality within the 21st century. The problem is that CO_2 emission reduction initiatives are segmentalized in the absence of any international agreement on the compliance with the Paris Agreement or of integrated GHG emission reduction measures. To resolve the problem, various industries and governments should choose the most cost-effective measures in consideration of market forces, according to Fogwill.

As noted in the IPCC report, global cooperation and collaboration would be indispensable for achieving zero emissions through the introduction of various zero-emission technologies and social and economic transformation. In considering zero-emission initiatives, countries or regions occasionally focus on how to maintain and increase their respective competitiveness. However, the entire international community would have to consider how international or intersectoral cooperation and markets should be for realizing global zero emissions.

Trend of China as Key Player

The direction and effectiveness of initiatives in China as the world's largest GHG emitter are important for realizing global carbon neutrality. Fuqiang Yang, senior advisor for the Climate Change and Energy Transition Program at the Beijing University Institute of Energy, introduced China's current initiatives to achieve net-zero emissions.

China accounts for the world's largest share at 28% of global CO_2 emissions, being the largest coal producer and consumer in the world. In an address to the 75th session of the United Nations General Assembly in September 2020, Chinese President Xi Jinping declared that China would pursue carbon neutrality by 2060 after CO_2 emissions peak out by 2030. China's 14th five-year plan set out milestones to become the most affluent, resilient country by 2050. Its Coal Cap Plan calls for reducing coal's share of total energy consumption to 48%, for setting strict emission standards, for raising non-fossil fuels' share of energy consumption to 21.5% and for cutting the CO_2 emission intensity by 20%. China plans to promote electrification and switch from natural gas to renewable energy in the power generation sector to allow emissions to peak out by 2030.

China has set an ambitious CO_2 emission reduction target for 2023, with the next milestone given for 2028. It sees a 70% cut in the CO_2 emission intensity as feasible and plans to raise renewable energy's share of energy consumption by 2030. To realize carbon neutrality, non-CO_2 GHG emissions including methane, black carbon and chlorofluorocarbon alternatives are planned to peak out around 2025. It was pointed out that south-south cooperation and the Belt and Road Initiative would play key roles in this respect.

China's carbon neutrality target for 2060 represents a political declaration attracting international attention and has exerted great influence on the attitude of Japan and other major countries. However, it must be noted that long-term policies from 2030 and onward and the probability of carbon neutrality are left uncertain. On the other hand, China has set out strategic national initiatives such as electric vehicle technology and market development, as well as the enhancement of its competitiveness in the renewable energy market. We would have to closely watch if such Chinese initiatives would work consistently with the international carbon neutrality cooperation cited by Fogwill.

Roles Government and Market Sectors Would Play in Realizing Global Carbon Neutrality

Finally, I would like to introduce experts' views about the roles government and market sectors would play in realizing global carbon neutrality.

Medlock noted that the market sector would play extremely important roles. Market-type approaches would be required for serious efforts to realize carbon neutrality by 2050. Government roles would be important, but the government sector alone would not be able to realize carbon neutrality. Government and other various sectors should consider and manage market systems that would play decisive roles in realizing carbon neutrality, according to Medlock.

Fogwill as well pointed out the need for a market in which government and other various sectors would participate. More government interventions in the market would be required. Then, social and economic prioritization would be important, but the market would not necessarily set any priority order. Fogwill noted that the government sector should (1) take advantage of policies, various incentives and tax measures to lower investment risks, (2) keep policies consistent and (3) create an international carbon market and develop governance for the creation.

Yang also pointed to the significance of market roles. The government sector would invest in the market while business administrators and other decision-makers efficiently implement investment and the distribution of resources through the market. While carbon pricing has yet to diffuse among companies, information about desirable investment destinations would allow them to raise investment efficiency to cut CO_2 emissions more rapidly. Carbon neutrality initiatives would drive economic development. The development of technologies for realizing carbon neutrality would lead to new businesses. Carbon neutrality could bring about a new economy and should be taken as a business opportunity as well as a cost, according to Yang.

These experts thus agreed that the world should take maximum advantage of market functions to realize carbon neutrality. As noted by Medlock, however, international differences regarding energy supply and demand, and economic and social conditions should be considered along with different time schedules when initiatives are developed and implemented. Over a short term, it would not be easy to develop a market through integrated carbon pricing amid international differences regarding energy supply and demand conditions, policies and technological strategies. Governments are required not only to develop their respective national initiatives but also to cooperate in building market and other governance mechanisms to simultaneously achieve sustainable national economic growth and carbon neutrality. We would have to closely watch national policies and negotiation stances to check how an economy-friendly cooperative framework would be developed for realizing carbon neutrality under the Paris Agreement.

Writer’s Profile

Hiroki Kudo

Mr. Kudo has served as ISO/TC207/SC7/WG5 (ISO 14064-2: Guidance for the GHG project) Convener, ISO/TC17(Steel)/WG24(ISO 20915) Convener (Life Cycle Inventory Calculation Methodology for steel products), and a committee member/working group members related to climate change policy (including emissions trading scheme) and renewable energy policy organized by central and local governments. Former UNFCCC, The Joint Implementation Supervisory Committee (JISC) member. He is an expert in Global Warming, Energy Conservation and Renewable Energy Policy, Standardization for GHG related activities and Sustainable Finance (ISO).

世界はカーボンニュートラルを実現できるか

工藤　拓毅*

はじめに

2015 年に採択、そして 2016 年に発効したパリ協定は、世界全体での気候変動対策の究極目標として今世紀末までに産業革命以降の気温上昇を 2℃にとどめる、更に 1.5℃にとどめる様に努力することが規定されている。そして、その気温目標の達成のためには、今世紀後半に世界全体での温室効果ガス（GHG）排出量をニュートラルにするという GHG 排出量の量的目標が併記されている。国際社会は、このパリ協定での合意事項に基づいて、それぞれの国における長期的な目標設定と政策措置等の戦略策定が求められることになった。その後、IPCC の 1.5℃特別報告書の公表や、国連を中心とした様々なステークホルダーによる働きかけが活発化し、100 を超える国や地域によって、カーボンニュートラルに向け取り組んでいくという立場の明確化がなされ、現在に至っている。特に欧州やバイデン新政権に移行した米国、そして日本をはじめとする主要先進国は、2050 年までにカーボンニュートラルを達成するという政治宣言を世界に向けて行い、2050 年の目標到達を意識して、中期的な 2030 年における GHG 排出削減目標が強化された。また、世界最大の中国も、2060 年にはカーボンニュートラルを達成するという目標を公表し、その実現可能性や具体的な取り組みは何なのか、国際的な注目が集まっている。

カーボンニュートラルは、深刻な気候変動影響を回避するために設定された目標であり、実現性の高い対策措置の積み上げによる量的目標ではない。その目標に当たっては、現時点では商業化されていない技術の革新と普及を全世界的に実現しなければならないという挑戦的な目標である。そのため、その目標達成に向けては、様々な技術開発の進展や、その結果として商業化を可能とする経済性の実現という不確実性を多く含んでいることに留意する必要がある。カーボンニュートラル目標の実現可能性はあるのか、経年的な技術開発の動向や政策措置等の効果を精査しながら、取り組みの実効性を高める対応を継続していくことが求められる。

第 6 回 IEEJ/APERC 国際エネルギーシンポジウムでは、米国やカナダ、中国の専門家により①今世紀半ばまでにカーボンニュートラルを実現できる可能性をどうみるか？、②カーボンニュートラル実現のためのボトルネックを解消するため、政府、企業など各アクターは、今、何をしないといけないか？、という論点について議論を行った。世界的なカーボンニュートラルの実現は、現在のエネルギー需給システムからの大幅な構造転換が求められる課題であるが、その実現可能性をどう見るか、そしてその実現に向けた政府や企業などの取り組みについて、それぞれの考え方が示された。2050 年まで残すところ 30 年を切った今、将来的なカーボンニュートラル実現に向けた課題は何か、専門家間の議論を通じて考えることにする。

カーボンニュートラル実現に向けた留意点

米国のライス大学ベーカー研究所のケン・メドロック氏は、カーボンニュートラルへの取り

* （一財）日本エネルギー経済研究所　理事　電力・新エネルギーユニット担任

組みは、各国の経済・社会的状況など、各国のファンダメンタルズが異なる点に留意することが必要であることを指摘した。世界全体を鳥瞰すれば、各国が複数の経済・社会、もしくはエネルギー需給の転換点に直面しており、カーボンニュートラルに向けた適切な取り組みは、地域や状況によってそれぞれ異なるという視点である。世界の総人口 78 億人中、先進諸国（OECD 加盟国）域内には 13 億人が、そして中国・インド・ASEAN 域内には 34 億人がそれぞれ居住し、経済成長に伴いエネルギー消費量が増加している。一方、30 億人が居住する中南米、アフリカや中東においては、近代的なエネルギーサービスへのアクセスが未だままならず、「持つ者」と「持たざる者」の存在を認識する必要性を指摘している。

特に非 OECD 諸国では、経済規模の拡大や人増加によって、OECD 諸国を上回るエネルギー需要の拡大が進行しており、そこで利活用されるエネルギー源の構成も、経済性やエネルギーアクセスの状況から引き続き化石燃料に依存しており、その結果、CO_2 排出量も急増しているのが現実である。そのため、こうした諸国でのカーボンニュートラル化の実現に向けては、化石燃料の依存度が引き続き高い可能性に留意すれば、二酸化炭素回収・貯留（CCS：Carbon dioxide Capture and Storage）や水素技術の利用が重要となると指摘した。脱炭素化の主要技術として再生可能エネルギーへの注目が高まっているものの、太陽光や風力の発電規模は未だ限定的であり、今後、それらの発電容量の増加が見込まれるが、そのための送電網などインフラ整備が必要という点を留意点として指摘していた。

カーボンニュートラル実現に向けたアプローチ

カナダのエネルギー研究所のアラン・フォグウィル氏は、世界的なカーボンニュートラル実現に向けた取り組みのあり方について、現状の課題と今後のアプローチのあり方について提起を行っている。

フォグウィル氏は、カーボンニュートラルについて、技術面では実現可能という楽観的な見方を持つ一方で、コスト面が課題であると指摘する。現在の温室効果ガス削減の取り組みは、国レベルでの各行政機関が管轄する範囲で行われているが、国際レベルでは各国の管轄の範囲でそれぞれ何を追求すべきか共有することが重要になるとしている。世界の温室効果ガス排出量はエネルギーセクターが 73%を占める。また、取り組みの対象はエネルギー供給面だけでなく多様な需要サイド排出源があることを認識しなければならず、複雑な経済活動プロセスや環境への波及プロセスを考慮する必要がある。全体的な排出量を減少させるためには、経済成長や貿易バランス、社会基盤といった全てを考慮しなければならないことが最大の課題であると指摘する。

21 世紀中のカーボンニュートラル目標の達成には、政府の関与が鍵になると同時に企業が緊密に連携する必要がある。問題は（CO_2 排出量削減に向けた）取り組みが細分化しており、国際的な取り組みであるパリ協定遵守においても、国を超えた合意は未だなく、温室効果ガス削減に対する統合的な対策は取られていない。この問題解決には、様々な業界や政府が市場を考慮に入れて、一番コストのかからない方法を選択する必要があるとしている。

IPCC の報告書でも指摘されているが、様々なゼロエミッション技術の導入や社会・経済の変容を通じて、ゼロエミッション化の可能性は高まるが、その前提として世界全体の連携・協調が不可欠である。ゼロエミッション化に向けた各国・地域の取り組みは、時として自国の競争力の維持・拡大に焦点が当てられているが、世界全体でのゼロエミッション実現に向けた各国、各セクター間の連携や、市場のあり方はどういったものか、国際社会全体としてのアプロ

ーチのあり方が今後問われることになる。

キープレーヤーである中国の動向

世界全体でのカーボンニュートラル実現には、最大の GHG 排出国である中国の取り組みの方向性や実効性が重要であることは論を待たない。中国の北京大学エネルギー研究所のフチャン・ヤン氏からは、現時点における中国のゼロエミッション実現に向けた取り組みが紹介された。

中国は、世界最大の CO_2 排出量（28%）を占め、世界最大の石炭生産国かつ消費国となっている。2020 年 9 月の第 75 回国連総会演説において、習近平国家主席は 2030 年までに CO_2 排出量をピークアウトし、2060 年までにカーボンニュートラルを目指すと宣言している。第 14 次五カ年計画においても 2050 年までに最も豊かで強靭な国を実現するとし、マイルストーンを定めている。コールキャッププランでは、石炭消費比率を 48%に減少させ、厳格な排出基準を定め、非化石燃料比率を 21.5%に増やし、CO_2 排出原単位を 20%削減する計画としている。2030 年までのピークアウトを目指して電化を推進し、発電セクターでは天然ガスから再生可能エネルギーにシフトしていく方向性が示されている。

CO_2 排出量削減について、2023 年までの野心的な目標を定めており、その次のマイルストーンは 2028 年となる。CO_2 排出原単位は 70%の削減が実現可能とみており、再生可能エネルギー比率を 2030 年までに高めていく。カーボンニュートラル達成のために、CO_2 以外の温室効果ガスであるメタン、ブラックカーボン、代替フロンについても、2025 年頃のピークアウトを想定している。その為には、「南南協力」と「一帯一路」が極めて重要な役割を果たしていくと指摘された。

中国の 2060 年カーボンニュートラル目標は、国際的に最も注目された政治宣言であり、日本をはじめとする主要国の姿勢にも大きな影響を与えたと考えられる。しかし、2030 年以降の長期的な政策のあり方については、ゼロエミッション実現の蓋然性も含めて不透明であることは留意が必要である。一方で、EV 化に関連した技術開発や市場形成、再生可能エネルギー市場での競争力の強化など、国としての戦略性の強い取り組みも顕在化している。フォグウィル氏が指摘する国際的な連携によるカーボンニュートラル実現と、中国のこうした取り組みが将来的に整合的に作用していくのかを注視していく必要がある。

グローバルなカーボンニュートラルを実現するため、政府・市場が果たすべき役割

最後に、グローバルなカーボンニュートラル実現に向けた政府や市場の果たすべき役割に関する専門家の意見を紹介する。

メドロック氏は、市場が極めて重要な役割を果たすと指摘する。2050 年カーボンニュートラル実現を真剣に目指すには市場型アプローチが必要であり、政府の果たす役割が重要であるが、政府単独では実現不可能である。政府のみならず、様々な主体の市場制度の検討や運営が不可欠であり、いずれにせよ市場が決定的な役割を果たすという点を強調した。

フォグウィル氏も同様に、政府や多様な参加者による市場の必要性を指摘した。そのためには、政府の介入を更に受け入れていかなければならない。そこでは、社会的・経済的な優先順位付けが重要となるが、必ずしも市場がそれらの優先順位を判断するとは限らない点に注意が必要であり、政府は①政策・各種インセンティブ・税制により投資リスクを下げる、②政策に

一貫性を持つ、③国際的なカーボン市場の創設とそれを可能にするガバナンスの整備を行う必要があるとした。

ヤン氏も同様に市場の役割の重要を指摘した。市場の仕組みがあり、政府が投資をする、或いは、経営者等の意思決定者が投資やリソースの配分を市場を通じて効率的に実行することが期待される。企業間のカーボンプライシングは普及していないが、企業がどこに投資できるのか分かればより効率性が高まり、CO_2 排出量をより早く削減することができる。カーボンニュートラルは経済の発展をもたらすエンジンであり、実現のための技術が開発されれば新たなビジネスになる。カーボンニュートラルをもって、これまで経験したことのないニューエコノミーが生まれる可能性があり、カーボンニュートラルはコストだけでなく機会と捉えるべきと指摘した。

この様に、カーボンニュートラル実現には、市場の機能を最大限に活用すべきという点で意見の一致をみた。しかし、メドロック氏が指摘したように、各国のエネルギー需給環境や経済・社会環境には明確に違いがあり、その違いに配慮した取り組みのあり方を、時間軸も含めて検討し、取り組んでいくことが不可欠である。現実的・短期的には、各国のエネルギー需給環境の違いや政策の違い、各国の目指すべき技術戦略の違いによって統合的な炭素の価格付けによる市場の形成は容易ではない。各国の政府の役割は、それぞれの国における取り組みのあり方に加え、国際社会が連携・協調して、それぞれの国の持続的な成長とカーボンニュートラルを同時達成する市場を含めたガバナンスの構築を目指すことが求められる。経済的に敵対的ではない、カーボンニュートラル実現に向けたパリ協定下での協調的な枠組みがどう形成されていくのか、各国の政策内容や交渉姿勢の推移を注視していく必要がある。

執筆者紹介

工藤　拓毅（くどう ひろき）

専門は地球温暖化政策、再生可能エネルギー政策、省エネルギー政策、温室効果ガスインベントリ・検証、サステナブル・ファイナンス等の国際標準化等。政府や地方自治体の気候変動関連委員会に委員として数多く参画。ISO/TC207/SC7/WG5（ISO 14064-2：GHGプロジェクトに関するガイダンス）議長、ISO/TC17（鉄鋼）/WG24（ISO 20915）議長（鉄鋼製品のLCI算定に関する規格）等を務める。元・気候変動枠組条約JI監督委員会メンバー。2018年6月より現職。

Can the World Achieve Carbon Neutral Energy Balances?

Jonathan Stern*

Introduction

Given the climate crisis repeatedly confirmed by the scientific community, most recently in the 6th Assessment Report (Working Group 1) of the International Panel on Climate Change (IPCC), the urgency to reduce greenhouse gas emissions from the energy sector has increased significantly. Around 40 countries have made pledges to reduce their emissions to net zero (ie carbon neutrality) by 2050 (2060 in the case of China), which account for 40% of the global population, 70% of global GDP and around 75% of CO_2 emissions.

In May 2021, in response to a request by the organisers of the November 2021 COP26 meeting, the International Energy Agency (IEA) produced a report, 'Net Zero by 2050 – a roadmap for the global energy sector'. The IEA's net zero energy (NZE) scenario is a modelled pathway which sets out actions which need to be taken if NZE is to be achieved by 2050. The study has provoked strong responses by critics, notably by the Saudi Arabian Energy Minister who was quoted (Financial Times, June 5/6 2021) as saying, "Whoever put that scenario [together] is not in touch with reality". However, it is not clear whether such critics are saying that NZE by 2050 is impossible, or whether the IEA have chosen the wrong modelling assumptions to achieve this outcome.

Required Milestones to Achieve NZE by 2050

Although the focus of net zero tends to be 2050, it is clear that unless certain milestones are achieved by 2030 it will be almost impossible to 'catch up' with emission reduction targets because the 'carbon budget' (ie the emissions which will already be in the atmosphere) necessary to ensure the limitation in global temperature increase, will have been exceeded, and because the lead times necessary to achieve key milestones for 2050 are measured in decades. Some of these milestones are:

- From 2021: no new oil and gas fields should be approved for development (although existing fields and extensions of those fields can continue); no new coal mines or mine extensions should be approved; no new unabated coal plants should be approved for development.
- By 2025 no new sales of fossil fuel boilers.

* Distinguished Research Fellow and Founder Natural Gas Research Programme, Oxford Institute for Energy Studies, UK/ Distinguished Fellow, IEEJ

- By 2030: all new buildings should be zero-carbon ready; 60% of global car sales should be electric; unabated coal plants should be phased out in advanced countries; more than 1000GW of solar and wind power plants should be built every year.

Table 1 Required Carbon Prices in Advanced and Emerging Economies (Real US$ 2019/tonne/CO_2)

	2025	2030	2040	2050
Advanced Economies	75	130	205	250
Select EMDEs*	45	90	160	200
Other EMDEs	3	15	35	55

*includes China, Russia, Brazil and South Africa
Source: IEA (2021), *Net Zero by 2050*, Table 2.2

In order to achieve these milestones, carbon prices need to increase significantly from current levels in both advanced and emerging and developing economies (EMDEs) as shown in Table 1. Very few advanced countries have carbon prices which are close to $75/tonne currently, and which need to be 70% above that level in 2030, and only a few EMDEs (eg China and South Africa) have carbon price regimes.

Fossil Fuel Production and Exports

One of the most controversial milestones is the requirement there should be no new fossil fuel development. The most immediate impact is on global coal production which falls by more than 50% in the 2020s. By 2030, oil production has fallen by 20% and by 2040 it is less than half the 2020 level. Table 2 shows that as demand falls, prices also fall and supply becomes concentrated in the lowest cost producers. This results in OPEC's share of global production rising to nearly 40% in 2030 and above 50% in 2050. Natural gas production is more resilient falling by only 12% by 2030 with the most immediate impact on global LNG trade which is 50% below 2020 levels by

Table 2 Oil and Gas Prices to 2050 (Real US$ 2019)

	2019	2020	2030	2040	2050
Crude Oil (US$/bbl)	91	37	35	28	24
Natural Gas (US$/mmbtu):					
United States	5.1	2.1	1.9	2.0	2.0
European Union	8.7	2.0	3.8	3.8	3.5
China	7.8	5.7	5.2	4.8	4.6
Japan	12.9	5.7	4.4	4.2	4.1

Source: IEA (2021), Net Zero by 2050, Table 2.1

2030 and 80% by 2040. This is largely due to most projects being unable to compete at the import prices (for Europe, Japan and China) of less than $5/mmbtu shown in Table 2, which should be of concern to promoters of new LNG projects. Natural gas producer income falls by 36% in the 2020s compared to the previous decade but remains relatively stable thereafter. By contrast a combination of falling demand and the prices in Table 2 greatly impact the income (and potentially also the political stability) of oil producing and exporting countries, Which falls by 55% this decade and continues to fall sharply over the following two decades.

Technologies and Modelling

The progress made with low and zero carbon technologies will clearly be very important for the achievement of NZE. The IEA also stresses the importance of consumer behaviour not only in relation to changes in lifestyle (such as personal transport and household heating choices) but also active involvement in efficiency investment and curbing wasteful consumption. For the industry and agriculture sectors, the importance of improving the collection and recycling of plastics, and increasing the efficiency of fertilisers, are key metrics. Overall, the importance of electrification in industry, transport and buildings, and the use of hydrogen in 'hard to electrify' sectors increases significantly.

The NZE scenario was benchmarked against 18 net zero scenarios assessed by the IPCC along different technology parameters. This is important because the selection of technologies and the speed of their development will determine much of cost and difficulty of achieving the desired level of greenhouse gas reduction targets. In comparison to the assumptions in the IPCC scenarios, NZE is: very low in relation to CCUS, direct air capture and bioenergy; moderately low in relation to total final energy consumption; and relatively high in relation to the share of hydrogen and wind and solar in total final consumption.

Although modern bioenergy increases significantly to compensate for the phase-out of traditional biomass, this is not significant in comparison to the IPCC scenarios. Carbon capture, utilisation and storage will be a very important technology for the success of any NZE target. By 2030, 1.7 billion tonnes of CO_2 will need to be captured globally, increasing to 7.6 bn tons by 2050, compared with just 40mt being captured and stored currently. Of the 2030 figure, 80% needs to be captured from fossil fuel production and processes, most of the rest from bioenergy and only 5% from direct air capture. If CCUS fails to achieve these levels – and growth in nuclear power generation is similarly modest – this would require an additional 2000-3000GW of renewable energy by 2030-2050. Hydrogen development relies on fossil fuels (some with CCUS) until 2030 when 'power to gas' (green hydrogen via electrolysis) begins to take off. By 2040, the majority of hydrogen production is from electrolysis, and more than 60% by 2050 with CCUS applied to all fossil-based production.

Investment Requirements and Impact on Household Energy Bills

By 2030, NZE sees a requirement for $5 trillion of investment – more than twice the level spent during 2016-20 – falling only marginally to $4.5 trillion by 2050. From a sectoral perspective, the majority of this investment in the first two decades is required for electricity generation and infrastructure, but with transport progressively increasing its share over the decades. In terms of technology investment, electrification, electricity systems and efficiency take the majority shares, with hydrogen only becoming important post-2030. Electricity network investment is 3-4 times higher compared to 2020, 60-70% of this being due to increased demand.

Household energy bills are projected to fall significantly in advanced economies both in absolute terms and in relation to share of income. In 2030 this is counterbalanced by the investments which will be required in electrification and efficiency, but by 2050 there is a net fall in household energy expenditure despite investment remaining relatively constant. In emerging and developing economies, energy bills per household increase substantially both in absolute terms and as a share of disposable income. A policy of requiring consumers to pay for efficiency improvements may prove politically contentious, and governments may choose to subsidise a large part of household energy efficiency refurbishment and electrification investments through taxation. But as consumers see the benefits of lower bills due to efficiency improvements, such policies may become increasingly popular.

Conclusions: the Importance of Government Policy

It is important to remember that the IEA NZE study is not intended to be a forecast of what <u>will happen</u>. It is an illustration of one possible pathway (but not the only one) showing <u>what needs to happen</u> if the world is to achieve net zero energy emissions by 2050. Returning to the question posed in the title of this article: “Can the world achieve carbon neutral energy balances?” This overview suggests that it is possible, but very difficult without revolutionary changes in the way the world uses energy and organises energy production and consumption. A large part of those revolutionary changes will need to be driven by government policies. Governments have signed up to pledges – either related to the Paris Agreement (COP 21) or achieving net zero emissions by 2050 – and must urgently demonstrate that they are on track to meet the interim targets they have set for 2030. Meeting 2030 targets will be essential if global net zero by 2050 is to remain a credible aspiration.

Writer’s Profile

Jonathan Stern

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 Imperial College, London; and fellowships at the Energy Delta Institute and the Institute of Energy Economics, Japan.

Key Areas in Which Nuclear Power can Help the World Achieve Carbon Neutral

Gerry Thomas*

There is an undeniable need to keep global warming below 1.5°C, to avoid the worst consequences of climate change, but in order to do this, greenhouse gas emissions must decline to zero in 2050 [1]. However, despite this looming deadline, the use of fossil fuels has continued to increase, resulting in annual global greenhouse gas emissions rising from 20.5 billion tonnes of CO_2 to 33.3 billion tonnes in 2019 [2].

Continuation of modern, healthy economies are predicated on the supply of energy sources that are both constant and sustainable. However, 73.2% of global greenhouse gas emissions are generated by the production of energy, with heat and electricity accounting for about one third of this. The use of fossil fuels accounts for 83.4% of all energy (electricity, heat and transport) and generate 63.3% of global electricity[3]. The demand for electricity continues to increase and is outpacing the recent increase in the production of electricity by renewable sources [4], which is why little progress is being made in achieving the global goal of net zero by 2050. Some 770 million people, largely resident in sub-Saharan Africa still lack access to electricity [5]. It is a humanitarian goal to raise living standards in these areas, but an estimated 5000GW of additional capacity above the existing 2500GW would be required for this, assuming that there was no further increase in the global population, and that electrification of the economy remained at a similar level to that in today's European economies, both of which are unlikely.

We would therefore seem to have an impossible problem to solve. How do we maintain our energy hungry, modern societies and ensure the continued development of low and middle income countries whilst reducing emissions of greenhouse gases? While the use of renewables has seen a rapid increase in growth, few countries seem to have taken the utility of nuclear power seriously, although the International Energy Agency has noted that without action to support developments in nuclear power, global efforts to transition to a cleaner energy system will become drastically harder and more costly [6]. Even some Green NGOs (www.greensfornuclearenergy) are starting to realise that excluding nuclear is not an option to achieve our decarbonisation targets. A number of countries e.g. Sweden [7] and France [8] have demonstrated that it is possible to dissociate economic growth from greenhouse gas emissions, which should give hope to the developing economies that their goals of societal improvement can be achieved without destabilising the climate for the rest of the world.

* Professor of Molecular Pathology, Imperial College London / Director, Chernobyl Tissue Bank / Distinguished Fellow, IEEJ

One of the major problems of renewables is that their use is largely restricted to production of electricity only. This is partly because of the area of land required to generate significant amounts of electricity. The high capacity factor of nuclear reactors (global average 82.5%) compares very favourably with other energy sources (coal 49%, gas 29-63%, offshore and onshore wind 45% and 35% respectively and solar PV 18%) and means that significantly less land is required to produce a given amount of energy. A 1000MWe nuclear reactor, which would power 2 million homes in Europe has a foot print of about 3.4 km^2. The land requirement to provide an equivalent output would be between 673 and 963 km^2 for wind farms and 194 km^2 for solar [9]. To use renewables to replace generation by coal, gas and nuclear seems not to be a practical solution, and the amount of land use involved to provide for even modest extension of wind and solar is becoming more of a social issue at the local level, despite being supported in public opinion polls.

Nuclear already has a proven track record in its ability to decarbonise domestic heating and to run air conditioning, which will become increasingly important as climate temperatures rise. Surplus heat from nuclear power plants is being used in a number of countries to provide district heating [10], and can be used to produce the very high temperatures required in a number of industrial processes such as the production of concrete, steel, and the production of alternative power sources such as hydrogen and synthetic fuels [11]. The production of the latter will be key to decarbonising the shipping and aero industries.

So what is preventing us from embracing nuclear power as a partner in climate mitigation? One factor that is often cited is the cost of nuclear energy, yet there are an increasing number of studies that suggest that putting a larger share of nuclear into the energy mix results in lower total cost of electricity for the tax payer and end consumer, due to the longevity of nuclear plants once built [12]. Another factor is nuclear waste, although in truth the nuclear industry is the only low carbon energy source that has sought to internalise all costs in its price. In reality the waste produced by nuclear power is small when compared with solar and wind, with the entire waste since nuclear power came on line being 400,000 tonnes (of which 30% is recycled for reuse in other reactors), whereas it is estimated that by 20-50 some 60-78 million tonnes of electronic waste (which contains toxic chemical entities such as cadmium, antimony and lead) will have been generated by solar PV and 43 million tonnes by the wind energy industry [13,14].

We are running out of time. The chances of reaching net zero by 2050 are diminishing by the second. Reaching these goals by relying on the public to make informed choices about their energy uses will not be enough. Isn't it time we listened to the science and started to invest in a nuclear future, rather than prevaricating and watching our climate becoming ever more unreliable, and reducing the rich biodiversity of this plane still further. As they say, there is no Plan(et) B.

〈References〉

1 IPCC, "Summary for Policymakers," in Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global

greenhouse gas emission pathways, V. Masson-Delmotte, et al, Eds.,Geneva, World Meteorological Organization, 2018.

2 S. Schlömer S , et al., “Annex III: Technology-specific cost and performance parameters,” in Climate Change 2014: Mitigation of Climate Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, O. Edenhofer et al., Eds., Cambridge and New York, Cambridge University Press, 2014, pp. 1329-1356.

3 BP Statistical Review of World Energy, BP, London, 2020.

4 Electricity Market Report, IEA, Paris, 2021.

5 Access to electricity 2021. Available:
https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity
{accessed August 2021}.

6 Nuclear Power in a Clean Energy System,International Energy Agency, Paris, 2019.

7 Lindberg JCH, Sweden’s silent phaseout, Nuclear Engineering International, vol. 62, no. 758, pp. 12-14, 2017.

8 The Silent Giant: The need for nuclear in a clean energy system. World Nuclear Association, London, 2019.

9 Land Needs for Wind, Solar Dwarf Nuclear Plant’s Footprint
https://www.nei.org/news/2015/land-needs-for-wind-solar-dwarf-nuclear-plants.
[Accessed July 2021].

10 Jasserand F et al., Initial economic appraisal of nuclear district heating in France, EPJ Nuclear Sciences & Technologies, vol. 2, no. 39, 2016.

11 Royal Society, “Nuclear cogeneration: civil nuclear energy in a low-carbon future policy briefing,” The Royal Society, London, 2020.

12 https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx (accessed September 2021).

13 Radioactive Waste – Myths and Realities
https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-wastes-myths-andrealities.aspx. [Accessed August 2021].

14 A. Atasu, S. Duran and L. N. Van Wassenhove, The Dark Side of Solar Power Harvard Business Review:
https://hbr.org/2021/06/the-dark-side-of-solar-power. [Accessed August 2021].

Writer’s Profile

Gerry Thomas

Prof. Gerry Thomas is Professor of Molecular Pathology at Imperial College London and the Director of the Chernobyl Tissue Bank (CTB). The CTB was established in 1998 to facilitate research, in cooperation with Belarussian, Ukrainian and Russian scientists, into the biological mechanism that are involved in development of thyroid cancer following a nuclear power plant accident. Since the Fukushima accident in 2011, she has been engaged in public communication of the real health risks of energy production, including exposure to low doses of radiation from nuclear accidents.

Issues for Carbon Neutrality (Science and Policy)

Mitsutsune Yamaguchi*

In my contribution titled "Is It Possible to Achieve Global-Scale Net-Zero Emissions by 2050" to a special issue of the IEEJ Journal in February 2021, I concluded that "achieving net-zero emissions by 2050 appears to be extremely difficult, if not impossible." Later, the European Union and the United Kingdom increased their emission reduction targets for 2030. Japan and the United States followed suit. In May 2021, the Group of Seven industrial democracies in their climate and environment ministers' meeting communique vowed to "lead by example and each commit to achieve net-zero greenhouse gas (GHG) emissions as soon as possible and by 2050 at the latest." This means that G7 and other advanced economies clarified their initiative to limit the increase in the global average temperature from pre-industrial levels to 1.5°C instead of 2°C as agreed by all Paris Agreement parties including developing economies and to move up the deadline for achieving net zero GHG emissions to 2050 from "as soon as possible in the second half of this century" under the Paris Agreement. The issue is whether the initiative could be used to persuade emerging market economies, including China, and developing ones to enhance emission reductions. Developing economies for their part may assert that they have agreed to the 2°C target rather than the 1.5°C target and that it would be absolutely impossible to achieve net zero GHG emissions by 2050. As a result, climate negotiations between advanced and developing economies could be stalled. This is because China and other emerging market economies, as well as Asian and other developing economies continuing economic development, may give less priority to climate change countermeasures than advanced economies. In the following, this paper considers essential issues regarding the target of Net Zero GHG emissions by 2050. Based on the consideration and without prejudice, we should discuss targets that would satisfy emerging and developing economies.

Issue 1: Net Zero – GHG or CO_2 emissions?

As noted above, the Paris Agreement calls for limiting the increase in the global average temperature to 2°C and achieving net-zero GHG emissions in the second half of this century. After the Intergovernmental Panel on Climate Change released a special report (IPCC/SR1.5) in 2018 concluding that net-zero emissions would have to be achieved by 2050 to limit the temperature increase to 1.5°C[1], however, the UK and EU rapidly shifted priority to the 1.5°C target and net-zero GHG emissions in 2050, followed by the G7 members including Japan. However, the IPCC/SR1.5 report called for net-zero CO_2 emissions instead of net-zero GHG emissions.

---

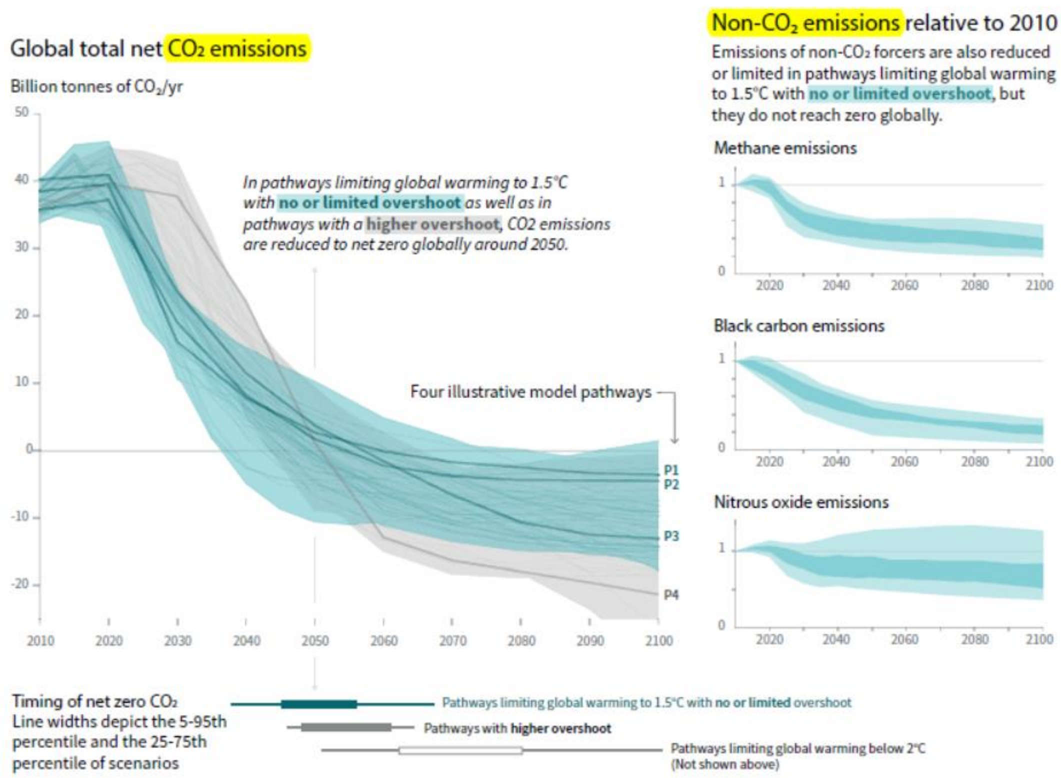
* Distinguished Fellow, IEEJ

[1] More accurately, the report discussed a case in which global warming would be limited to 1.5°C with no or limited (less than 0.1°C) overshoot.

Fig. 1 indicates emissions pathways limiting global warming to 1.5°C in the IPCC/SR1.5 report. Left pathways are for CO_2 and right ones for other GHGs. Approximately, CO_2 emissions would have to reach net zero around 2050 if we allow no or limited overshoot in global warming. However, other GHG emissions including methane would not have to do so. This is because CO_2, once emitted, will remain in the atmosphere over a very long time and surely contribute to boosting temperatures, while other GHGs stay over a shorter time (e.g., 12 years for methane). Other GHG emissions, as far as staying stable, would not contribute to boosting temperatures. However, the Paris Agreement and the G7 have stuck to net-zero GHG emissions instead of net-zero CO_2 emissions. Any clear reason for this is uncertain. One possible reason may be that the UK became the first country in the world in 2008 to set a statutory target of cutting GHG emissions by 80% from 1990 by 2050 and raised the target cut to 100% in 2019, remaining influential in negotiations at the Conference of Parties to the United Nations Framework Convention on Climate Change.

This means that net-zero GHG emissions would be excessive for the target of limiting global warming to 1.5°C and would not have to be reached by 2050 from the scientific viewpoint.

Fig. 1 CO_2 and Other GHG Emission Pathways toward Achieving the Target of Limiting Global Warming to 1.5℃



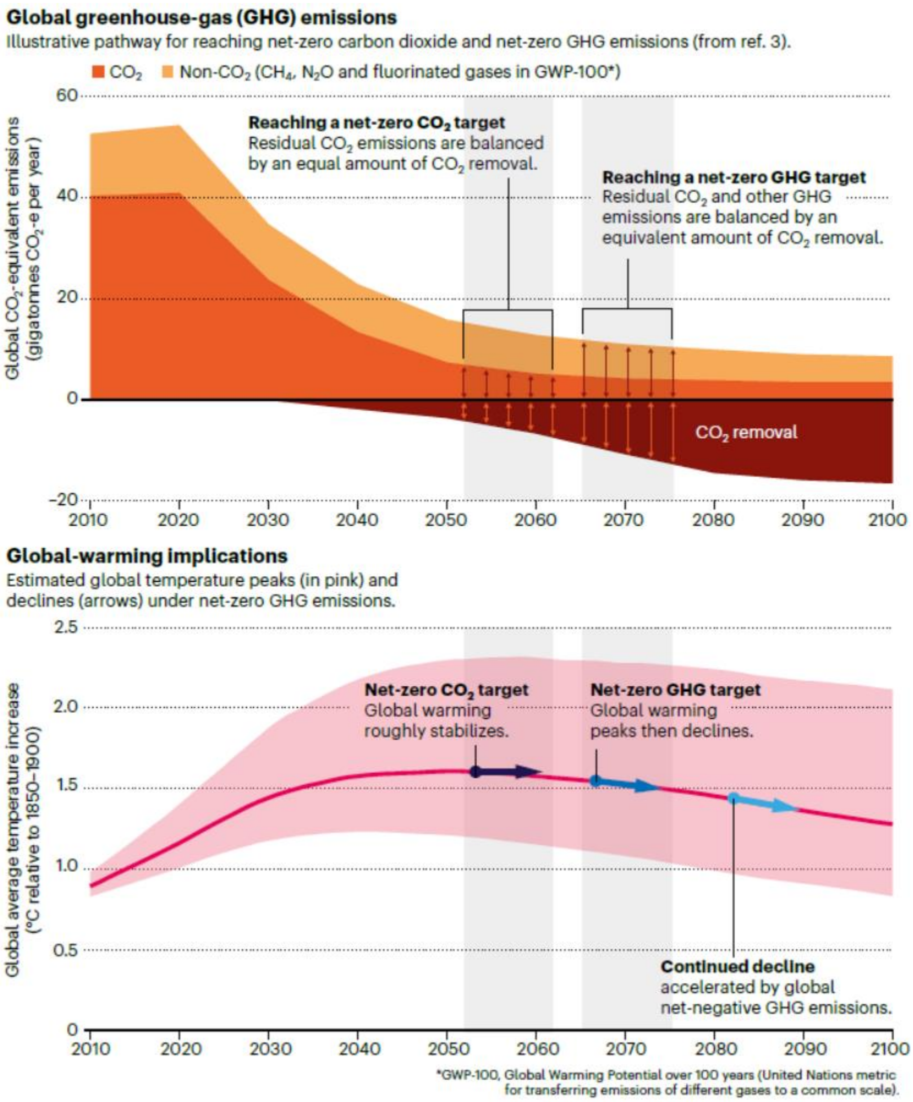
Source: IPCC/SR1.5/SPM p.15 Yellow highlights were given by the author.

Issue 2: Meaning of the Temperature Target – How long net negative CO_2 emissions would continue to extend?

Fig. 2 represents excerpts from a paper that was authored mainly by key contributors to the IPCC/SR1.5 report based on scenarios in the report and published in the refereed journal *Nature.*

The figure's upper half represents an illustrative pathway for reaching net-zero CO_2 and net-zero GHG emissions based on the IPCC/SR1.5 report, indicating CO_2 (red) and other GHG (brown) emission cuts and CO_2 removal (dark brown) through BECCS (bioenergy with carbon capture and storage), DACCS (direct air carbon capture and storage), afforestation and other measures for negative emissions. This shows that CO_2 emissions would become net zero (emissions offset by negative emissions) in the 2050s and total GHG emissions including CO_2 would become so around 2070.

Fig. 2 Global GHG Emission Cuts (upper) and Temperature Trend (lower)



Source: J. Rogelj et al. Three ways to improve net-zero emissions targets, Nature 591, 365-368

The lower half shows temperature changes from pre-industrial levels as a result of the above emission cuts. As temperatures are stabilized after CO_2 emissions reach net zero as noted above, the global average temperature increase would follow a trend indicated by the black arrow. Although other GHG emission cuts would make little progress towards 2100, the gap between CO_2 removal and emissions would expand in a manner to increase net negative CO_2 emissions. In line with such change, the global average temperature increase from pre-industrial levels (red line) would continue to fall, reaching some 1.3°C in 2100. If the target limit is 1.5°C, the increase from pre-industrial levels should be stabilized at the target level. The ultimate goal of climate change countermeasures is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Article 2 of the 1992 UNFCCC, underlined by the author) while ensuring sustainable economic growth. As the real objective is to limit losses from temperature rises to some extent, the goal should be the stabilization of temperatures. Given great uncertainties about the relationship between GHG concentrations and temperature rises, or the climate sensitivity, however, the stabilization of GHG concentrations might have been chosen for the convention. The temperature increase would slightly exceed 1.5°C when CO_2 emissions reach net zero. Later, temperatures would stabilize with CO_2 emissions remaining net zero[2]. In the IPCC 1.5°C scenario as indicated by the figure, however, the temperature increase from pre-industrial levels would continue to fall below 1.5°C with net negative emissions expanding. It is doubtful if the IPCC 1.5°C scenario meets the objective of the convention.

Issue 3: Uncertainties

Uncertainties over the science of climate change were discussed in detail in Chapter 8 of a recommendation[3] by the UK Committee on Climate Change to the government in December 2020. This paper briefly discusses the carbon budget in this regard. The carbon budget is a concept paying attention to a proportional relationship between cumulative CO_2 emissions and a temperature increase. The fifth IPCC assessment report on climate change published in 2013/2014 became the first IPCC report to discuss the carbon budget. In the report, the carbon budget (cumulative CO_2 emissions) to stabilize global warming at a given level (e.g., 1.5°C at the probability of 50%) was estimated at 2,250 gigatons. The 2018 IPCC/SR1.5, released four to five years after the fifth report, gave cumulative CO_2 emissions through 2017 at 2,200 Gt, meaning that the remainder in the carbon budget was 50 Gt, less than two years' global CO_2 emissions. In the IPCC/SR1.5 report, however, the carbon budget estimate was raised to 2,780 Gt, indicating that the remaining carbon budget (allowable future emissions to achieve the target) would be 580 Gt (2,780 Gt – 2,200 Gt), up more than 10-fold from 50 Gt based on the fifth IPCC report. This change is attributable to the development of scientific knowledge and methodology. If the global mean surface temperature (GMST) is used

[2] As the temperature increase slightly exceeds 1.5°C, some additional CO_2 (or GHG) emission cuts would be required to push the increase down to 1.5°C. Here, however, I would like to refrain from discussing details. The essential question is if a long-term decrease in temperatures would be the objective that we should attain.

[3] The Sixth Carbon Budget, The UK's path to Net Zero, Committee on Climate Change, December 2020

instead of the traditional near surface air temperature (SAT) to measure temperatures, the carbon budget would increase further. The carbon budget, particularly the remaining carbon budget, is an important indicator to project future emissions pathways to reaching targets and the timing for net zero emissions and to consider the feasibility of targets. This important indicator is so uncertain. Research may be making progress towards the sixth IPCC report. If the carbon budget increases in the sixth report, climate targets may become easier to achieve. If it decreases, however, they may become more difficult to attain[4].

The above discussed typical uncertainties about the science of climate change. The Paris Agreement has failed to specify any long-term target year for limiting the temperature increase or to discuss whether overshoot is allowable and to what extent. These points are susceptible to the carbon budget. Given the above, it must be noted that the 1.5°C target and the net-zero CO_2 emissions in 2050 are not necessarily linked to each other. This is the same case with the net-zero GHG emissions.

In the above, I cited the three issues. What I would like to emphasize here is that scientific grounds are not solid enough for the 1.5°C target and the net-zero GHG emissions by 2050 for which G7 is pursuing. Given its significance, climate change is a challenge that should be addressed immediately and globally. For the future, however, I hope that world-leading policymakers would have the courage to verify the adequacy of climate targets from scientific and policy viewpoints without any prejudice and formulate new international agreements as necessary.

Writer's Profile

Mitsutsune Yamaguchi

Mr. Yamaguchi's previous position include Visiting Professor/Project Professor, University of Tokyo (2006–2015), Professor of Economics, Keio University (1996-2004), and Former Special Advisor, Research Institute of Innovative Technology for the Earth (RITE). Prior to this, he was Senior General Manager at Tokio Marine & Fire Insurance Co., Ltd. He served in numerous positions on committees and councils related Climate Change and Environmental issues such as a Lead Author of IPCC Working Group III and Chief Japanese Delegate and vice chair at Joint working party of Trade and Environment, Organisation for Economic Co-operation and Development (OECD).

[4] In the Working Group 1 report of the IPCC 6th assessment report released in August 9, 2021, carbon budget of achieving, for example. 1.5 degree C target at 50% probability is estimated as 2890GtCO_2 and, as 2390GtCO_2 has already been emitted by the end of 2019, remaining carbon budget from 2020 onward as 500GtCO_2.

カーボンニュートラルの論点（科学と政策）

山口　光恒*

本年 2 月の日本エネルギー経済研究所（IEEJ）の特別号で、筆者は「2050 年までに地球規模でのゼロエミッション達成は可能か」というテーマで寄稿し、「不可能とは言わないまでも極めて困難」と結論づけた。その後の動きとしては、EU やイギリスに続いて日本やアメリカも 2030 年目標を大幅に引き上げたこと、更に本年 5 月の G7 気候・環境相会議で工業化以降の気温上昇限度を 1.5℃とし、これに向けて G7 メンバー国は極力早い時期（遅くとも 2050 年）までに GHG net-zero の達成をコミットしたことが主たるところである。つまり G7 を中心とした先進国が、パリ協定で途上国も含む全ての加盟国が合意した 2℃目標ではなく、努力目標である 1.5℃への変更を先導し、このために GHG net-zero の達成時期をパリ協定の「今世紀後半のできるだけ早い時期」から「2050 年」に早める方向で自らこれを率先垂範する姿勢を明確にしたと言うことである。問題はこうした姿勢を示すことで中国を含む新興国や途上国を説得可能かどうかである。途上国からすれば自分たちが合意したのは 2℃目標であり、net-zero の時期も 2050 年は到底無理だと主張する可能性が高く、交渉が行き詰まる可能性もある。中国を含む新興国やアジアを中心に経済発展を続ける途上国では気候変動問題の Priority が G7 より低いだろうからである。以下本稿では気候変動対策の本質的な論点に絞って 2050 年 net-zero 問題を検討する。これを踏まえた上で、途上国の納得を得る形の目標について予見無しで議論することが必要と考える。

論点 1　Net-Zero の対象－GHG か CO_2 か

上述の通りパリ協定では気温目標（2℃）と今世紀後半の GHG net-zero をセットで目標としている。しかしパリ協定後に発表された 2018 年の IPCC1.5℃特別報告書（IPCC/SR1.5）が、1.5℃を達成するのであれば[1]2050 年に排出量を net-zero にする必要があるとの内容を公開後、先ずイギリスと EU、次いで日本を含む G7 メンバー国が 1.5℃目標とそのための 2050 年 GHG net-zero に急速に重心を移した。しかし IPCC/SR1.5 で要請されているのは 2050 年 CO_2 net-zero であって GHG net-zero ではない。

IPCC/SR1.5 による 1.5℃達成の排出経路は図 1 の通りである。左が CO_2、右がその他 GHG である。CO_2 については期中の気温の一時的超過（overshoot）の有無と程度で net-zero の時期に多少のずれが生じるが、大凡のところは 2050～2060 年頃に net-zero となる必要がある。他方図右のメタン等 CO_2 以外の GHG はゼロに達していない。この理由は CO_2 は大気中の滞留時間が極端に長いので、今後たとえ 1 トンでも排出するとそれに対応する分だけ確実に気温が上昇するのに対し、それ以外の GHG は基本的には滞留時間が短い（例えばメタンは 12 年）ので毎年の排出量が安定していれば気温は上昇しないからである。しかし何故パリ協定や G7 は CO_2 ではなく GHG net-zero に固執したのか。この明確な理由は不明であるが、イギリスが 2008 年

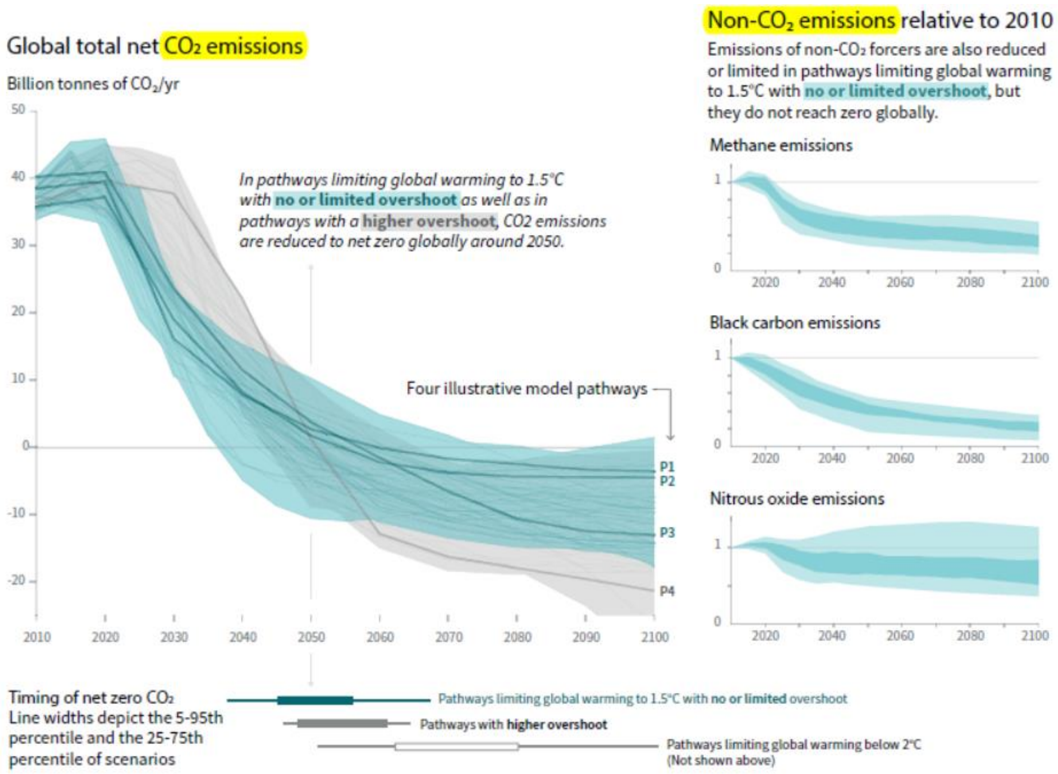
* （一財）日本エネルギー経済研究所　特別客員研究員

1　より正確には期間中に 1.5℃を一度も超えないか、超えたとしても 0.1℃以内という条件付きである。

に世界で初めて 2050 年 GHG80％減（90 年比）を法律で決めたこと、また、2019 年にこれを GHG100％減（net-zero）に強化したこと、そして COP の交渉でもイギリスは強い力を持っていたことが一つの原因ではないかと思われる。

要は科学的見地からすると、1.5℃を Global な目標とする場合であっても GHG net-zero はやり過ぎだし、net-zero の時期も必ずしも 2050 年というわけではないということである。

図 1　1.5℃目標達成に向けた CO_2 及び CO_2 以外の GHG の排出経路



出典：IPCC/SR1.5/SPM p.15　黄色のハイライトは筆者によるもの

論点 2　気温目標の意味－net CO_2 negative をいつまで続けるのか

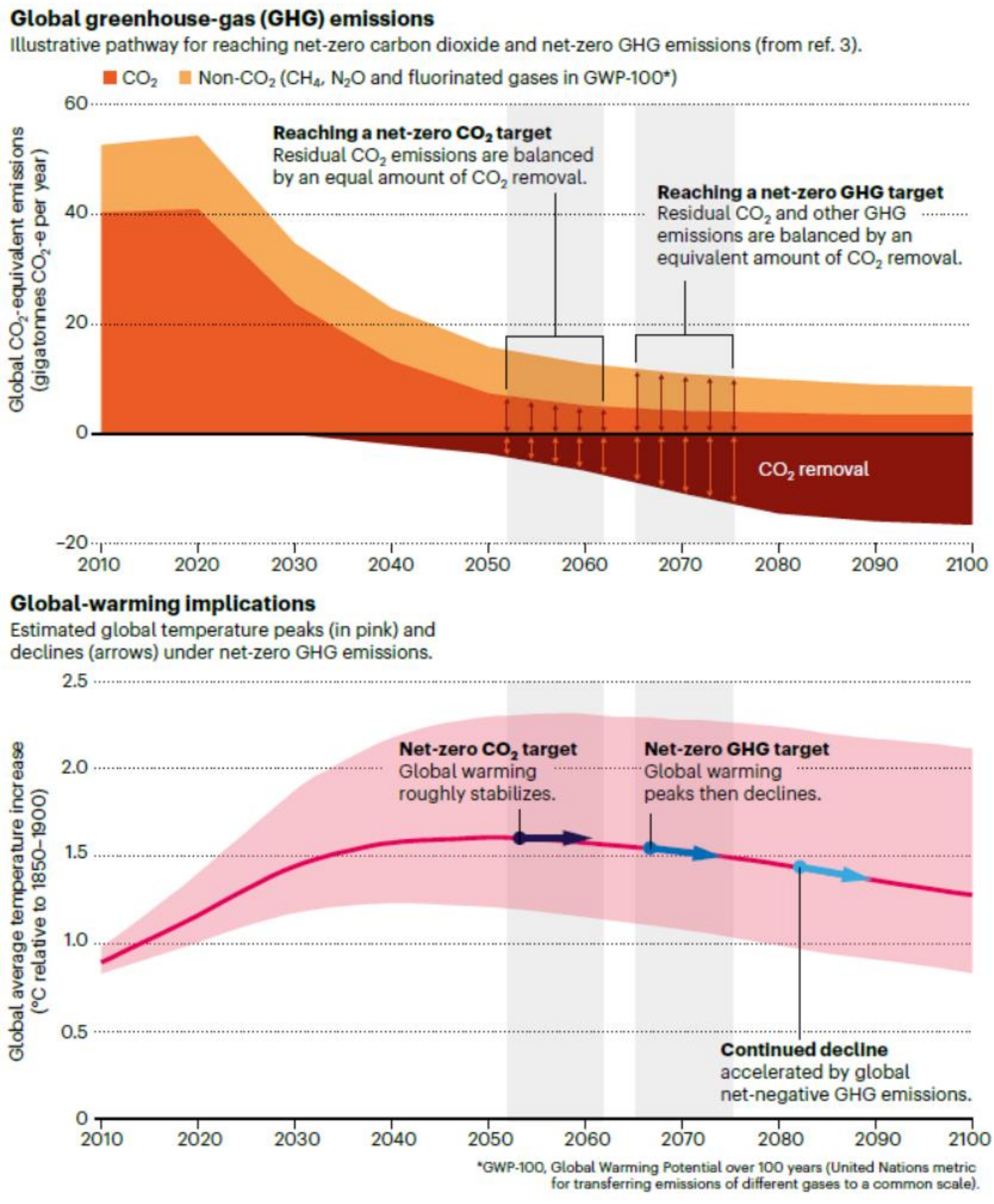
図 2 は IPCC/SR1.5 で中心的な役割を果たした研究者が中心となって学術誌 *Nature* に発表した論文からの抜粋で、IPCC/SR1.5 のシナリオに基づき作成されたものである。

上半分の図は 2020 年以降の CO_2（赤）及びその他 GHG（茶色）の排出削減状況と、それを相殺する CO_2 除去（BECCS、DACCS、植林等のマイナス排出、焦げ茶色）の状況である。図から CO_2 は 2050 年代、CO_2 を含む GHG 全体では 2070 年前後にそれぞれ net-zero となる（プラスの排出量とマイナスの排出量が同量となる）。

図の下半分はその結果の工業化以降の気温の変化を示す。既述の通り CO_2 排出が net-zero になると気温は安定するので、気温は黒の矢印の通りとなる。この後 2100 年に向けてその他 GHG の削減はあまり進まないが、上の図から分かるとおり CO_2 の除去と排出の差が拡大し net CO_2 のマイナスは年々増加する。これに伴い地球の平均気温（赤の線）は低下を続け、2100 年では 1.3℃程度となる。1.5℃を目標にするなら 1.5℃で安定すれば良い。そもそも気候変動対策の究極目標は持続可能な経済成長と両立しつつ、気候システムに危険でないレベルでの濃度安定化

である（1992 年の気候変動枠組み条約第 2 条、下線筆者）。本当の狙いは気温上昇による損害を一定の範囲で抑えることが目的なので「気温」安定化であるべきところだが、GHG 濃度と気温上昇の関係（気候感度）に大きな不確実性があるので、濃度の安定化を謳ったものと思う。CO_2 排出が net-zero に達した時点では気温は 1.5℃をわずかに超えているが、以後は CO_2 net-zero 状態を続けることで気温は安定する[2]。しかし図にあるとおり IPCC の 1.5℃シナリオでは、その後もさらに net でのマイナス排出を拡大し、その結果気温上昇幅が 1.5℃を下回って更に下降を続ける。IPCC の 1.5℃シナリオは条約の目的に合致しているのかとの疑念を抱かざるを得ない。

図 2　世界の GHG 排出削減（上の図）と気温の変化（下の図）



出典：J. Rogelj et al. Three ways to improve net-zero emissions targets, Nature 591, 365-368

[2] 厳密には気温上昇が 1.5℃をわずかに超えているので、これを 1.5℃に戻すために CO_2（或いはそれに相当する GHG）追加削減が必要となるが、ここでは詳細には立ち入らない。事の本質は気温が長期に亘って低下を続けることが果たして我々が目指す目標かどうかと言うことである。

論点 3　不確実性

気候変動の科学を巡る不確実性は、英国の気候変動委員会（CCC）の昨年 12 月の政府への勧告[3]第 8 章に詳細に整理されている。本稿ではこのうち炭素予算について簡単に述べる。炭素予算とは CO_2 の累計排出量と気温上昇が比例関係にあることに着目した概念で、IPCC 報告書が初めてこれに言及したのは 2013 年から翌年にかけて完成した第 5 次報告においてである。それによると、気温上昇を所与のレベル（例えば 50%の確率で 1.5℃）で安定化するための炭素予算（CO_2 累計排出量）は 2250Gt とされた。それから僅か 4-5 年後に公表された 2018 年の IPCC/SR1.5 では 2017 年までの累計 CO_2 排出量が 2200Gt とあるので、残りは世界の CO_2 排出量 2 年分にも満たない 50Gt ということになる。しかし SR1.5 では炭素予算は 2780Gt に増加し、その結果残余炭素予算（目標達成のための今後の許容総排出量）は 580Gt（2780Gt－2200Gt）と IPCC 第 5 次報告の 50Gt に比べて 10 倍以上と大幅に増えている。この理由は知見の進展と方法論の進展によるとある。さらに、詳細は省略するが気温の計測方法として従来の気候モデルによるもの（near Surface Air Temperature、SAT）ではなく、計測された実績値（Global Mean Surface Temperature、GMST）を用いると炭素予算は更に増える。炭素予算、とりわけ残余炭素予算は目標達成のための今後の排出経路と net-zero 到達の目処が決まる極めて重要な指標であると共に、目標の実現可能性を探る上で重要な数値である。その数値がこれほど不確実なのである。この点は IPCC 第 6 次報告書に向けて更に研究が進んでいると思われるが、もしそこで更に増加するようなことがあれば目標達成に余裕が出来、減少しているとこの反対の結果となる[4]。

以上代表的な気候科学の不確実性について述べたが、この他、そもそもパリ協定では長期の気温上昇限度目標の達成時点を明記しておらず、また、目標気温を一時的に超えること（overshoot）やその程度などについても言及がない。これらはいずれも炭素予算に影響する。上記から、1.5℃目標と 2050 年 CO_2 net-zero が必ずしもリンクとはいえない点に留意が必要である。況んや GHG net-zero に於いておやである。

以上 3 つの論点を挙げたが、筆者が強調したいのは G7 が目指している「1.5℃目標とそのための 2050 年 GHG net-zero」についてはその科学的根拠に疑問があることである。気候変動問題はその重大性から直ちに Global に取り組むべき課題ではあるが、今後は科学や政策的観点から先入観無しでこの目標の適切性を検証し、必要に応じて新たな国際合意を構築する勇気を持つことを、世界をリードする政治家に期待するものである。

執筆者紹介

山口　光恒（やまぐち みつつね）
1999年東京海上火災保険株式会社を退社後（役員待遇理事）、慶應義塾大学経済学部教授、東京大学先端科学技術研究センター特任教授等を歴任。元（公財）地球環境産業技術研究機構参与。気候変動に関する政府間パネル（IPCC）第3作業部会リードオーサー、第5次IPCC報告書国内連絡会座長代理、OECD貿易と環境作業部会日本政府代表兼副議長等、気候変動・環境問題にかかる審議会・委員会委員を多数歴任。

---

3 The Sixth Carbon Budget, The UK's path to Net Zero, Committee on Climate Change, December 2020
4 本稿執筆後の本年 8 月 9 日に IPCC 第 6 次報告第 1 作業部会報告書が公表された。それによると 2019 年までの累計 CO_2 排出量は 2390Gt、これに対して例えば 1.5℃を 50%で達成する場合の炭素予算は 2890GtCO_2 なので残余炭素予算は 500Gt と推定されている。

2. Can Developing Countries Pursue the Dual Goal of Carbon Neutral and Economic Growth?

途上国は、カーボンニュートラルと経済成長を両立できるのか？

Can Developing Countries Pursue the Dual Goal of Carbon Neutral and Economic Growth?

Wim Thomas*

The world is moving faster towards accelerating net zero emission goals from energy use as early as 2050. This raises the question if all countries could achieve such pathway and in particular if such target and accompanying regulations will disrupt Developing Countries' economic growth? This paper will argue that such goals are feasible for Emerging Economies as well as Developing Economies and that it will not be dependent on technologies being available or aid from Advanced Economies[1].

Reaching the Paris Goals Become Increasingly an Emerging Economies Issue to Achieve

In practical terms, the energy transition to a 1.5°C world is mainly an Advanced and Emerging Economies' problem to solve. With the World population growing 25% over the next 3 decades to 9.7 bln from 7.8 bln today, over 85% will live in Emerging Economies and Developing Economies, while the population in the Advanced Economies will remain stable around 1.1 bln.

World GDP may rise ~130% over this period to 2050. Advanced Economies share in the total pie is around 40% today, while the Emerging Economies share is ~55% and only some 5% from Developing Economies. This will have changed by 2050 with the share of the Advanced Economies declining to around 27%, while that of the Emerging Economies grows by some 10% points to 65%. Developing Economies' share is expected to be one and a half times larger than today. But in GDP/Capita terms the Advanced Economies are about 3 times richer than the Emerging Economies and 10 times than Developing Economies today and that relationship is not expected to move much over the next decades.

World CO_2 emissions from energy today comes for about 64% from Emerging Economies and for about 33% from Advanced Economies with the remaining 3% from the Developing Economies. By 2050 Emerging Economies' share will have grown strongly to ~75% while the Advanced Economies drop to around 20%. In particular China's role in reducing global emissions will be crucial, being about 30% today, which is half of all Emerging Economies. The role of Developing Economies remains very modest and their priority can remain in achieving the UN's Sustainable Development Goals without overdue concern in reducing CO_2 emissions.

* Former Chief Energy Advisor, Shell International BV / Distinguished Fellow, IEEJ

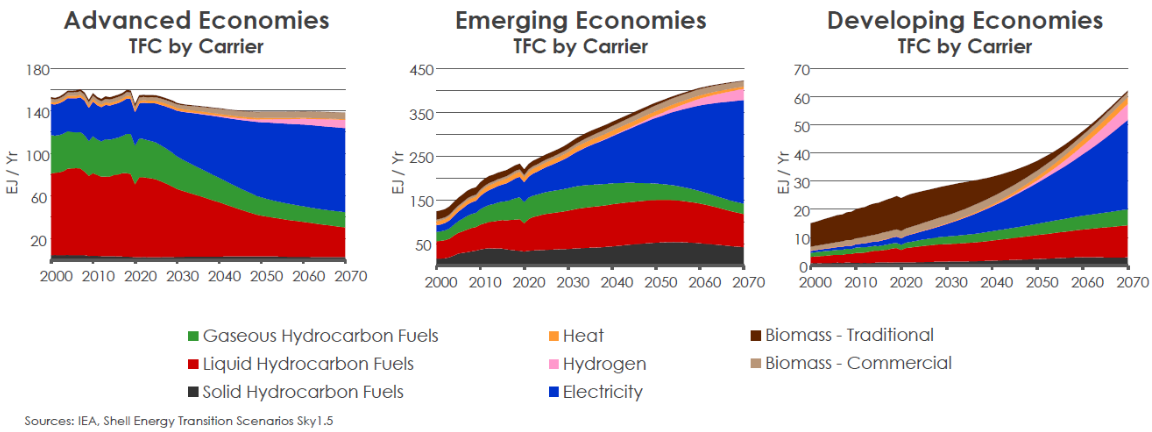
[1] IMF 2020 classification of Advanced, Emerging and Developing Economies are used throughout this paper.

Globalisation and Efficiency Improvements Drive Energy and CO_2 Intensity Reduction

The share of energy use between Advanced Economies and Emerging Economies will remain similar to their shares of global GDP with China being dominant with around 23% of the world and 40% of Emerging Economies. With continuing global economic growth and a strong focus on efficiency, energy intensity as well as CO_2 intensity will continue to decline.

Efficiency and Lower CO_2 Emissions Go Hand in Hand with Electrification

With key countries' pledges to accelerate the energy transition towards net zero by 2050, all type of economies see an acceleration of electricity and bio-mass/fuels use. Presently, electricity share is about a fifth of end-user energy demand, but that will need to more than double over the next 30 years in Advanced Economies and Emerging Economies, while Developing Economies will see a fourfold increase.



Wind, Solar and Biomass are the New Energy Sources

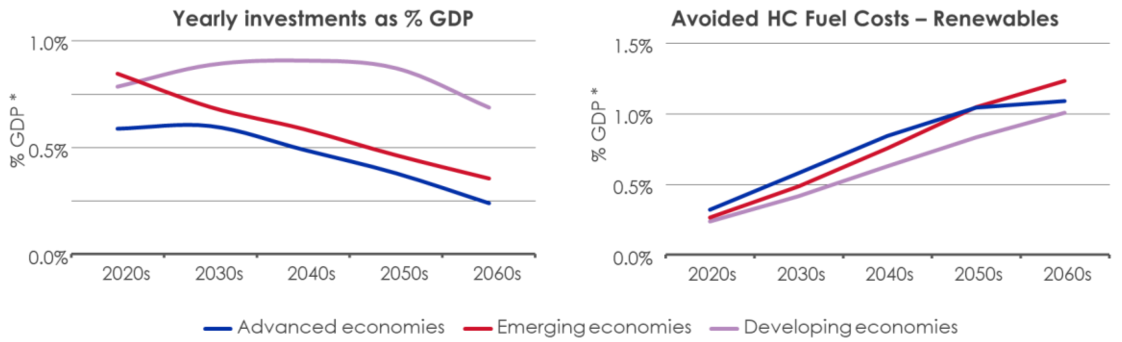
Wind and solar are the new energy sources as the economics of new power generation has already turned the corner in their favour. Wind and solar PV are becoming an order of magnitude cheaper than gas, coal and nuclear, as economies of scale and integration with storage and green hydrogen production will give additional benefits. Remaining gas and coal fired generation get more and more burdened by CO_2 mitigation costs and increasingly being run at low Load Factor for back-up of renewables.

Biomass remains expensive, but necessary to reduce CO_2, also via BECCS[2]. If it ever becomes the marginal price setter in fully developed electricity markets, it could form a solid revenue stream for wind and solar, opening taxation space for governments, which can be used to stimulate or subsidise the energy transition in other sectors.

[2] Bio-Energy Carbon Capture and Storage is a true negative emissions measure, actually removing CO_2 from the atmosphere by storing it underground.

The Energy Transition is Affordable to All Economies

With falling unit costs, the investment cost as a percentage of GDP for Advanced Economies and Emerging Economies come down fast. Unfortunately not so for Developing Economies which will stay longer in a historical range. But this is mainly a GDP effect, so on cost terms they still benefit as well. Cost of investments should also be put in context of avoided fuel costs to estimate the overall effect on economies. All types of economy benefit from avoided fuel cost, reducing overall energy costs as % of GDP. If avoided CO_2 abatement costs are added, the prospect becomes even more compelling. Moreover, investment in renewables will generally create more jobs and hence more economic growth and tax income for States if a country is not a major oil, coal or gas producing country. Renewable Energy cost, once it set its own local price dynamics, will also be less volatile than fossil fuels. Finally, it decreases import dependence, improves trade balance, and helps to reduce energy-related geo-political risks.



* Indicative, mainly Energy supply, excluding upstream, depending on many cost assumptions over time. Relativeness is more important than absolute numbers
Source: Shell Energy Transition Scenarios

Developing Countries Can and Should Pursue the Dual Goal of Carbon Neutral and Economic Growth

On the supply side, economics of new electric energies has already turned the corner in favour of wind and solar PV. So it would be more expensive to remain on the fossil fuel path in many sectors. Emerging Economy China and to an extent India, will have to address faster phase-out of legacy assets though to meet the goals of the Paris Agreement. Industry will be able to look after itself if it competes on the global market, which increasingly demands lower CO_2 products. They will still be able to remain competitive on e.g. labour costs. Moreover, lagging countries risk rising CO_2 related import duties for their export at the border of those countries actively implementing energy transition strategies.

On the demand side it may be a bit more difficult. Energy efficient appliances and buildings are key for lowest CO_2 emissions and overall cost of ownership, but the initial hurdle of higher purchasing and investment costs may inhibit rapid and large scale application. Nevertheless, this end-use (re)design is key for large scale electrification and here government policy intervention will be needed for setting standards and facilitate financing.

Conclusion

Achieving the Paris Goals is not only a matter for the Advanced Economies. To he contrary, success is highly dependent on the successful implementation of energy transition strategies by the Emerging economies. This is particularly true for China and for those countries that are still burning coal. Fortunately, unit costs are decreasing rapidly, making wind and solar cost competitive globally. It is expected that this will also be the case for hydrogen in the next decade. Beside cost, there are many additional benefits to aggressively execute energy transition strategies by all countries. The required acceleration of actions will benefit from strong cooperation between Advanced and Emerging Economies, and cannot afford that the political agenda gets frustrated or blurred by other political topics. While Advanced and Emerging Economies can largely handle the transition themselves, Developing Economies must get aid to not fall behind. This aid is likely as much in financing as in building institutional and industrial capabilities and capacity.

Writer’s Profile

Wim Thomas

Mr. Thomas was part of Shell’s Scenarios Team, which is part of the Group Corporate Strategy Department. He led a team responsible for worldwide energy analysis and long-term global energy scenarios, and advised Shell’s Executive Committee and the Board and its businesses on a wide range of energy issues, including oil & gas markets and pricing, global supply & demand for all energies, regulations, energy policy and industry structure. He had been with the Shell group of companies for some 35 years, with prior international positions in drilling operations, subsurface reservoir management, upstream commercial and regulatory affairs in gas. Presently, he is a non-executive director at MARIN, a world leading maritime research institute in the Netherlands, and on the Advisory Board of the Buccaneer, an accelerator for innovation on sustainable energy in the maritime sector. He is a Fellow of the Energy Institute of the UK and Distinguished Fellow of the IEEJ. He is a former Chairman of The UK National Committee of the World Petroleum Council and of the British Institute of Energy Economics. Wim holds a postgraduate degree in Maritime Technology, Delft University, The Netherlands.

The Scenario Plausibility Vacuum

Roger Pielke Jr.*

Climate research is a natural fit for the use of scenarios, given its roots in long-term planning and the energy industry and the need to offer projections far into the future. Early scenarios were highly idealized and, for instance, focused on exploring what would happen if carbon dioxide concentrations doubled from their preindustrial levels or increased at a steady rate of 1% per year. The Intergovernmental Panel on Climate Change (IPCC) introduced scenarios not just to explore scientific questions, but to project or predict alternative futures in order to inform decision making related to adaptation and mitigation policy making.

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). The *plausibility* of scenarios is a concept that can be defined in a variety of ways (Ramírez and Selin 2014). Plausibility is obviously central to future-oriented scenario planning.

However plausibility might be defined, the IPCC has a design flaw in that across its three working groups no one actually evaluates scenario plausibility. Indeed, in 2008 the IPCC noted of its then-newly developed Representation Concentration Pathway scearnios, "It is an open research question as to how wide a range of socioeconomic conditions could be consistent with a given pathway of forcing, including its ultimate level, its pathway over time, and its spatial pattern" (Moss et al. 2008). More recently, an author of the IPCC AR6 chapter on scenarios noted, "We do not consider the degree of realism of any one scenario."[1] Scenarios are developed and used without consideration of their plausibility.

In climate research and assessment, scenarios are prioritized and adopted for research purposes with no consideration of their likelihood, probability or plausibility. This can lead to confusion and misplaced research effort. For instance, the 2021 IPCC AR6 Working Group 1 report noted that the most commonly used scenarios in climate research have been judged in the literature to be low likelihood, and yet these scenarios made up ore than half of the total references to scenarios throughout the report.[2] Such a disproportionate focus on implausible scenarios has potential to mislead. More generally, in a series of recent papers we have documented that the IPCC, and indeed much of climate research, has focused attention disproportionately on implausible scenarios and has largely ignored much more plausible scenarios (Burgess et al. 2020, Pielke and Ritchie 2021a, Pielke and Ritchies 2021b, Pielke et al. 2021).

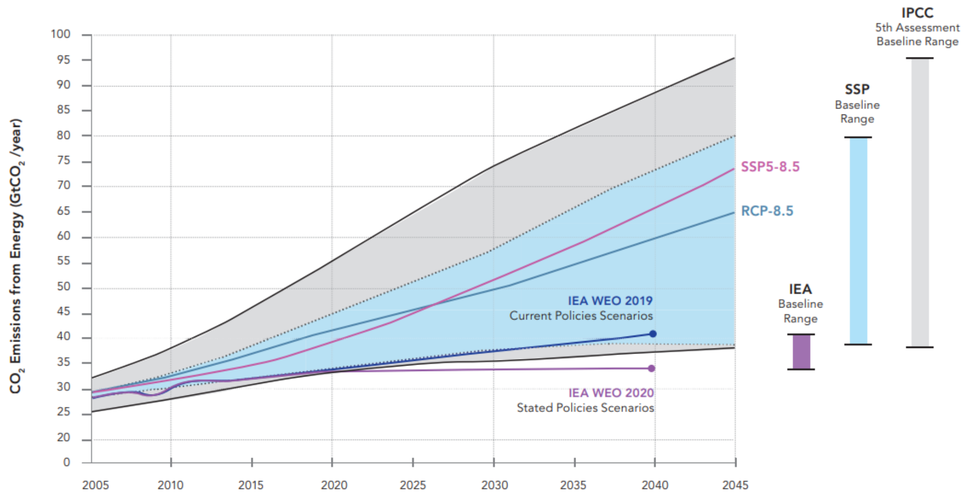
In one analyses we have assessed the alignment of key assumptions – specifically Kaya

* Professor, Environmental Studies Program, University of Colorado Boulder, US / Distinguished Fellow, IEEJ

1 https://www.vox.com/22620706/climate-change-ipcc-report-2021-ssp-scenario-future-warming

2 https://rogerpielkejr.substack.com/p/how-to-understand-the-new-ipcc-report

Identity factors – of the IPCC AR5 scenarios and Shared Socioeconomic Pathway scenarios with observations of these variables and near-term projections of their evolution, as summarized in the figure below (for details, see Burgess et al. 2020).



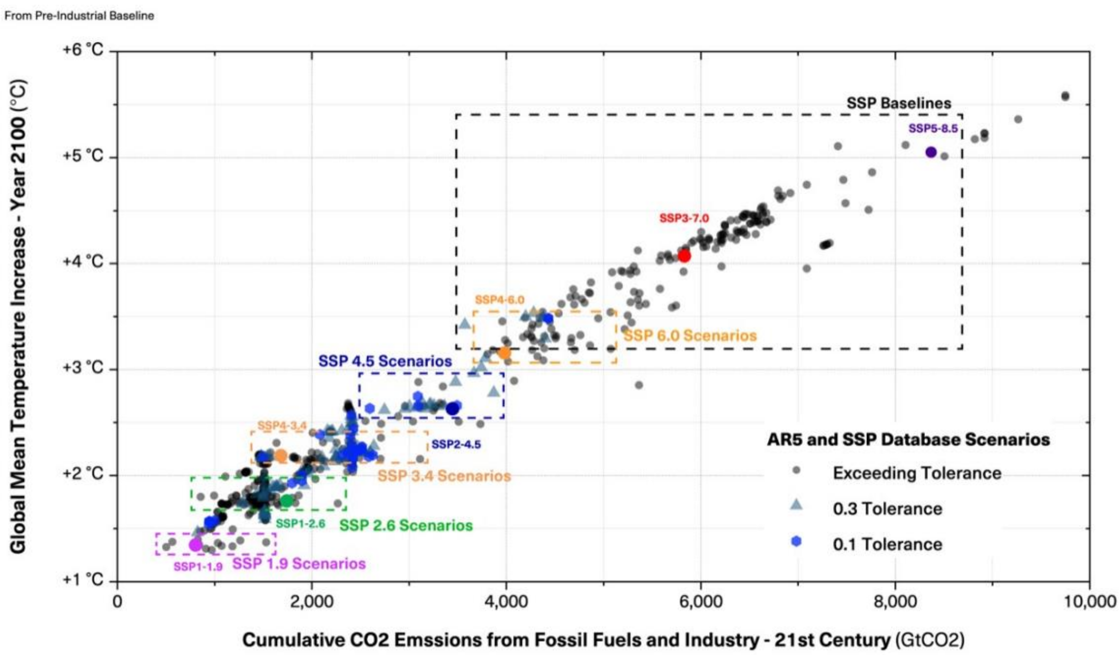
The range of fossil fuel baseline emissions projected by the International Energy Agency in 2019 and 2020 lie almost entirely outside the full range of baseline scenarios for the IPCC Fifth Assessment Report and the SSP scenarios shaping the IPCC Sixth Assessment Report.

We conclude:

> Recent (post-2005) trends and energy outlook projections (to 2040) of global CO_2 emissions are substantially lower than projected by baseline scenarios used in the IPCC's Fifth (AR5) and Sixth (AR6) Assessment Reports, and are well off-track from widely-cited high-emission marker scenarios such as RCP8.5. We show that this divergence owes largely to per-capita GDP and carbon intensity growth slower than projected in baseline scenarios. The gap between observed and projected carbon intensity is very likely to continue to increase throughout the 21st century due to the implausible assumptions high-emission scenarios make about future fossil-fuel expansion

Thus, many scenarios that are at the focus of climate research and assessment have already diverged from real-world trends, making them implausible representations of not just the present, but also the future.

In a follow-on analysis we have identified the subset of scenarios that are consistent with observations and near-term projections (Pielke et al. 2021). We find that about 10% of IPCC AR5 and SSP scenarios meet our most stringent criteria of plausibility. Under less stringent criteria ~27% of AR5 scenarios and ~39% of SSP scenarios meet our criteria of plausibility. The figure below summarizes the analysis of plausible scenarios (for details, see Pielke et al. 2021).



The figure shows that the scenarios most consistent with trends and near-term observations project a median warming in 2100 of ~2.2 degrees Celsius., in-line with SSP 3.4 scenarios. The analysis further underscores the implausibility of the more extreme scenarios, such as SSP 6.0 and greater.

Recent rends and near-term projections of carbon dioxide emissions offers optimism that a worst-case scenario for the next several decades is likely a long-plateau in emissions and approximately 3°C of warming by 2100. This perspective is supported by the envelope of scenarios identified in the figure above as plausible. Of course, the future is uncertain and contingent on policy choices. Decision makers around the world could choose to intentionally grow carbon dioxide emissions, but that currently seems highly unlikely.

Deep decarbonization remains an enormous challenge, and net-zero carbon dioxide emissions by 2050 – a common policy goal – remains outside the envelope of even the plausible scenario trajectories, and thus its achievement will require additional policy efforts. However, the world sits in an enviable position to take on this challenge, at least as compared to where IPCC baseline scenarios – and some of the public discourse of recent years – projected the world to be in 2021. To support deep decarbonization, climate research should develop, regularly update, and focus on plausible scenarios to inform policy. A focus on plausible scenarios will require that someone take responsibility for addressing the scenario plausibility vacuum.

〈References〉

Burgess, M. G., Ritchie, J., Shapland, J., & Pielke, R. (2020). IPCC baseline scenarios have over-projected CO_2 emissions and economic growth. *Environmental Research Letters*, *16*(1), 014016.

Moss, R. M. Babiker, S. Brinkman, E. Calvo, T. Carter, J. Edmonds, I. Elgizouli, S. Emori, L. Erda, K. Hibbard, R. Jones, M. Kainuma, J. Kelleher, J. F. Lamarque, M. Manning, B. Matthews, J. Meehl, L. Meyer, J. Mitchell, N.a Nakicenovic, B. O'Neill, R. Pichs, K. Riahi, S. Rose, P. Runci, R. Stouffer, D.van Vuuren, J. Weyant, T. Wilbanks, J. P. van Ypersele, and M. Zurek, 2008. Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies. Intergovernmental Panel on Climate Change, Geneva, 132 pp.

Moss, R.H., J.A. Edmonds, K.A. Hibbard, M.R. Manning, S.K. Rose, D.P. Van Vuuren, T.R. Carter, S. Emori, M. Kainuma, T. Kram, G.A. Meehl, 2010. The next generation of scenarios for climate change research and assessment, *Nature* 463:747-756.

Pielke Jr, R., Burgess, M. G., & Ritchie, J. (2021, in review). Most plausible 2005-2040 emissions scenarios project less than 2.5 degrees C of warming by 2100. https://osf.io/preprints/socarxiv/m4fdu/

Pielke Jr, R., & Ritchie, J. (2021a). Distorting the view of our climate future: The misuse and abuse of climate pathways and scenarios. *Energy Research & Social Science*, *72*, 101890.

Pielke Jr, R., & Ritchie, J. (2021b). How Climate Scenarios Lost Touch With Reality. *Issues in Science and Technology*, Summer.

Ramírez, R., & Selin, C. (2014). Plausibility and probability in scenario planning. *Foresight*.

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.

Energy Transition and Sustainable Growth

Yukari Yamashita*

From an environmental perspective, the year 2021 has been very important with the scheduled COP26 meeting, later this year. There have been a series of events such as Biden's climate change summit, the release of the IEA Special Report, the ASEAN Summit, the G7 and G20 Energy and Climate Ministers' Meetings and finally the IPCC Sixth Report of the first Working Group (AR6-WG1). The IPCC report states that it *is unequivocal that human influence has warmed the atmosphere, ocean and land*[1]. The public's response to climate change is accelerating and companies are increasingly decarbonizing.

【Introduction】

This paper/summary is organized according to Session 2 of the April 2021 IEEJ/APERC Symposium. Because climate change is a challenge facing all of humanity and cannot be solved without all countries contributing a fair share, the Symposium invited representatives from different countries to discuss their energy. Within the all-embracing philosophy of sustainable growth, the main question was: "Can developing countries achieve the dual goal of carbon neutrality and economic growth?" The key is whether all humanity, including emerging and developing countries, can tackle climate change while moving in the same direction. As specific measures for developing countries cannot be fully and clearly identified, it would seem the carbon neutral (CN) movement is not perfect.

For the Symposium, we also asked the speakers if they learn anything from Covid-19 that would support achieving the CN target. Dr. Jirapongphan[2], who has served in many key positions in Thailand, including being the Minister of Energy, pointed out the importance of international cooperation and the need of sharing the benefits of economic growth with other regions. He also discussed overcoming the world efforts toward the decarbonization issue by utilizing all technologies, despite social needs and cultural differences. The vaccines to combat the corona virus are an example of international cooperation toward a common goal,

Dr. Srivastava of IIASA[3], who has long been involved in energy and environmental policy in India, explained that technological innovation should be expected, but warned that without a change in people's behavior, technology would not yield the expected effect. For example, when

* Managing Director, Charge of the Energy Data and Modelling Center, IEEJ

1 IPCC 6th Evaluation Report, First Working Group Report, Summary for Policy Officers (SPM), Sixth Assessment Report (ipcc.ch)

2 Dr. Siri Jirapongphan, Former Minister of Energy, Thailand, Current Advisor to the Ministry of Energy, Thailand

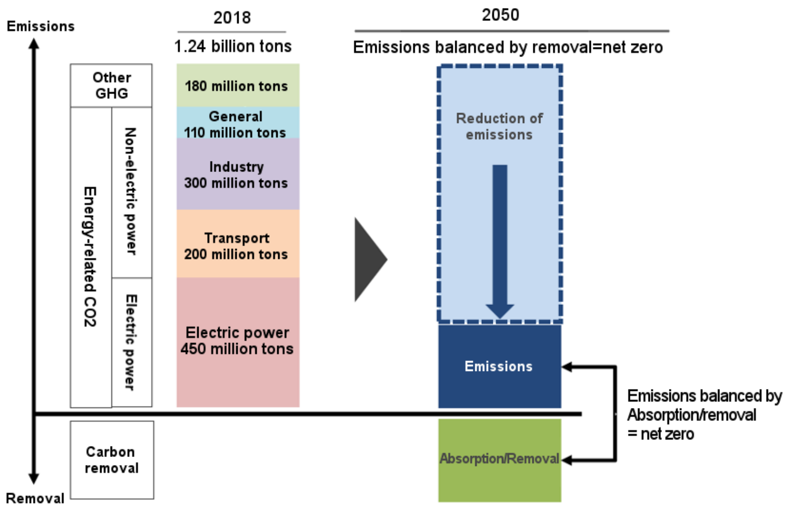
3 Dr. Leena Srivastava, Deputy Director General for Science, International Institute for Applied Systems Analysis (IIASA)

the pandemic behavior restrictions were lifted anywhere in the world, people quickly returned to pre-corona customs only to face a third, fourth, and fifth wave. If we don't quickly and fully reap the benefits of innovation, the cost of CN will keep rising. She argued that the role of government in introducing regulations and incentives is important for a successful energy transformation.

【Carbon Neutrality Targets and Challenges】

More than 120 countries and regions around the world have set "CN 2050" goals and many of them aim to net zero GHG emissions by 2050. Consequently, carbon neutrality refers to not only carbon dioxide but also includes all greenhouse gases (GHG) emissions (N_2O, methane, fluorocarbons, etc.). While it is difficult to completely eliminate emissions, net zero means that any remaining direct emissions can be offset by the "absorption" or "removal" of emissions by other means (Fig. 1). For the energy sector, reductions in carbon dioxide emissions are the main actions to combat climate change.

Fig. 1 Japan' s GHG Emissions and Image of 2050 Net Zero



Source: Agency of Natural Resources and Energy Website：
https://www.enecho.meti.go.jp/en/category/special/article/detail_164.html

According to an IEEJ review[4] of the major countries (EU, UK, France, Germany, Japan, China) that identified specific scenarios and measures to achieve their target, the 5 main components that emerged are as follow. (1) energy saving, (2) electrification, (3) zero-emission power generation (renewable energy, nuclear power), (4) measures other than electric power, (5) absorption by forests, etc. for residual emissions, and CO_2 removal technology (BECCS, DACCS, etc.).

[4] Takahiko Tagami, "Trends in Major Countries toward Achieving Carbon Neutrality Targets: How Are Major Economies Trying to Achieve Carbon Neutrality? " (The 438th Annual Research Report Meeting), July 27, 2021.

With the first 4 components, GHG emissions are expected to decrease by about 80% by 2050 and the remaining amount would use the 5th component to absorb and remove the surplus. Final energy consumption will decrease by 30-40% from current levels, and the rate of electricity consumption (as a percentage of final energy) will rise to 40-60% by 2050, excluding China which expects 70%[5].

The ratio of renewable energy generation, which is key to reach zero emissions in the electricity sector, is slightly over 80% in the UK and EU, 75% in China and 54% in Japan. In 2050, the share of nuclear power will be between 9 and 16 percent in most countries, except for France[6], which is highly dependent on nuclear power. Hydrogen, which is attracting attention as a new fuel, accounts for about 20% of final energy consumption in 2050 in the UK and about 10% in China, Japan, and the EU. Including synthetic fuels and synthetic methane, those fuels will account for 18% in the EU and 15% in Japan which is expected to be high in hydrogen.

Most countries would absorb less than 20% of total emissions by 2050 (compared to the current level). While the amount of forest absorption in France and the EU should increase significantly, Japan is currently on a downward trend, with only about 4% of GHG's total in 2019. The amount of absorption by CO_2 removal technologies, including CCS, is particularly large in Japan (14%) and the UK (12%) relative to their total emissions in 2015-20.

【Emerging and Developing Countries and Carbon Neutral Targets】

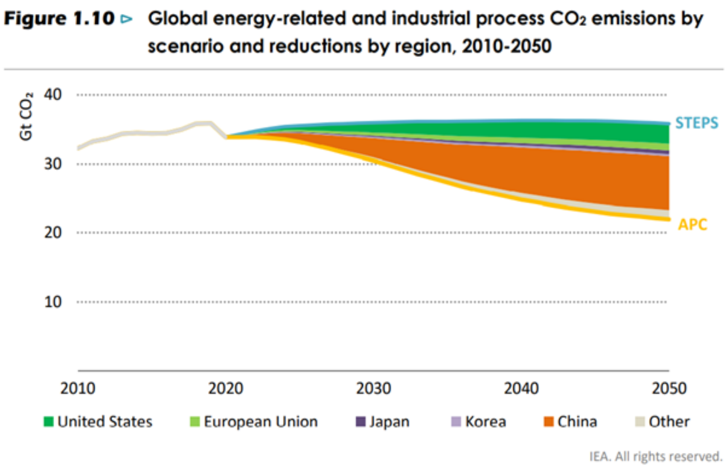
According to the IEA[7], only a limited number of CN-declared countries have specific policies. Fig. 2 shows the CO_2 emissions of the APC (Announced Pledges Case) in the IEA roadmap analysis. Compared to existing policy scenarios (STEPS) centered on current policies and existing technologies, emissions will decrease by 14GtCO_2 in 2050, mainly due to reductions in China and the United States, but emissions after the reduction will be 22GtCO_2, far short of net zero in 2050. The APC includes 44 countries and the European Commission, which have so far announced net zero and currently account for 70% of the world's emissions and GDP. These countries are China, the United States, the EU, Japan, South Korea, and others (U.K., Norway, South America, etc.). Southeast Asia, India, and African countries where the ratio of energy demand to CO_2 emissions is expected to increase in the future are not included in the APC; the future trends in these countries will be key.

5 China's power consumption rate in 2050 is as high as 71%, and power consumption will be the key to realizing CN.

6 France is targeting a combined share of 50% of renewable energy and nuclear power in 2035 but has not yet decided on 2050.

7 According to the "Net Zero by 2050: A Roadmap for the Global Energy Sector" released in May 2021, CO_2 emissions will only be reduced to 30Gt in 2030 and 22Gt in 2050, as shown by the Announced Pledges Case (APC).

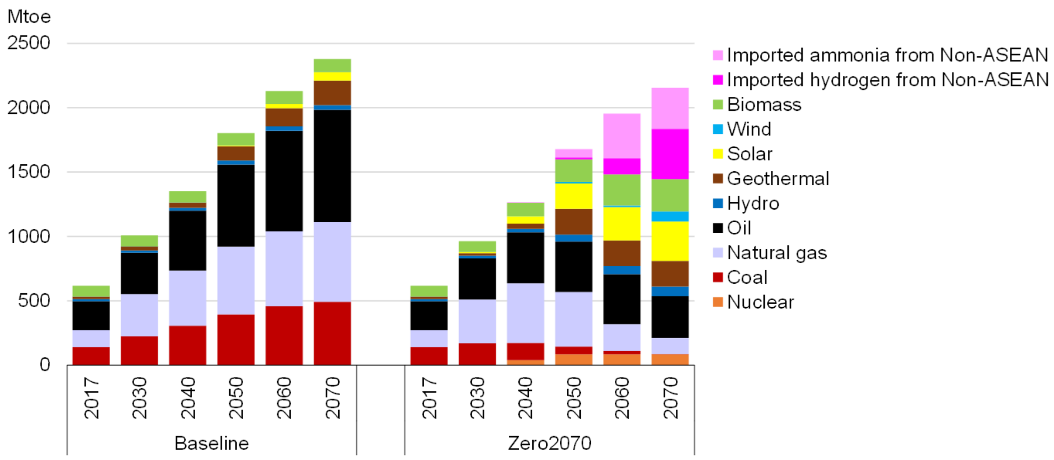
Fig. 2 Carbon Neutral Declaration Country Reduction Cases (APC, IEA Analysis)



Source: IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector (May 2021)

The Economic Research Institute for ASEAN and East Asia (ERIA) and the IEEJ analyzed the economic impact of aiming for carbon neutrality across ASEAN. While ASEAN's energy demand is expected to continue to rapidly grow for a few more decades, the ERIA/IEEJ analysis compares the economic impact of different target years scenarios for achieving CN (2050, 2060 and 2070). The right side of Fig. 3 shows a scenario of ERIA/IEEJ analysis aiming for net zero by 2070. Until 2050, it is expected to shift from oil and coal-fired power generation to mixed-firing power generation of gas, ammonia, and hydrogen, and gas-fired power generation with CCUS. From 2050 onwards, in addition to solar and biomass power generation, 100% hydrogen and ammonia power generation will be required. Emissions from the transportation and industrial sectors are expected to continue in 2070, requiring technologies such as DACCS and BECCS as a means of reducing the remaining carbon dioxide.

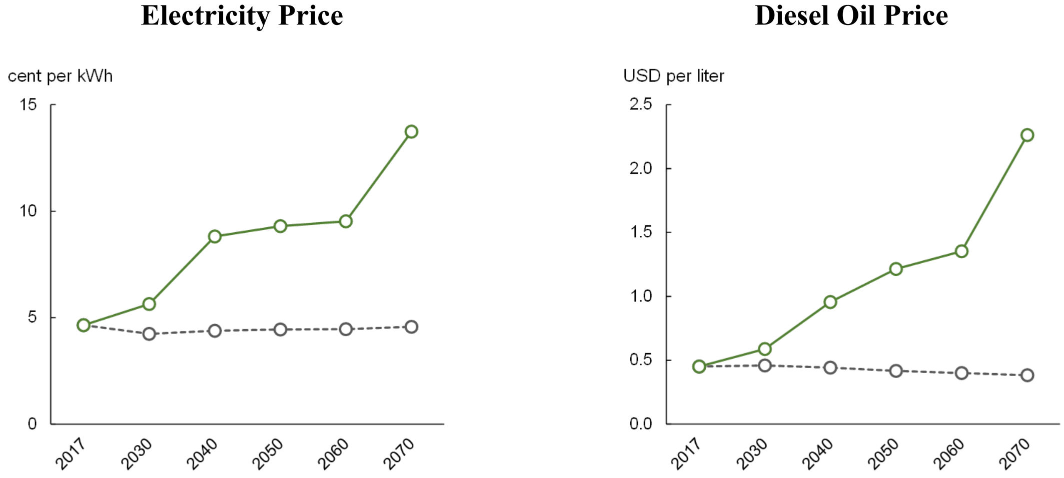
Fig. 3 Scenarios for Achieving Carbon Neutrality in 2070 across ASEAN



Source: ERIA-IEEJ, "Model Analysis for Carbon Neutrality in ASEAN by the Center for Economic Research in East Asia and ASEAN (ERIA) (Current Edition) " (June 2021)

The energy transformation towards achieving CN in the ASEAN region by 2070 will cause energy prices to rise substantially. Electricity prices could triple from current levels and light oil prices can rise five-times, straining people's lives (Fig. 4).

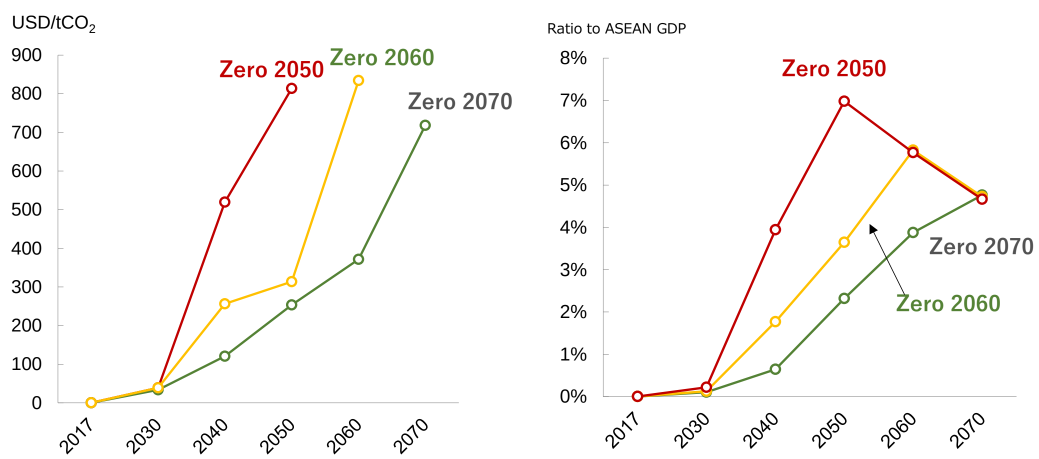
Fig. 4 Carbon Neutrality and Changes in Electricity and Diesel Oil Prices by 2070



Source: ERIA-IEEJ, "Model Analysis for Carbon Neutrality in ASEAN by the Center for Economic Research in East Asia and ASEAN (ERIA) (Current Edition) " (June 2021)

The left side of Fig. 5 shows the marginal cost of reducing CO_2. If the aim is to be carbon neutral by 2070, the cost of reducing the last ton of CO_2 will exceed \$700, due to a sharp rise in costs after 2040. If the target is brought forward and CN is achieved by 2050, the marginal cost of reduction will rise to more than \$800/ton by 2050.

Fig. 5 Marginal Reduction Costs and Ratio of Additional Costs to GDP



Source: ERIA-IEEJ, "Model Analysis for Carbon Neutrality in ASEAN by the Center for Economic Research in East Asia and ASEAN (ERIA) (Current Edition) " (June 2021)

The right side of Fig. 5 shows the annual additional cost expressed as a ratio to ASEAN's GDP. The ratio expands as various costs, including energy prices, rise and follows a different trajectory if the net-zero is achieved earlier or later. If it is net-zero in 2050, the cost will rapidly increase to 4% by 2040 then 7% by 2050, before declining to 5% of GDP by 2070. In the case of net-zero by 2070, it is small in 2040, about 2% in 2050 and reaching 5% of GDP by 2070. Consequently, setting a target year for achieving carbon neutrality early is expected to weigh on the economy, partly because the cost of the necessary technologies has not come down sufficiently.

The many developed countries' declaration for CN by 2050, should leave plenty of room for reflection as to whether it is also desirable for emerging and developing countries to aim for CN by 2050. Those countries have not yet benefited from economic growth to the same extent as the developed countries did.

Mr. Thomas, a debater at the IEEJ/APERC symposium and a former shell chief economist, said the scale of investment required for rapid decarbonization was enormous. The level of investments per capita in emerging and developing countries accounts for a significantly higher share of GDP, and disproportionally burdens those countries. He also pointed out that the 1.5-degree energy transformation to the world is a major issue that developed countries and some emerging economies should address. The developed countries should cover in part the increased investment burden on developing and emerging economies.

【In Conclusion】

The trend for "decarbonization", which implies a move or transformation towards cleaner energy, accelerated in part because of the introduction of additional policies for economic recovery from the economic disaster caused by Covid-19. Nuclear power which could have played the leading role for clean energy is becoming more costly, and there is a noticeable delay in its use in developed countries. Except for renewable energy, there are no other existing technologies to rely on.

The use of coal-fired power generation continues to increase in Asia which is considered the economic growth center for the world. Coal use is increasing even in China despite its CN declaration. Cars on the road will not be replaced by electric vehicles any time soon, and the need for oil products will continue for some time. It is difficult not only for Japan but also for the Asian emerging countries to completely and rapidly switch to renewable electricity. Therefore, it is expected that the use of gas-fired power, which is the cleanest fossil fuel, will also continue for some time. In the transition phase of the energy transformation, it is necessary for Asia to strongly appeal to the world that decarbonization of fossil fuels is important.

With an expected drop in production cost, blue hydrogen could be an option for Asia as a consumer and the Middle East as producers. It is necessary for countries to cooperate while competing. To reduce the cost of new forms of energy, including hydrogen, it is essential to not only create a demand, but it is also important to create rules and guidelines that reflect the circumstances of Japan and Asia (such as international standards).

For Asia, hydrogen will be an imported form of energy that relies on the willingness of foreign countries to supply and perform CCS. Therefore, "Energy security" continues to be a challenge. It is necessary to come up with a portfolio that considers responses through a variety of energy, technology, and system combinations.

Dr. Srivastava, a presenter at the Symposium, said that it is possible to get close to CN if the world fully utilizes the currently available technology. The CN targets can be achieved with the addition of a few new innovations and technologies and CCS. However, she stressed (1) the importance of strengthening international cooperation and governance based on a fair approach, (2) the need for resetting economic infrastructure and development by including sustainability, and (3) the will for spreading knowledge about sustainability throughout society. Mr. Thomas added that nature-based solutions improve habitats.

Energy is taken for granted most of the time, and its importance only recognized during emergencies. As the big wave of CN will be a major challenge for the next 30 years until 2050, the need for concerted efforts to not leave anyone behind will become imperative.

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 was the 2020 President of the International Association for Energy Economics (IAEE) and is the 2021 Executive Vice President of IAEE.

エネルギー変革と持続可能な成長

山下　ゆかり*

COP26 が開催される 2021 年は、バイデン新政権の気候変動サミット、IEA 特別レポートの発表、ASEAN 首脳会議、G7 及び G20 のエネルギー・気候大臣会合等が続く。8 月初旬には温暖化が人為的であることを断定する IPCC 第 6 次報告の第 1 作業部会の報告書が発表された[1]。企業による脱炭素化の動きも活発化しており、気候変動対応は加速している。

【はじめに】

本稿は 2021 年 4 月の IEEJ/APERC シンポジウムのセッション２「途上国はカーボンニュートラルと経済成長を両立できるのか？」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。

シンポジウムでは CN 目標について COVID-19 対応から学べる点を登壇者に尋ねた。タイでエネルギー大臣等多くの要職を歴任したジラポンファン氏[2]は新型コロナワクチンが世界に行きわたらない問題を取り上げ、国際協力と経済成長の恩恵を特定地域・国だけでなく他の地域と共有する重要性において、脱炭素化に向けた世界大での連携との共通点を指摘。また、社会ニーズや文化の違いを認めつつ技術活用で課題を乗り越える可能性に言及した。

インドで長くエネルギー・環境政策にかかわった IIASA のスリヴァスタヴァ氏[3]は、イノベーションは可能だが、人々の行動変革とその定着がなければ、期待する効果が続かないことへの警鐘を鳴らした。コロナ禍の行動制限が解除されると人々はコロナ前の習慣に戻り、第３、第４，第５の波が各国を襲った。コストを伴うイノベーションの利益をフルに享受できなければ、コストはより高くなってしまう。エネルギー変革においても規制やインセンティブ等、政府の役割が重要であることを指摘した。

【カーボンニュートラル目標と主要国の対応】

世界で 120 以上の国と地域が「2050 年 CN」目標を掲げる。エネルギー分野では二酸化炭素（CO_2）排出削減が主体だが、気候変動対策としては温室効果ガス（GHG）の排出削減が必要で、CO_2 の他にも窒素、メタン、フロン類などが対象だ。カーボンニュートラル（炭素中立）は CO_2 排出量と吸収量の相殺を指すが、目標の多くは 2050 年までの GHG 排出量ネットゼロを目指している。ネットゼロの含意は排出を完全にゼロに抑えることが難しい中、排出せざるを

* （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

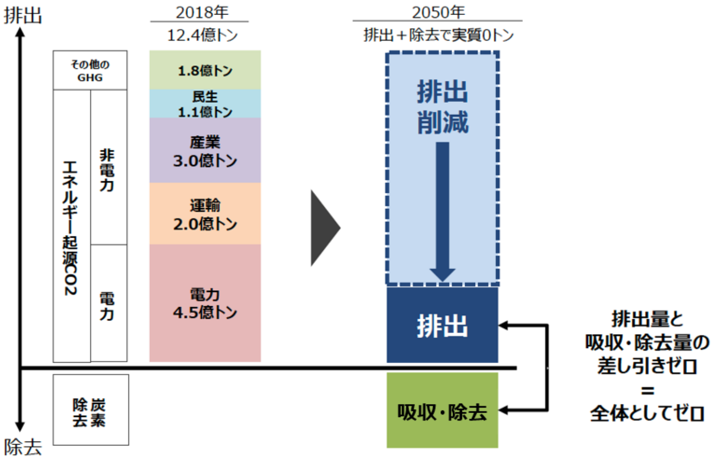
1 IPCC 第 6 次評価報告書、第 1 作業部会報告書、政策担当者向け要約（SPM）仮訳、A.1.1 https://www.data.jma.go.jp/cpdinfo/ipcc/ar6/IPCC_AR6_WG1_SPM_JP_20210820.pdf

2 Dr. Siri Jirapongphan, Former Minister of Energy, Thailand, Current Advisor to the Ministry of Energy, Thailand

3 Dr. Leena Srivastava, Deputy Director General for Science, International Institute for Applied Systems Analysis (IIASA)

得なかった分については同量を「吸収」または「除去」することで、正味ゼロを目指すという意味である（図１）。

図１　温室効果ガス（GHG）の 2050 年ネットゼロの概念図



出所：資源エネルギー庁サイト：
https://www.enecho.meti.go.jp/about/special/johoteikyo/carbon_neutral_01.html

CN 目標達成の具体的な対策等の数値を示す主要国（EU、英国、フランス、ドイツ、日本、中国）を分析すると[4]、達成手段は①省エネ、②電力化、③電力のゼロエミッション化（再エネ、原子力）、④電力以外の対策、⑤残余排出量の森林等による吸収、CO_2 除去技術（BECCS、DACCS 等）に整理できる。GHG 排出量は 2050 年で約 8 割減と想定し、残余分は吸収・除去で対応する姿を描く。最終エネルギー消費は現在よりも 3～4 割減少、電力化率（最終エネルギーに占める電力の割合）は 7 割の中国を除き、2050 年に 4～6 割まで上昇する[5]。

電力のゼロエミッション化のカギとなる再エネ電力比率は英国･EU が 8 割強、中国が 75%、日本は 54%である。2050 年の原子力シェアは原子力依存度の高いフランス[6]を除き、多くの国で 9～16%程度である。注目される水素の 2050 年最終エネルギー消費シェアは英国が約 20%、中国・日本・EU が約 10%である。合成燃料や合成メタンを加えると、EU は 18%、日本は 15%となり、水素への期待の高さが窺われる。

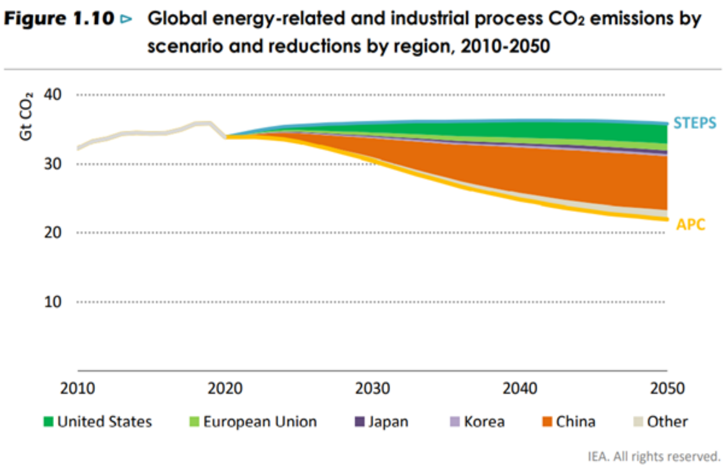
なお、ほとんどの国が 2050 年に現在の総排出量の 2 割弱の吸収を想定。森林等の吸収はフランスや EU が大幅増加を見込む一方、日本では足元で減少傾向にあり、GHG 全体の約 4%（2019 年）にとどまる。CO_2 除去技術による吸収量は日本と英国が比較的大きく、それぞれ足元（2015～20 年）の総排出量比 14%（日本）、12%（英国）を想定している。

[4] 田上貴彦、「カーボンニュートラル目標達成に向けた主要国の動向：主要国はどのようにカーボンニュートラルを実現しようとしているのか？」（第 438 回定例研究報告会）、2021 年 7 月 27 日
[5] 中国の 2050 年の電力化率は 71%と高く、電力化が CN 実現のカギとなる。
[6] フランスは 2035 年の再エネと原子力を合わせたシェア 50%を目標とするが 2050 年は未定。

【新興国・途上国とカーボンニュートラル目標】

IEA によれば CN 宣言国で具体的な政策を示す国はまだ限定的である[7]。図 2 に IEA のロードマップ分析の APC（Announced Pledges Case）の CO_2 排出量を示した。現行政策や既存技術中心の既存政策シナリオ（STEPS）と較べ、2050 年で主に中国と米国の削減で 14Gt-CO_2 減少するものの、22Gt-CO_2 が残り、2050 年ネットゼロには程遠い。APC にはこれまでネットゼロを表明した 44 か国及び欧州委員会を含み、足元の排出量と GDP で世界の 7 割を占める。これらの国は中国、米国、EU、日本、韓国、その他（英、ノルウェー、南米等）で、APC に含まれず、エネルギー需要/CO_2 排出量の増加が見込まれる東南アジア・インドやアフリカ諸国の今後の動向がカギを握る。

図 2　カーボンニュートラル宣言国の削減ケース（APC、IEA 分析）

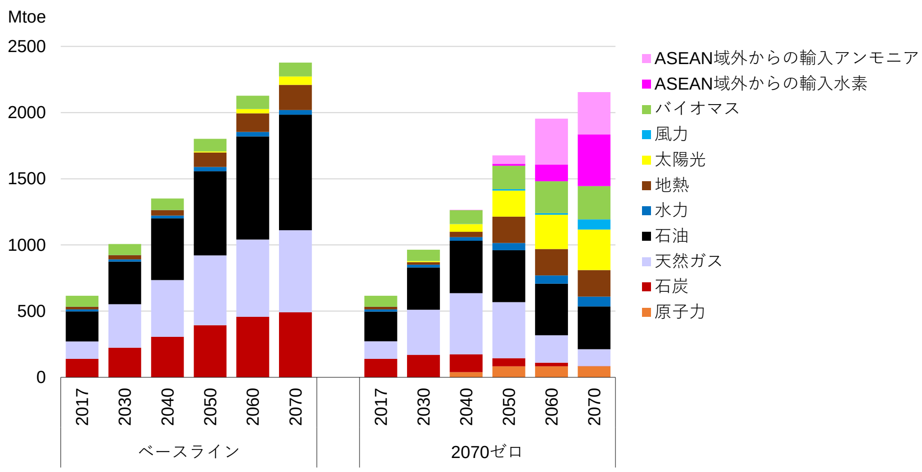


出所：IEA、Net Zero by 2050: A Roadmap for the Global Energy Sector（2021 年 5 月）

東アジア・アセアン経済研究センター（Economic Research Institute for ASEAN and East Asia, ERIA）と弊所（IEEJ）では、アセアン全体で CN を目指した場合の経済影響を分析した。アセアンのエネルギー需要は今後も増加が見込まれるが、ERIA/IEEJ 分析では 2070 年を CN 達成年にした場合と 2050 年や 2060 年を目標にした場合の経済影響を比較、成長しつつ CN を実現する道筋を探っている。図 3 右は ERIA/IEEJ 分析の 2070 年ネットゼロ達成シナリオを示す。2050 年までは石油や石炭による火力発電からガス、アンモニア、水素の混焼発電や CCUS 付きのガス火力などへのシフトを想定。2050 年以降は太陽光やバイオマス発電に加えて水素やアンモニア 100%の発電も活用する。2070 年も運輸・産業部門からの排出は続く見込みで、残る CO_2 削減の手段として DACCS や BECCS などの技術が必要となる。

[7] IEA が 2021 年 5 月に発表した Net Zero by 2050：A Roadmap for the Global Energy Sector 分析の APC（Announced Pledges Case）によれば、ネットゼロを表明したうち 44 か国及び欧州委員会がコミットした削減パスによれば 2030 年に 30Gt、2050 年に 22Gt までしか CO_2 排出量は削減されない。

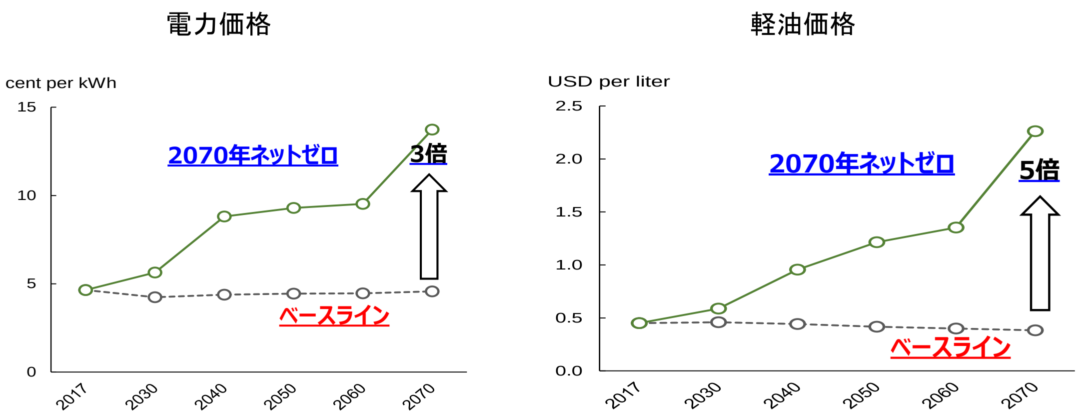
図 3　ASEAN 全体で 2070 年にカーボンニュートラルを達成するシナリオ



出所：ERIA-IEEJ、「東アジア・ASEAN 経済研究センター（ERIA）による ASEAN のカーボンニュートラル実現に向けたモデル分析（現時点版）について」（2021 年 6 月）

2070 年 CN 達成に向けた変革で ASEAN のエネルギー価格は上昇する。電力価格が足元の 3 倍になる他、軽油価格は 5 倍まで上昇し、生活を圧迫する可能性がある（図 4）。

図 4　2070 年カーボンニュートラル達成と電力及び軽油価格の変化

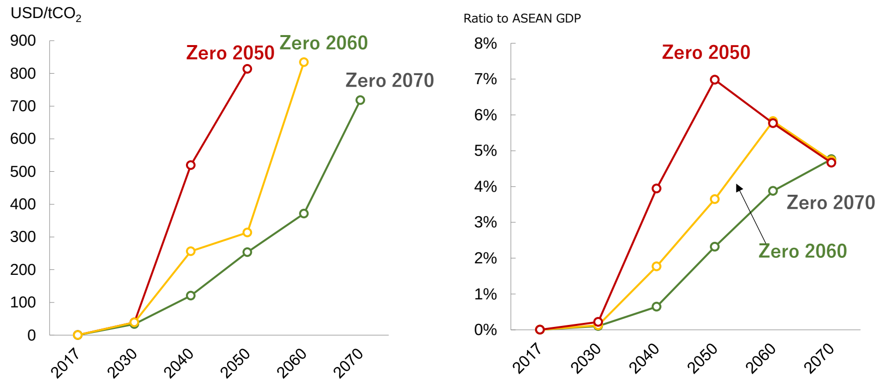


出所：ERIA-IEEJ、「東アジア・ASEAN 経済研究センター（ERIA）による ASEAN のカーボンニュートラル実現に向けたモデル分析（現時点版）について」（2021 年 6 月）

図 5 左は CO_2 限界削減コストを示す。2070 年にＣＮを目指す場合、2040 年以降のコスト急上昇で、CO_2 の最後の 1 トンの削減コストは 700 ドル/トンを超える。目標を前倒しして 2050 年の CN 達成を目指すと、限界削減コストは 2050 年で 800 ドル/トンを超える水準まで上昇する。

図 5 右は年間追加コストの対 GDP 比で、エネルギーを含む各種コスト上昇で拡大する。2070 年ゼロの場合で ASEAN 全体の GDP の 5%程度であるが、2050 年ゼロの場合には 7%までコストは増大する。ＣＮ達成目標年を早期に設定する場合、必要な技術コストが十分下がらないことが経済を圧迫することが予想される。

図 5　限界削減コストと追加的コストの GDP 比



出所：ERIA-IEEJ、「東アジア・ASEAN 経済研究センター（ERIA）による ASEAN のカーボンニュートラル実現に向けたモデル分析（現時点版）について」（2021 年 6 月）

先進国中心に 2050 年ＣＮ宣言が続く。今後成長する新興国や途上国でも一様に 2050 年までの CN を目指すことが望ましいかどうかは検討の余地が十分にある。

シンポジウム討論者で前シェルチーフエコノミストのトーマス氏は、急激な脱炭素化に必要な投資規模は莫大で、一人当たりの投資が GDP に占める割合は新興国や途上国で極めて高くなり、負担が大きいとした。また、1.5 度の世界へのエネルギー変革は主に先進国と一部の新興国が取り組むべき課題で、途上国や新興国の投資負担の増大は先進国がカバーすべきだと指摘した。

【おわりに】

脱炭素化はコロナ禍からの経済回復策もあり加速している。一方で、クリーンエネルギーの 1 つである原子力は高コスト化もあり先進国の利用に遅れが目立ち、再エネしか頼れる既存技術のない状況にある。

世界の成長センターであるアジアでは域内で安価に手に入る石炭利用が続き、CN 宣言をした中国でも石炭火力が増え続けている。世界の自動車はすぐに電気自動車に置き換わるわけではなく、石油利用は続く。日本やアジア新興国ではすぐに再生可能エネルギーだけで電力を賄うことも難しい。そのため、最もクリーンな化石燃料であるガス利用の継続が予想される。エネルギーの移行段階では、化石燃料の脱炭素化が重要であることを、強くアジアから世界に訴え続ける必要がある。

ブルー水素はコストの削減でアジア消費国と中東生産国の新たな選択肢となり得る。各国が競争しつつも連携することが必要だ。水素を含む新燃料のコスト削減には需要創出が必要であり、日本やアジアの事情を反映した、国際認証などのルール作りも大切である。但し、アジアにとっては水素も輸入エネルギーであり、CCS を含めて海外に依存する場合のエネルギー安全保障は引き続き課題となる。多様なエネルギー、技術、システムの組み合わせで対応を考えるポートフォリオの発想が必要だ。

シンポジウム登壇者の Srivastava 氏は、既存技術の十分な活用で CN に相当程度近づくことが可能であり、新技術や CCS が加われば CN 目標は達成可能だと述べた。但し、実現には公正なアプローチに基づく国際協力やガバナンスの強化、さらに経済インフラや開発におけるサス

テナビリティを組込んだリセット、加えて社会全体へのサステナビリティに関する知識普及の大切さを強調した。Thomas 氏は Nature-Based Solution による生息環境の改善重視を提案した。

平時はあることが当然のエネルギーだが、有事に重要性が改めて認識される。今回の CN の大変革は今後 30 年続く大きなチャレンジだが、誰一人取り残さない取組みが求められる。

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を経て、2021年より同学会 Executive Vice President。

Can Developing Countries Pursue the Dual Goal of Carbon Neutrality and Economic Growth?

Joan MacNaughton*

Introduction

The influential 2018 IPCC Report painted an alarming picture of the implications of a 2 degree versus a 1.5 degree scenario for global warming. In the wake of the report, countries covering over half of global GDP had (as of June 2021 – according to the World Resources Institute) committed to reach carbon neutrality in their economies, usually expressed in terms of reaching ‘Net Zero’ by (mostly) 2050. This will be a stretch for any country. But for developing and emerging economies, many of whom have experienced a big economic shock from the pandemic, it will be especially challenging. Often, their position is exacerbated by currency depreciation and/or greater exposure to the effects of climate change – including extreme weather events or diminished viability of traditional crops. It is legitimate and important, therefore, to ask whether they will be able to attain carbon neutrality while lifting their populations out of poverty. In doing so, we need to recognise the wide variations within this somewhat loosely defined group – in terms of stage of economic development, the characteristics of their energy sectors, differing natural resource endowments, and share of population having access to modern energy services. So what follows is an attempt to pull out the extent to which they may face different challenges, or have different opportunities, from advanced economies – typically, but not universally, so.

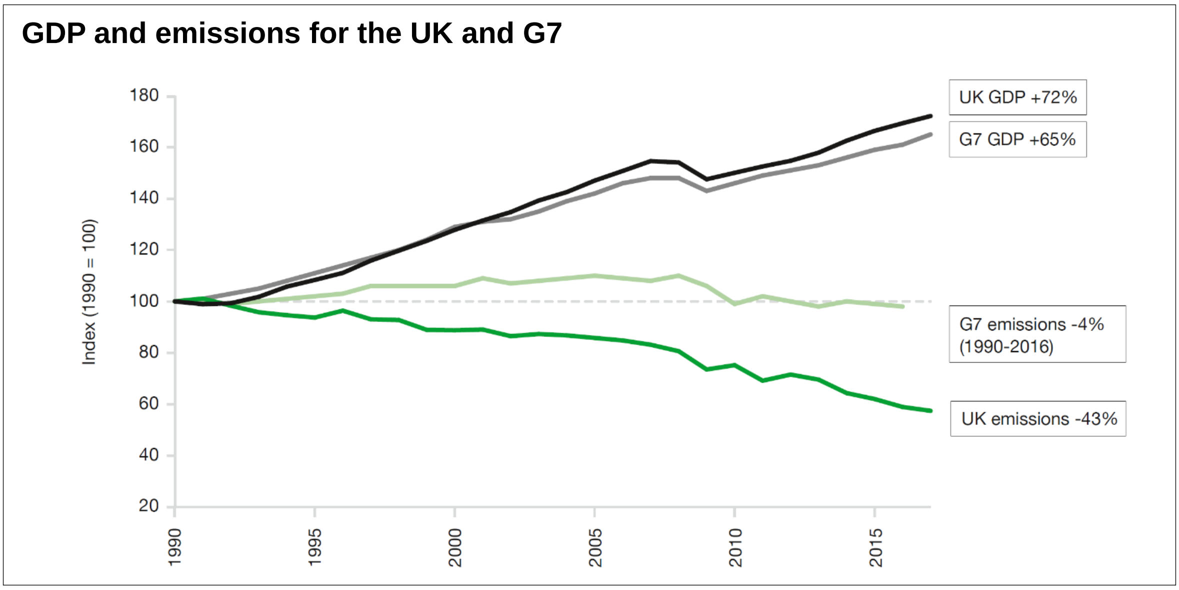
GDP Growth and the Trajectory of Carbon Emissions

Historically, GDP growth has been closely correlated with increases in carbon emissions. However in developed countries this link appears to have been broken, if one takes the chart below at face value.

But there is a caveat here. While much of the decoupling has indeed been driven by changes in fuel use, the application of clean technologies, and/or enhanced energy efficiency, some of it also comes from offshoring production of goods consumed in those countries. This has led to an increase in emissions attributed to the *producing countries* and an equivalent reduction for the *countries which are importing those goods*. The effect is significant: in 2015, net imports constituted one-third of the material-related carbon footprint of the EU; while net exports amounted to 13% of China’s material-related emissions and 18% of the emissions from the BRITS (Brazil,

* Chair of the Board, The Climate Group / Distinguished Fellow, IEEJ

Russia, Indonesia, Turkey, South Africa).[1]



Opportunities and Challenges for Developing Countries in the Low Carbon Transition

Attribution of responsibility for emissions is particularly relevant to developing countries. Many of those economies may be more reliant on sectors lower down the value chain, and their economic strategy may entail growing such sectors further by utilising low cost labour. This method of accounting for a country's emissions potentially disadvantages them further; it goes to the heart of how 'Net Zero' is defined for an individual country, given the current emphasis in international negotiations on national contributions to reducing emissions. (Of course this is not the only accounting issue around countries' responsibilities – others include the weight to attach to historical responsibility for the concentration of GHG's in the atmosphere, or the significance of per capita emission levels. But those are debates for another article.)

If one accepts (as I do) that clean economic growth is now entirely feasible, given the availability and cost competitiveness of zero (or at least near zero) carbon technologies, the most important challenge for developing economies is how to secure the needed investment. Some are 'locked in' to carbon intensive legacy infrastructure, such as low efficiency coal fired power generation. For these countries, funding the early retirement of such assets on a large scale is even more of an issue than for richer countries who have been progressively investing in higher efficiency and cleaner generation. To take just one example, coal plant retirements have been running at a record level in the US and no new coal plant projects are on the horizon. Most new build coal generation is concentrated in less advanced economies.

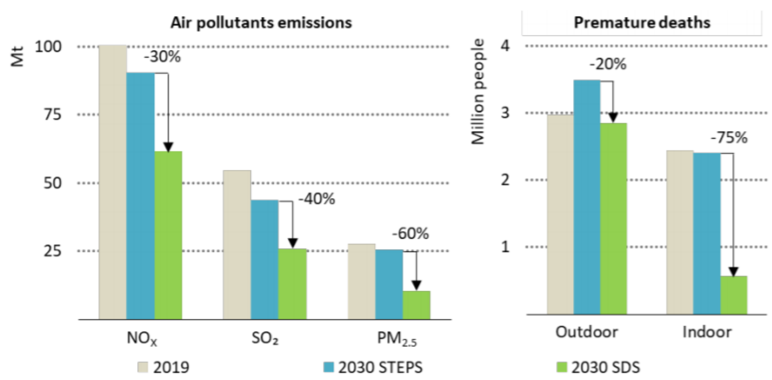
[1] Increased carbon footprint of materials production driven by rise in investments.

Nor will those countries benefit from any recently discovered oil and gas reserves to the same extent as long established oil and gas producing regions. Recent IEA analysis of oil demand and prices under a net zero pathway[2] implies a price of $35 per barrel in 2035, which one suspects would offer little or no return for projects which are at an early stage in their lifecycle, and hence their payback period. Much attention seems to have focused on the destabilising effect of reduced oil demand/prices in traditional oil producing countries; less so on the implications for countries newly developing such resources.

The impact on developing countries' economies of the transition away from traditional fuels is not necessarily wholly negative. The net impact may even be positive. Energy efficiency (a key component of the transition to Net Zero) is now assessed as a larger driver of economic growth than most assume[3]. It could well be a source of improved competitiveness for early adopters, and also underpin affordability for the consumer; but only with the right policies in place to encourage investment in high efficiency appliances or energy services.

For those countries who are net importers of oil and gas, reducing the carbon intensity of their economies will reduce balance of payment deficits, and their exposure to oil (or gas) price volatility. Perhaps most immediately, clean energy solutions will reduce deaths (and illness) associated with air pollution. Even without attributing a specific value to avoided premature deaths, or pollution induced illness, this is clearly worth a lot in economic terms – as well, obviously, as in human ones.

Air pollution emissions by pollutant and related premature deaths, 2019 and 2030



Air pollutant emissions fall slightly in the STEPS, but rising urban populations lead to an increase in premature deaths from outdoor pollution to 2030

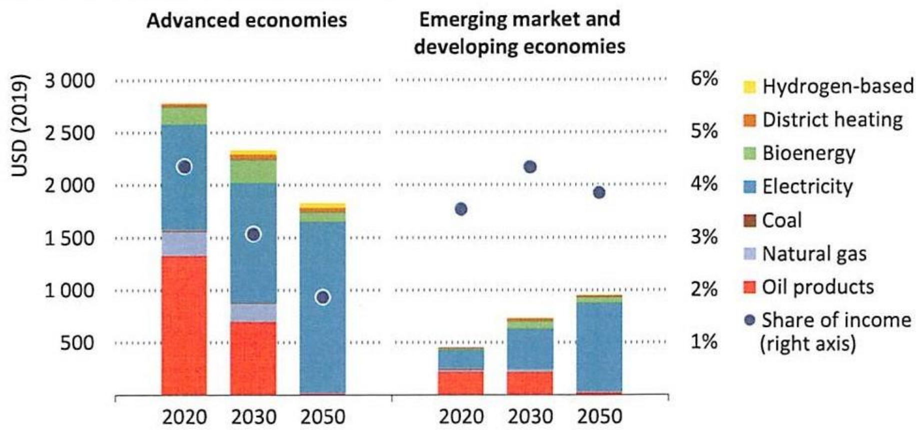
Moving to clean sources of energy not only drastically reduces mortality and morbidity associated with air pollution; it helps tackle the lack of access to electricity currently afflicting

[2] IEA 'net Zero by 2050 – A Roadmap for the Global Energy Sector', May 2021.

[3] 'Energy efficiency contributed 25% of UK economic growth between 1971 and 2013', Guest post, Dr Paul Brockway, Dr Marco Sakai, Prof John Barrett and Prof Peter Taylor, Carbon Brief.

hundreds of millions of people – damaging their quality of life and constraining their ability to lift themselves out of poverty. As well as access, the question of affordability must also be addressed. The IEA assesses that increases in household energy bills will be relatively minor, but international development assistance needs to flow to prevent this becoming a barrier to universal access to clean energy.

Figure 4.14 ▷ Average annual household energy bill in the NZE



The proportion of disposable household income spent on energy is stable in emerging market and developing economies, and drops substantially in advanced economies

Note: Hydrogen-based includes hydrogen, ammonia and synthetic fuels.

This matters enormously, for developing economies face a larger requirement for clean energy investment and do so from a weaker economic position. The pandemic hit to their economies may be expected to persist at least until their vaccination rates catch up with advanced economies, and probably even beyond. Again the contrast with the advanced economies is stark – developing economies are likely to have neither the balance sheet, nor the borrowing power, to inject significant stimulus to help their economies recover and to do so in a way to advance their path to Net Zero. The question to my mind therefore is not whether they can attain Net Zero while fostering the economic growth needed to give their citizens an adequate standard of living. Rather, it is whether they can be helped to get the necessary investment flowing on a scale that will set them on a clean energy growth path. Richer countries must urgently make good on their promise, from as long ago as COP 15 in Copenhagen in 2009, to mobilise $100bn a year to support climate mitigation and adaptation measures in less affluent parts of the world. There must be development aid to build capacity in developing countries – otherwise the development and implementation of fit for purpose policy frameworks will take too long. Examples abound of what can be achieved – such as the Under2 Coalition 'Pathway' project run by the Climate Group, supported by the Norwegian government. But they are far from widespread enough. Without the right policy frameworks, the risk premium attached to the cost of capital in developing countries will rule out many otherwise viable projects. Unless private investors can be given confidence in the protection of private property rights, and in the predictability of regulatory decisions, the rate of flow of such investment will be inadequate to save the climate from catastrophic levels of climate change.

It is a matter of enlightened self-interest for advanced economies to accelerate the ramp up of investment in the developing world – if only to safeguard the planet as a place fit for human habitation. But enlightened self-interest extends further even than that, to include greater overall prosperity: joint modelling by the IEA and the International Monetary Fund estimates that making the investments needed during the current decade to get to Net Zero by 2050 would add 4% to global GDP by 2030[4]. One may wonder why governments are not moving faster to do so.

Writer's Profile

Joan MacNaughton

Ms. MacNaughton chairs The Climate Group and the International Advisory Board of the New Energy Coalition, and is a Non Executive Director of En+ Group plc., and of Heathrow Airport Holdings Limited. She sits or has sat on several other boards in the academic, public and corporate sectors, and the Advisory Boards of the Grantham Institute, the Joint Institute for Strategic Energy Analysis, and Engie 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, and a former Director General of Energy in the UK Government.

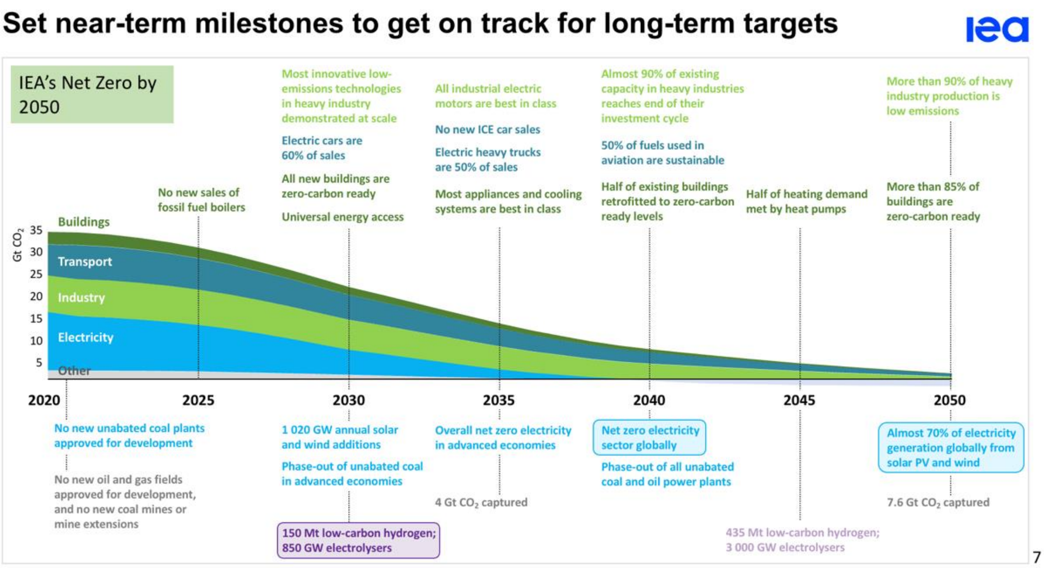
[4] IEA 'net Zero by 2050 – A Roadmap for the Global Energy Sector', May 2021.

Net-Zero Emission Scenario and Energy Security

Nobuo Tanaka*

Net Zero 2050 (NZ2050): A Roadmap for the Global Energy Sector, a recent publication by the International Energy Agency (IEA), is causing controversy worldwide. A comment by Dr. Fatih Birol, Executive Director of the IEA, that all new oil and gas development projects must stop immediately if NZ2050 is to be achieved, attracted a barrage of criticism from oil-producing countries and oil and gas companies as an utterly unrealistic scenario. Saudi Energy Minister Abdulaziz bin Salman dismissed NZ2050 as a fantasy similar to the movie La La Land; Russia Energy Minister Alexander Novak mocked the scenario, stating that oil prices would surge to $200 if all investments were stopped immediately. Oil experts have criticized the IEA for being inconsistent: calling for halting long-term investments while backing the need for investment in oil in its short-term outlook. The IEA was established in 1973 as a strategic joint stockpiling mechanism following the oil shocks, but this time it was the Agency that caused a shock among oil and gas producers and companies.

First, we must note that the IEA scenario (roadmap) is not a forecast; it is a backcast drawn up by setting a policy target to be achieved at a certain date in the future and then working backwards based on a model to identify how the target can be achieved. So far, more than 120 countries including European countries, Japan, and the US have pledged to go carbon neutral by 2050. If this is to happen, the scenario estimates that at least 70% of power must come from wind and solar PV by 2050, the power sector must achieve net-zero emissions worldwide by 2040, new cars with



* Special Advisor, Sasakawa Peace Foundation / Distinguished Fellow, IEEJ

internal combustion engines (ICE) must be banned from 2035 (the EU has recently decided to do so), coal-fired thermal power must be banned from 2030, and new oil and gas development projects must be banned from 2021 (Table 1).

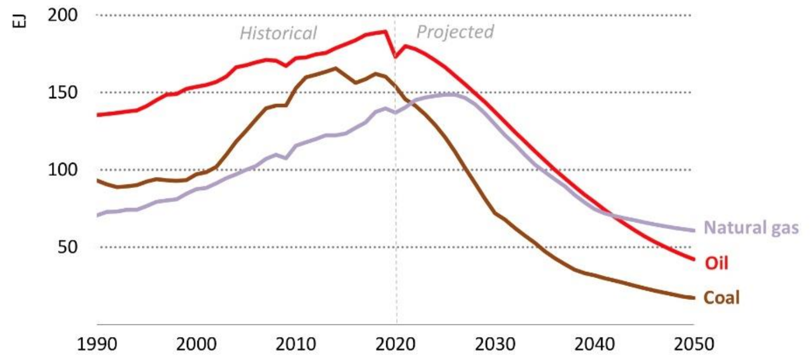
None of these milestones in the IEA roadmap is easy to achieve, if at all. The criticism that the roadmap's scenario is "easier said than done" is understandable. However, it is not the IEA but the governments that have pledged carbon neutrality that should be held accountable for setting unrealistic targets and misleading the public.

Is decarbonization possible? No one knows the future, and scenario analysis is a way of examining the uncertain future. We may not know the future, but we can at least prepare for it; this is the underlying principle of security. In the oil industry, oil major Royal Dutch Shell is renowned for its ability to create scenarios – it is believed to have drawn up scenarios anticipating the oil shocks and the collapse of the Soviet Union. But creating scenarios is only half the battle. The question is what Shell's management decided to do based on them. The decisions Shell made based on those scenarios are thought to include shifting from oil to liquefied natural gas (LNG) and investing in the Sakhalin LNG projects. Shell's 2050 net-zero emission scenario is named Sky 1.5. When its original version appeared 3 years ago, the Sky scenario astounded everyone with its boldness, and Shell themselves described it as visionary. However, with the recent revision of the scenario, the CEO of Shell pledged in February this year that the company would expand the scope of its 2050 net-zero emissions target to include all the products it sells, and declared that the company's oil production had peaked in 2019. While other European oil majors have also declared that they will decarbonize, the decision must have been momentous for Shell. Nevertheless, in May this year, a Dutch regional court ruled that the company's efforts to reduce carbon dioxide are not sufficient. The post-Covid world is moving quickly in search of safety and reassurance. Exxon Mobil has recently been forced by a general shareholder's meeting resolution to accept three board members recommended by environmental activist investors. It is easy to criticize the IEA's NZ2050 scenario as unrealistic and impossible, but it is up to the leaders of countries and companies to plan what to do in case the scenario is implemented and to take bold action.

Middle East oil-producing countries and their state-run oil companies are likely to be affected most by the trend toward carbon neutrality. Their enormous underground oil resources are at risk of becoming stranded assets. Former Saudi Oil Minister Ali Al-Naimi, with whom I often talked when I was the Executive Director of the IEA, said that "Saudi Arabia will aim to become a major solar power country rather than a major oil producer." He also said that the country will make not clean coal but "clean oil." It is possible to produce green hydrogen by using solar power, an inexhaustible energy source, to electrolyze water, and to produce blue hydrogen by extracting hydrogen from oil or gas and burying the emitted carbon dioxide back into oil wells. Ahmad Al-Khowaiter, CTO of Saudi Aramco, says that "the technology for utilizing hydrogen is maturing and Aramco considers that the hydrogen market is at an inflection point." Even if petroleum loses its value as a source of revenue for oil-producing countries, the carbon capture and storage (CCS) service, in which carbon dioxide is stored in old oil wells, will begin to create value. US OXY is considering selling clean, negative-emission oil, produced by filling oil wells with carbon dioxide captured from the atmosphere (Direct Air Capture, DAC) and using the pressure of the gas to recover oil (Enhanced Oil Recovery, EOR). The oil produced this way locks away more carbon dioxide during production than is emitted when consumed. European oil majors are more serious about exiting oil than US oil companies. They appear to be taking the Covid shock-induced slump in oil demand not as a short-term phenomenon but a precursor to larger structural changes, in which decarbonization policies become the mainstream and changes in consumer behavior become the new normal. This is presumably why BP and Royal Dutch Shell announced massive write-offs of resources of $17.5 billion and $22 billion, respectively, in 2020 in quick succession. The conventional business model, in which the Seven Sisters oil majors and OPEC sell their underground resources drilled at a slow rate through their own cartel at high prices to earn an economic rent, is becoming a thing of the past.

Though its carbon dioxide concentration is lower than that of oil, natural gas will not remain unscathed as decarbonization progresses. It is true that the US has managed to reduce carbon dioxide emissions by replacing coal-fired thermal power with cheap and abundant supplies of natural gas derived from the North American shale gas revolution; this marked the dawn of the golden age of natural gas, which the IEA predicted 10 years ago. Indeed, gas-fired power will most likely survive as a bridge fuel until coal-fired power plants cease to exist, but thereafter, gas will also be required to decarbonize. Methane leakage is also a serious problem. An estimated 70 million tonnes of methane is leaking in the world each year, with a greenhouse gas impact equivalent to the entire CO_2 emissions of the EU. According to satellite images of the locations of leaks, the largest source is Russia, followed by the US. This situation must be addressed immediately. The EU is unlikely to accept natural gas as a clean energy unless it becomes free of methane and CO_2 emissions. Even Russia, a monoculture economy based on fossil fuels, has now begun to consider a strategy to convert oil and gas into blue hydrogen and export it. Also, in the world of liquefied natural gas trading, a product known as clean LNG, which has had carbon emissions offset with forestation and other means, has begun to appear in the market. NZ2050 estimated that oil demand peaked in 2019; natural gas demand is also due to peak before 2030 (Table 2).

Figure 3.2 ▷ Coal, oil and natural gas production in the NZE



Between 2020 and 2050, demand for coal falls by 90%, oil by 75%, and natural gas by 55%

If oil and gas suppliers are pinning their hopes on blue hydrogen, who will buy it? The biggest prospective importers are emerging Asian economies that have high growth potential. Heavy and chemical industries such as steel and cement are highly carbon-intensive and not easy to decarbonize. The region also has many coal-fired thermal power plants. These infrastructure facilities are still new compared to those of developed countries and will take several more decades to depreciate. Clean hydrogen is essential to move forward with decarbonization while using existing infrastructure. JERA, a thermal power joint venture by TEPCO and Chubu Electric, has declared the goal of becoming carbon neutral by 2050, and the key to achieving that goal is the mixed combustion of clean ammonia and coal in coal-fired power generation. A demonstration experiment for 20% mixed combustion is currently under way, and ammonia-only combustion is a future goal in sight. Natural gas turbines can also be decarbonized through mixed combustion of hydrogen and, eventually, pure hydrogen combustion. Thermal power has been regarded as an enemy by environmental NGOs, but with transformative ideas such as the use of clean ammonia and hydrogen, thermal power generation can help achieve the dual goals of carbon neutrality and economic growth. Innovative use of hydrogen is also entering the demonstration phase for the steel and cement industries, which are hard to decarbonize. For the CO_2 that will remain even then, it may be commercially feasible to launch a service for isolating the gas, transporting it through pipelines, and storing it underground, or transporting it in liquid form to oil-producing countries and sealing it in oil wells. The issue is cost. Fifty years ago, Japan successfully launched its first LNG project in which Alaskan natural gas was liquefied and transported to Japan. Japan accelerated the shift to natural gas by lowering the initial investment risk through guaranteeing long-term offtake and linking its price to oil prices; going forward, Japan will need to build clean hydrogen supply chains to meet the decarbonization demand of emerging Asian nations as well. Japan has three technologies for transporting and storing hydrogen that are most useful for this purpose: clean fuel ammonia, liquefied hydrogen carrier vessels, and organic hydride methylcyclohexane (MCH). All the technologies are undergoing demonstration testing for transportation with Saudi Arabia, Australia, and Brunei, respectively. Fuel ammonia will provide a means of transition for gradually decarbonizing existing coal-fired thermal power infrastructure. The advantage of MCH is that it can be handled in existing oil tanks and petroleum product carrier vessels as it is a liquid under normal temperature and air pressure. It will provide a strategic stockpile of electricity by storing it in oil tanks, of which there will be a surfeit going forward. Furthermore, liquefied hydrogen carrier vessels will be an economic mode of transport when the demand for hydrogen rises in the future. It will then be possible to create a business model that links hydrogen producer countries with Asian consumer countries and leverages the unique advantages of both. The future challenge is how to expand the scale and lower costs.

Along with transporting hydrogen and CO_2, another way to spur clean energy trade is to import renewable electricity through direct grid connection. The reason Europe can use large amounts of wind and solar power is because it can adjust fluctuations thanks to its large, Europe-wide electricity market. Europe is now planning to increase the storage of excess electricity in batteries and in hydrogen form as a means to address output fluctuations. Japan's new Strategic Energy Plan includes plans to increase the share of renewables in the power mix to 36-38% in 2030. This is double the present level and is a daunting target. The grid coordination among Japan's nine power companies, which each have a regional monopoly, is poor, as symbolized by the country being split into two major frequency zones, East Japan with 50 Hz and West Japan with 60 Hz. This raises the risk of power cuts (as exemplified by the power cuts in the TEPCO area after the Fukushima Daiichi accident and the prefecture-wide power cut caused by the earthquake off the coast of Tomakomai in Hokkaido) and preventing the wider use of natural energies. With a timeframe of 15 years, for example, it would be possible to integrate the frequencies between East and West Japan, but will Japan make that decision? Dismantling the fragmented electricity markets, currently divided into nine, and strictly separating the ownership of the power generation business and the transmission business are the way to address Japan's energy security and global warming. This should also pave the way to establishing connections with the grids of other countries and importing cheap and clean electricity. Europe is also planning to utilize its existing infrastructure by injecting green hydrogen into its gas pipelines. At the Northeast Asia Gas Pipeline Forum (NAGPF), a forum for advancing the linkage of gas pipelines between the five countries of Japan, China, Russia, South Korea, and Mongolia of which I am the chairperson, we are planning to consider mutually providing clean electricity through an interconnected grid network, and hydrogen through pipelines. This will be a clean energy platform that can transform the energy geopolitics of Northeast Asia in the future.

Hydrogen will help achieve net-zero emissions, protect the global environment, and enhance energy security. The Golden Age of hydrogen is approaching.

Writer's Profile

Nobuo Tanaka

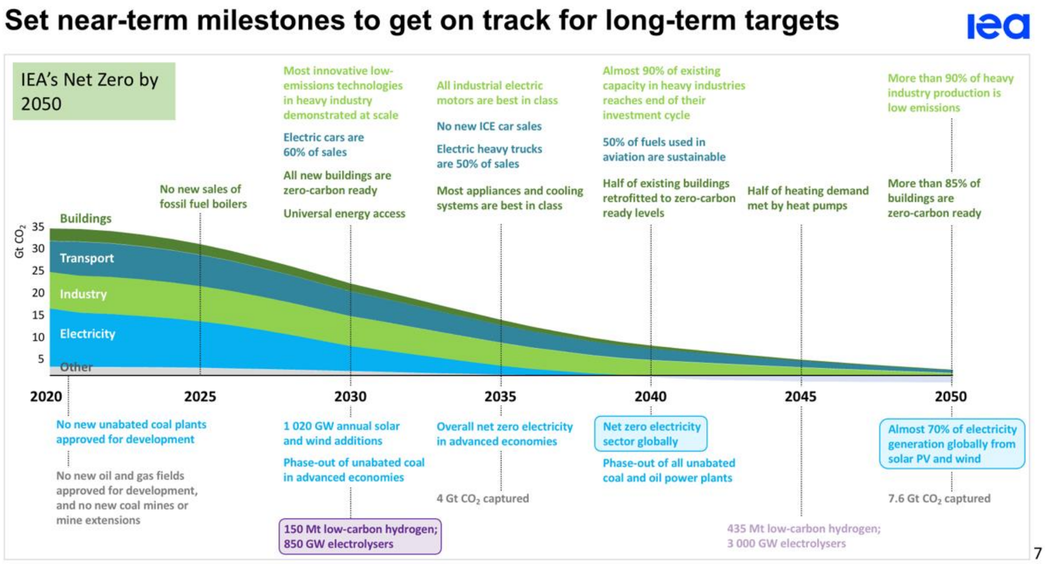
Mr. Tanaka is the Distinguished Fellow at the IEEJ. He is the chairman of the Steering Committee of Innovation for Cool Earth Forum (ICEF). As Executive Director of the International Energy Agency (IEA) from 2007 to 2011, he initiated a collective release of oil stocks in June 2011. He also played a 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.

ネットゼロシナリオとエネルギー安全保障

田中　伸男*

国際エネルギー機関（IEA）の最近の出版物「ネットゼロ 2050 ロードマップ」（NZ2050）が世界中で炎上中である。ビロル事務局長が NZ2050 が実現するとすれば、石油やガスの新規開発プロジェクトは直ちに中止すべきだと発言したことが産油国や石油ガス企業からそんなシナリオは非現実的だと集中砲火を浴びている。サウジアラビアのアブドルアジズ・ビン・サルマンエネルギー大臣は NZ2050 は映画「ラ・ラ・ランド」のようなファンタジーだと批判し、ロシアのノバックエネルギー大臣はもし投資をやめれば石油価格はバレル二百ドルになるだろうと冷笑した。また石油専門家は短期見通しでは石油への投資が必要という IEA が長期では投資をやめろというのは矛盾すると批判する。IEA は 1973 年の石油ショックに対処するために石油の戦略的共同備蓄機構として設立されたが、今回は石油やガス生産国、企業の間で「IEA ショック」を起こしたようだ。

そもそも IEA のシナリオは予測（フォーキャスト）ではない。未来の一定時点で成し遂げたい政策目標に対してどうすればそれが実現できるかをモデルから逆算するバックキャストである。今回の場合は欧州、日本、米国など 120 ヵ国以上が 2050 年までに脱炭素を実現すると宣言しており、それが実現するとすれば 2050 年の電源の 70%以上が風力太陽光になっているはずだし、2040 年までには世界中の電源でネットゼロを実現し、2035 年には内燃機関の新車販売が禁止され（EU は最近これを決定をした）、2030 年には石炭発電が禁止され、2021 年には新規油田ガス田開発プロジェクトが禁止されなければならない。（別表 1）



* （公財）笹川平和財団　顧問/元・国際エネルギー機関（IEA）事務局長/（一財）日本エネルギー経済研究所　特別客員研究員

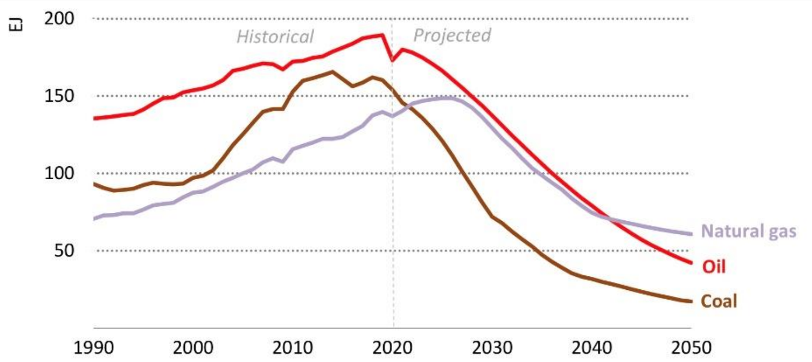
IEA が提示するどのマイルストーンをとってみても実現するのは大変なことばかりである。これを見れば「言うは易く、行うは難し」だとの批判はもっともだが、それなら IEA でなく脱炭素を宣言している各国政府こそ非現実的な目標を立て世間をミスリードした責任を問われるべきだろう。

脱炭素が本当にできるのか、未来は誰にもわからない。シナリオ分析という手法は不確実な将来に対応するための手法である。未来はわからなくとも準備することならできる。それが安全保障の要諦である。石油の世界では大手石油メジャーのロイヤルダッチシェルがシナリオ作りで有名である。石油ショックやソ連邦崩壊なども想定したシナリオが作られたという。しかし作っただけでは意味はない。問題はそれを受けて経営幹部が何を決めたかである。シェルは石油から液化天然ガス（LNG）への転換やサハリン LNG プロジェクトへの投資をこれらのシナリオから決めたという。2050 年にネットゼロを目指すシナリオはスカイ 1.5 と命名されている。3 年前にオリジナル版のスカイシナリオが出された時にはその大胆さに驚いたが彼ら自身もビジョナリーと説明していた。しかしシェルの CEO は今回の改定シナリオを受けて今年の 2 月に 2050 年までに販売する製品からの排出も含めネットゼロを目指すとし、自社の石油生産は 2019 年のレベルを上回らないと宣言した。他の欧州メジャーが脱炭素宣言をしているがシェルにとっても大変な決断であったろう。それでも去る 5 月オランダの地方裁判所で二酸化炭素の削減努力が不十分だとする判決が下された。ポストコロナの世界は安心安全を求め急速に動いている。エクソンモービル社は株主総会決議で環境派投資家の推薦する三人の取締役を受け入れざるを得なくなった。IEA の NZ2050 シナリオを非現実的で実現不可能だと言うは易いが、それが起こる場合に備え今から何をしておくべきかを考え、それを果敢に行うのが国の指導者や企業経営者のやるべきことではないのか。

最もカーボンニュートラルの影響を受けるのは中東の石油生産国および国営石油企業であろう。地下の巨大な石油資源が座礁資産（stranded asset）化する危機にある。IEA 事務局長時代によく話したサウジアラビアのアルナイミ石油大臣は「サウジは石油大国ではなくソーラー大国を目指す」と言っていた。またクリーンコール（石炭）ならぬ「クリーン石油を作る」とも。無尽蔵な太陽光で水を電気分解すればグリーン水素が、石油やガスから水素を取り出し余った二酸化炭素を油田に埋め戻せばブルー水素ができる。サウジアラムコのアルコウェイター CTO は「水素利用技術は成熟しつつありアラムコは水素市場が屈折点（inflection point）にあると考える」と語る。例え産油国の収入の源泉である石油に価値がなくなっても古い油田に二酸化炭素を閉じ込める二酸化炭素分離貯蔵（CCS）サービスが価値を生むようになる。米国のオクシー社は空中の二酸化炭素を捕まえて（DAC）油田に封入しその圧力で石油を回収すれば（残存原油増進回収法 EOR）そこで生産された原油を消費することで排出される二酸化炭素より多い二酸化炭素を封入できるというネットマイナスのクリーンオイルとして売ることができると考えている。ヨーロッパ系の大手石油メジャーは米系より脱石油に真剣だ。彼らはコロナショックによる石油需要の消滅は短期的な話ではなく脱炭素政策がメインストリーム化し、消費者の行動変化もニューノーマルになっていく、より構造的な変化の先触れだったと考えていると思う。2020 年に BP やロイヤルダッチシェルが相次いで巨大な資源の減損（それぞれ 175 億ドル、220 億ドル）を発表したのもそれが背景だろう。地下の資源を少しずつ掘り出し、セブンシスターズと言われた石油メジャーや OPEC がカルテルを維持しながら高い価格で売って経済レントを稼ぐビジネスモデルは過去のものになる。

石油よりは二酸化炭素濃度が低いとはいえ脱炭素となれば天然ガスも無傷ではすまない。確かに北米のシェールガス革命で安いガスが大量に供給された米国では石炭発電が天然ガス発電で代替され二酸化炭素排出を削減した。IEA が 10 年前に予言した天然ガスの黄金時代の到来である。石炭発電所がなくなるまではガス発電もブリッジとして生き延びるであろうがその先は脱炭素を求められる。またメタンリークも深刻だ。現在世界全体で 7000 万トンもメタンが漏れていると推定されるがこれは EU 全体の二酸化炭素排出に匹敵する温暖化効果ガスである。人工衛星からの画像でどこでリークされているか把握できるが最大の発生源はロシアついで米国である。これはすぐに手を打つ必要がある。EU はメタンや二酸化炭素を除去しない限り天然ガスもクリーンとは認めない可能性が高い。化石燃料モノカルチャー経済のロシアも石油やガスをブルー水素に変えて輸出する戦略を考え始めた。また液化天然ガス貿易の世界でも植林などでカーボンオフセットした LNG が市場に出始めている。いわゆるクリーン LNG である。NZ2050 では石油の需要ピークは 2019 年だったが、天然ガスでも 2030 年前に需要のピークに至る。（別表 2）

Figure 3.2 ▹　Coal, oil and natural gas production in the NZE



Between 2020 and 2050, demand for coal falls by 90%, oil by 75%, and natural gas by 55%

石油ガス供給サイドがブルー水素に救いを求めるなら誰がそれを買うのか。最大の輸入国は今後経済成長が期待されるアジアの新興国であろう。鉄鋼セメントなどの重化学工業は炭素集約度が高く簡単には脱炭素できない。また石炭発電所が多くこの地域に立地している。これらのインフラは先進国と比べ比較的若く償却するには数十年かかる。既存のインフラを活かしつつ脱炭素を進めるために必要なものがクリーン水素である。東京電力と中部電力の合弁火力発電会社である JERA は 2050 年脱炭素を宣言したが、その鍵となるのが石炭火力におけるクリーンアンモニアと石炭の混焼である。20%の混焼を目指した実証試験が行われているがいずれはアンモニアの専焼も視野に入れる。天然ガスタービンにもクリーン水素の混焼、さらには水素専焼で脱炭素を実現できる。火力発電は環境派 NGO から目の敵にされてきたがクリーンアンモニア、水素利用という発想の転換でカーボンニュートラルと経済成長の両立に貢献できる。脱炭素が難しい鉄鋼セメントなども水素を使ったイノベーションが実証の段階に入る。どうしても除去できない二酸化炭素については分離しパイプラインで集めてきて地下に貯蔵するか、産油国などに液化して運び油田に封入するサービスが商業的に成り立つかもしれない。問題はコストである。日本は 50 年前にアラスカの天然ガスを液化して日本に運ぶという LNG 事業を成功させた。長期にわたり引き取りを保証することで初期投資リスクを軽くし石油価格にリンクさせることで石油からの転換を進めたが今後はアジア新興国での脱炭素需要にも応えるた

めのクリーン水素のサプライチェーンを構築する必要があろう。日本がもつ水素の輸送と貯蔵の三つの技術が役に立つ。クリーン燃料アンモニア、液化水素運搬船、有機ハイドライト MCH である。それぞれサウジ、オーストラリア、ブルネイとの輸送実証実験段階にある。燃料アンモニアは石炭火力発電の既存インフラを徐々に脱炭素するためのトランジションを提供する。MCH は常温常圧で液体なので既存の石油タンクや石油製品運搬船が使えるというメリットがある。今後余る石油タンクで備蓄すれば電気の戦略備蓄になる。液化水素運搬船は水素需要が拡大したときに経済的な輸送法となろう。生産国とアジアの消費国を繋ぎ、それぞれに異なる利点を生かしたビジネスモデルが可能となる。今後の課題はスケールを拡大しコストを下げることだろう。

水素や CO_2 輸送と並んでクリーンエネルギーの貿易を拡大するためには再生可能エネルギー電力を系統線を直接連携して輸入する道があろう。欧州が大量の風力太陽光を使えるのも欧州ワイドの大きな電力市場が存在して変動を調整できるからである。欧州は変動対策として余った電力を蓄電池や水素による貯蔵を拡大しようとしている。日本の新しいエネルギー基本計画では再生可能エネルギーの電力シェアは 2030 年に 36 − 38%を占めるという見通しが示された。現状を倍増させるのは大変だ。日本国内では東西が 50、60 ヘルツに分断された周波数帯があるなど地域独占型の九電力間の系統連携が不十分であり、これが停電のリスクを高める（福島事故後の東電管内での停電や北海道苫小牧沖地震による全道の停電がそれだ）とともに自然エネルギー利用拡大を妨げている。15 年後と決めて東西周波数帯を統一することは決してできない話ではない。問題はやる気である。九つの分断した電力市場を壊し発送電の所有分離を徹底することが安全保障と温暖化への答えである。そして海外とグリッドを繋ぎ安くてクリーンな電力輸入への道を開くはずだ。また欧州はグリーン水素をガスパイプラインに流すことで既存インフラを活用しようともしている。私が議長をしている北東アジアガスパイプラインフォーラム（NAGPF）という日中露韓モンゴル五カ国がガスパイプラインの連携を進めてきた会議があるが、今後はクリーン電力の系統線連携や水素をパイプラインで融通しあうことも検討したいと考えている。北東アジアのエネルギー地政学を将来的に大きく変えうるクリーンエネルギープラットフォームである。

ネットゼロを実現し地球環境を守るためにもエネルギー安全保障の強化のためにも水素の黄金時代がすぐそこまで来ている。

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。笹川平和財団顧問。現Tanaka Global, Inc. CEO。

3. How will the Middle East Respond to the Global Carbon Neutral Movement?

中東は、世界のカーボンニュートラルにどう対応するのか？

How will the Middle East Respond to the Global Carbon Neutral Movement?

Paul Stevens*

What 'carbon neutral' implies is complex. Carbon neutral is not equivalent to net-zero carbon emissions because carbon neutral implies carbon offsets, which simply shifts responsibility to someone else to reduce carbon emissions and some regard this as public relations in disguise i.e. 'greenwashing'. For this brief paper, 'carbon neutral' will be treated as implying falling future global oil demand and considers three questions: 1. Will there be a decline in global oil demand? 2. What impact will this have on MENA producers? 3. What are the policy responses of MENA producers?

1. Will There be a Significant Decline in Global Oil Demand?

The current energy transition from hydrocarbon molecules to electrons has been accelerating and has been grossly under-estimated by the "Energy Establishment" such as the IEA, OPEC, other analysts, and the major international oil companies (IOCs). Their main argument is that energy transitions are slow. Historically this has been true. For example, the switch from wood to coal in the USA (1865-1900) took 35 years. However, more recent transitions, especially when governments have been involved, have been much faster. For example France's switch from oil and coal to nuclear – 10 years and the UK's switch from coal to renewables – 8 years. Furthermore, the COVID pandemic is probably increasing the speed. It has changed politics and the role of government intervention. Thus the "Washington Consensus" of leave it all to market forces is dead. Voters now expect governments to intervene in a crisis and climate change and poor urban air quality, which are driving the transition, is now seen as a crisis. The pandemic has also prompted changes in behaviour to reduce oil demand, notable working practices significantly reducing travel. Oil demand has now peaked and is likely to decline rapidly.

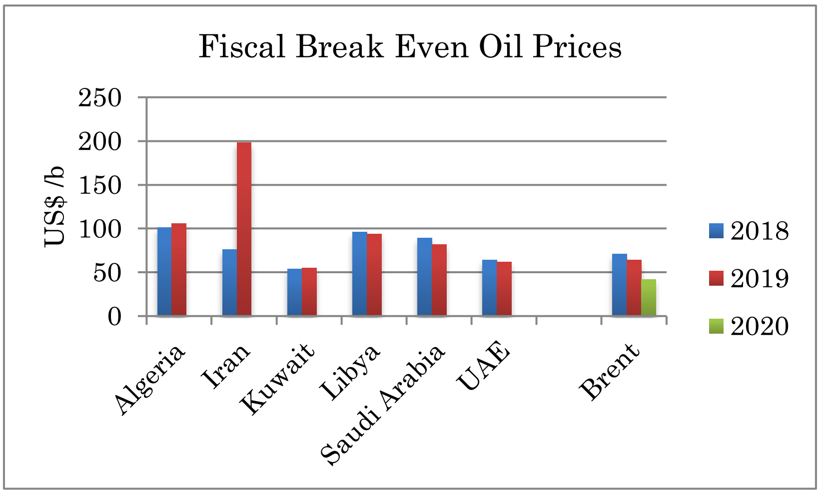
2. What Impact will This Have on MENA Producers?

Obviously, the consequent fall in MENA's oil revenues will create financial difficulties to maintain the 'social contract' to provide subsidies and jobs and defuse domestic opposition to the ruling elites. The figure below illustrates the IMF's estimated fiscal break-even prices and the actual price of Brent and clearly illustrates the problem. There will also be growing competition for market share in a declining market and in an increasingly unpredictable and troubled region; this is

* Associate Fellow, Chatham House UK, Emeritus Professor, University of Dundee / Distinguished Fellow IEEJ

likely to aggravate conflict with Saudi-Iranian relations at the forefront.

Fig. 1 Fiscal Break Even Prices



Sources: Fiscal breakeven https://data.imf.org/regular.aspx?key=60214246.
Brent: EIA Website

3. What are the Policy Responses of MENA Producers?

So far, for the most part, the tendency has been to ignore the problems and deny the energy transition is a threat. However, it is increasingly clear this will no longer work as the transition speeds up. New options are being considered. These include developing renewables, reducing carbon emissions by use of carbon capture and storage, and developing hydrogen production to name but a few. There are two major problems with these approaches. The first is that currently many are unproven and high cost. The second is they lack the ‘economic rent’, which historically has paid for their ‘social contract’ obligations. ‘Economic rent’ in a commodity is the difference betweens the full cost of production including the require return on capital and the market price. This is key. The MENA oil producers have always enjoyed a huge amount of ‘economic rent’. This comes from two sources. First, low cost production creates ‘producers surplus’. Second, a rigged market, which has characterized oil since 1945, has ‘super-normal profit’. There is little ‘economic rent’ in renewables. There are limited cost differentials thus very little ‘producers’ surplus’ and the market is extremely competitive thus no ‘supernormal profit’. Moves away from oil will be unable to maintain the ‘social contract’ possibly encouraging a repeat of the ‘Arab Uprisings’ of 2011.

The only effective solution for the MENA countries to manage declining global oil demand is to diversify their economies away from dependence on oil exports. Since the first oil shock of 1973-4 this has been promised regularly but, with few exceptions in MENA, has failed. The reasons for this past failure are complex but revolve around the political economy of a weak private sector arising from an absence of property rights and the rule of law coupled with the stifling behaviour of ruling elites grabbing all the best deals for themselves. The issue goes back to the

Soviet Union at the time of Mikhail Gorbachev. The debate was then: "can you have *'perestroika'* (economic liberalization) without *'glasnost'* (political reform)?" Russia said "no" but China said "yes". For the MENA region, it is clear that political reform will be essential if a vibrant private sector is to lead the way to greater economic diversification. Absent this, the region is likely to face an increasing number of failed states as oil demand and oil revenue fall dramatically undermining the 'social contract' that has ensured economic and political stability for so long.

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.

Accelerating Global Decarbonization Trend and Middle Eastern Challenges

Ken Koyama*

Introduction

Decarbonization and carbon neutrality initiatives are accelerating globally. In 2020, Japan and the United States followed the European Union in announcing plans to reach net-zero greenhouse gas emissions or carbon neutrality by 2050. China vowed to realize carbon neutrality by 2060. More than 120 economies have already offered to achieve carbon neutrality by around 2050. On the other hand, however, the world now depends on fossil fuels such as oil, natural gas and coal for more than 80% of primary energy supply. Fossil fuels backed by abundant supply and excellent price competitiveness support the global economy and civic life. A pathway from the present to carbon neutrality would represent a thorough energy transition accompanied by revolutionary changes.

At a time when fossil fuels account for most of global energy supply, the Middle East is the center of fossil fuel supply including oil and natural gas/liquefied natural gas (LNG). As of 2020, the Middle East commanded 31% of global oil production, 34% of oil exports and 26% of LNG exports, being one of the world's leading energy producers and exporters. For oil and gas producing countries in the Middle East, oil and natural gas/LNG revenue plays the most important role in stabilizing their economies, governments and societies. If the world enhances decarbonization initiatives to reduce traditional fossil fuel consumption, it may exert huge impacts on the stability and survival of Middle Eastern countries over a long term.

Based on the above awareness, I would like to summarize the global decarbonization trend, its impacts on fossil fuel markets and the Middle East's relevant initiatives and challenges.

1. Global Decarbonization Trend and Oil/Natural Gas Markets

Any country has prescriptions indispensable for achieving carbon neutrality. First, any country must cap and reduce energy consumption by improving energy efficiency as much as possible and promote renewable, nuclear and other non-fossil energy consumption. Second, any county must promote electrification (raising electricity's share of final energy consumption) as much as possible and achieve net-zero emissions in the power sector. However, the two prescriptions are insufficient for net-zero GHG emissions. The massive introduction of new fuels such as CO_2-free hydrogen and ammonia and negative emission technologies like direct air capture to collect CO_2 from the

* Senior Managing Director and Chief Economist at IEEJ

atmosphere would be indispensable. Technological progress, market penetration, cost cuts and social acceptance regarding these technological options are plagued with high uncertainties, leading pathways to carbon neutrality to range widely, with multiple scenarios developed.

However, various scenarios for achieving carbon neutrality commonly include the high likeliness of oil, natural gas and coal demand peaking out. In an analysis released in May 2021, the International Energy Agency described that if the world realizes net-zero GHG emissions in 2050, oil and natural gas production would decline by 75% and 55%, respectively, from 2020 to 2050, with global oil and natural gas demand plunging. The IEA analysis represented one of various future scenarios. Even if the world goes in the direction of carbon neutrality, future oil and natural gas demand is very uncertain.

If global oil and gas demand goes in a downward direction, however, it may exert huge impacts on oil and gas revenue that is indispensable for economic and social management in the Middle East. This is because oil and gas revenue may substantially decline due to lower production and export volume and a market shrinkage that may drive down prices. If decarbonization is promoted over a long term to cut oil and gas consumption, oil and gas resources in the Middle East may become stranded assets. The world going in the direction of carbon neutrality could pose grave risks or threats to the Middle East.

2. Middle Eastern Initiatives and Challenges Responding to Global Decarbonization

The global decarbonization trend basically exerts downside pressure on oil and natural gas production in the Middle East. However, we must note that the competitiveness of Middle Eastern oil and natural gas production featuring the world’s lowest cost can play a key role in the shrinking market. If the entire market shrinks, the Middle East may take advantage of its high cost-competitiveness to increase its share of the market. Nevertheless, it must be reiterated that oil and gas production and exports in the Middle East would decline in volume. The production volume fall would be combined with price drops to substantially lower oil and gas revenue for the Middle East, forcing the region to make some responses.

In response to oil and natural gas revenue falls and stranded oil and gas assets, oil and gas producing countries in the Middle East may have to phase out their dependence on oil and gas revenue. There are various approaches to the phaseout. Among approaches that directly respond to the global decarbonization trend and attract attention from the Middle East and energy stakeholders in the world is the decarbonization of the region’s oil and gas resources for CO_2-free hydrogen and ammonia exports. Since Saudi Arabia hosted a summit of Group of 20 major countries in 2020, the Kingdom became a center in the Middle East to advocate the concept of a carbon circular economy seeking to decarbonize and utilize fossil fuels. The concept envisages that Middle Eastern countries would produce hydrogen from their oil and gas resources and subject subsequent CO_2 emissions to CCS (carbon capture and storage) or CCUS (carbon capture, utilization and storage) technologies, resulting in CO_2-free hydrogen (blue hydrogen) that would be exported to energy consuming countries to help them achieve carbon neutrality. International supply chains to produce hydrogen as the ultimate clean energy fuel from fossil fuels, treat subsequent CO_2 emissions with CCS or CCUS technologies and utilize such hydrogen in energy consuming countries would be developed, including Middle Eastern oil and gas producing countries as the supply source. Technological, economic and social challenges exist before the realization of the concept and must be overcome. Particularly, ultralow temperature facilities and infrastructure would be required to produce and transport liquefied hydrogen. In response, Saudi Arabia and Japan have cooperated in demonstrating an initiative to use existing supply chains for CO_2-free ammonia to lower overall hydrogen supply chain development costs. They are promoting the strategic initiative to begin with ammonia for the effective utilization of oil and gas resources in the Middle East in response to global decarbonization.

As a matter of course, technological challenges exist in regard to relatively low cost CO_2-free ammonia, including the development of supply chains and relevant infrastructure to further reduce costs and accommodate massive supply. More difficult challenges must be overcome for CO_2-free hydrogen. Numerous challenges would have to be overcome to pave the way for the Middle East to contribute to global decarbonization and effectively use their domestic resources over a long term. To this end, the Middle East would have to cooperate with Japan and other Asian countries that would become major consumers of CO_2-free hydrogen and ammonia.

Even if the Middle East successfully realizes massive CO_2-free hydrogen and ammonia exports through its own efforts and international cooperation, various other challenges may have to be considered during the process. First, many resource-rich countries would tackle CO_2-free hydrogen and ammonia export initiatives in consideration of growing interests in the clean energy fuels, leading to international competition. Second, global certification would have to be secured for CO_2-free hydrogen and ammonia. Another fundamental challenge is that rent from CO_2-free hydrogen and ammonia exports would be lower than from traditional oil or natural gas production. Regarding rent levels, it must be remembered that oil prices under the current production management of the Organization of the Petroleum Exporting Countries and other oil producing countries are higher than those in a completely competitive market. Furthermore, CO_2-free hydrogen and ammonia supply chain costs, including CCS/CCUS and transportation costs, would be higher than oil supply chain costs. The successful utilization of CO_2-free hydrogen and ammonia is expected to contribute to preventing oil and gas resources from becoming stranded assets, but rent revenue from CO_2-free hydrogen and ammonia would be lower than from oil. If so, a big challenge would remain for economic and social management in oil and gas producing countries in the Middle East.

In this sense, oil and gas producing countries in the Middle East would have to not only decarbonize fossil fuels but also diversify and advance their economies structurally. Such structural reform efforts would have to be enhanced in the future. In this area, their cooperation with Japan and other major countries would be indispensable.

3. Conclusion: Challenges for Stabilizing the Middle East

Oil and gas producing countries in the Middle East face a mountain of challenges in addition to those regarding the globally accelerating decarbonization trend. Over the short term, they must keep crude oil prices at levels required to secure financial resources for advancing their economies for the future. To this end, they will have to continue difficult oil production adjustment in the fast-changing international oil market.

Factors that complicate the international oil situation include the destabilization of the Middle East. At present, we must watch how the U.S. Biden administration would handle its Iran policy and how the Biden administration's diplomacy giving priority to values including human rights and democracy would influence the stability of the Middle East. As the United States gradually reduces its engagement in and influence on the Middle East over a medium to long term, we would have to pay attention to how China and Russia would enhance their respective engagement in the Middle East. Particularly, we should watch how China would increase its presence in and influence on the Middle East amid the intensifying U.S.-China confrontation and how such change would impact the stabilization of the Middle East.

The stability of the Middle East will remain one of keys to that of the international energy situation. Middle Eastern countries' stabilization efforts are indispensable for the stability of the Middle East. At the same time, their relations with major countries surrounding the region and the geopolitical situation exert great influence on the regional stability. As the global decarbonization trend complicates the Middle Eastern situation, the region must make further efforts for its stabilization and prosperity. Middle Eastern countries' future efforts will grow even more important along with international initiatives to support their efforts.

Writer's Profile

Ken Koyama

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.

加速化する世界の脱炭素化の潮流と中東の課題

小山　堅*

はじめに

世界的に脱炭素化・カーボンニュートラルへの取組みが加速化している。2020 年には EU に次いで中国、日本、米国等が相次いで 2050 年を目途に（中国は 2060 年）温暖化ガス（GHG）排出を実質ゼロにするカーボンニュートラル達成を目指す方針を発表した。既に 120 を超える国・地域が 2050 年頃を目途にしたカーボンニュートラル目標を発表している。他方、現時点で世界は一次エネルギー供給の 8 割超を石油・天然ガス・石炭など化石燃料に依存している。豊富な供給量と優れた価格競争力に裏打ちされた化石燃料が世界の経済と市民生活を支えている。この現状からカーボンニュートラルに向かう道筋は抜本的「エネルギー転換」の Pathway であり、革命的な変化を伴うものである。

化石燃料が世界のエネルギー供給の大宗である中、中東は化石燃料、とりわけ石油と天然ガス・LNG 供給の重心である。2020 年時点で中東は世界の石油生産の 31%、石油輸出の 34%、LNG 輸出の 26%を占める世界有数の生産・輸出地域である。同時に中東の産油・産ガス国にとって、石油および天然ガス・LNG からの収入が各国の経済運営や政治・社会の安定にとって不可欠で最重要の役割を果たしている。その状況下、世界が脱炭素化の取組みを強め、結果として伝統的・従来型の化石燃料消費が減少していく場合、中東では国家の安定やサバイバルにとって、長期的に甚大な影響が生じることになる。

以下では、こうした問題意識を踏まえ、世界の脱炭素化の潮流と化石燃料市場への影響、それに対応する中東の取組みと課題等について、論点を整理することとしたい。

1.　世界の脱炭素化の潮流と石油・天然ガス市場

いかなる国においても、カーボンニュートラルを達成するためには不可欠となる「処方箋」が存在する。第 1 は、可能な限り省エネルギーを進めエネルギー消費そのものを抑制・削減することであり、同時にそのエネルギー消費において再生可能エネルギーや原子力など非化石エネルギー利用を推進することである。第 2 は、可能な限り電力化（最終エネルギー消費に占める電力消費の割合を高めること）を進め、電力部門をゼロエミッション化することである。しかし、GHG 排出実質ゼロのためには、上記 2 つの処方箋だけでは不十分であり、CO_2 フリー水素・アンモニアなどの新燃料を大量導入すること、CO_2 を大気中から直接回収する DAC などのネガティブエミッション技術が不可欠である。これらの技術・オプションに関しては、技術進歩・市場普及・コスト削減・社会受容等に関して、高いレベルの不確実性が伴うため、カーボンニュートラルに向かう道筋は多様であり、複数の将来像・シナリオを描くことができる。

しかし、様々な可能性の中においても一つの重要な共通点は、カーボンニュートラルに向かう世界においては、石油・天然ガス・石炭の需要が下押しされ、ピークアウトし、減少に向かう可能性があることであろう。2021 年 5 月に発表された IEA の分析では、世界全体が 2050 年

* （一財）日本エネルギー経済研究所　常務理事　首席研究員

に GHG 排出ネットゼロを実現するとするならば、という前提の下で、世界の石油・天然ガス需要は大きく減少、結果として世界の石油生産は 2020 年水準から 2050 年には 75%、天然ガス生産は 55%減少する将来像が描かれた。IEA のこの分析は、あくまで一つの将来像を描いたものであり、実際に世界がカーボンニュートラルの方向に向かうにせよ、石油・天然ガス需要の将来像には大きな不確実性がある。

しかし、方向性として、世界全体の需要が低下すれば、中東にとって経済・社会運営に不可欠な石油・ガス収入確保にとって甚大な影響が出ることは避けられない。これは、単に量的に石油生産・輸出が下押しされるだけでなく、市場が縮小する中で石油・ガス価格も低下し、量・価格双方の影響で石油・ガス収入が大幅減少する可能性が高いからである。そして、豊富な資源を有する中東産油国・産ガス国にとっては、長期的に脱炭素化が進んで、石油・ガスの利活用が減少すれば、彼らの資源そのものが「座礁資産化」することも懸念しなければならない。カーボンニュートラルに向かう世界は中東の石油・天然ガスにとって重大なリスク・脅威をもたらしうるのである。

2.　世界の脱炭素化に対応する中東の取組みと課題

世界的な脱炭素化の潮流の下では、中東の石油・天然ガス生産にも基本的には下押しの力が働く。ただし、生産コストが世界でも最も低位にある中東の石油・天然ガス生産の競争力が、縮小する市場において重要な役割を果たすことにも留意が必要である。全体として市場のパイが大きく縮小すれば、高いコスト競争力を背景に、中東の市場シェアが高まる可能性もある。しかし繰り返しにはなるが、量的には中東の生産・輸出が低下し、そして価格低下も合わせた石油・ガス収入の大幅低下の可能性に中東は対応せざるを得ない。

石油・天然ガス収入低下と石油・天然ガスの座礁資産化に対応するには、中東産油・産ガス国自身による石油・ガス収入依存体質からの脱却が必要になる。石油・ガス依存からの脱却にも様々なアプローチがあるが、世界の脱炭素化の潮流に直接対応する取組みとして中東自身が、そして世界のエネルギー関係者が注目するものに、彼らの石油・ガス資源の脱炭素化とそれを通した CO_2 フリー水素・アンモニアの輸出がある。中東、特にサウジアラビアでは、2020 年の G20 ホストを契機に、化石燃料の脱炭素化による利活用を重視した炭素循環経済（Carbon Circular Economy）のコンセプトが唱導されるようになり、中東産油・産ガス国が保有する石油・ガス資源から水素を製造し、その過程で排出される CO_2 を CCS あるいは CCUS によって処理、CO_2 フリーの水素（ブルー水素）を製造、それを消費国に輸出して彼らのカーボンニュートラル達成の一手段とする方策が模索されるようになっている。究極のクリーンエネルギーである水素を化石燃料から製造し、CO_2 を処理、消費国で利活用する国際サプライチェーンを構築し、その中核に中東産油・産ガス国が供給源として位置するという構想である。その実現には、技術的・経済的・社会的な課題が存在しており、その克服がカギとなる。中でも水素を輸出・輸送するためには液化水素製造のための超低温に対応した設備・インフラが必要になるなど、大きな課題が存在する。これらに対応し、供給チェーンを構築するための全体コストを引き下げる手段として、まず既存供給チェーンの活用が可能な CO_2 フリーアンモニアからスタートしようとした構想がサウジアラビアと日本の協力で実証された。長期的には水素を念頭に置きつつ、アンモニアから着手し、世界の脱炭素化に対応して中東の石油・ガス資源を有効活用する戦略構想が進められているのである。

もちろん、相対的に低コストの CO_2 フリーアンモニアにせよ、さらなるコスト削減や大量の

供給を可能にするサプライチェーン・関連インフラの形成や様々な技術的課題が存在する。CO_2フリー水素に関しては、さらによりチャレンジングな課題に取り組んで行く必要がある。多くの課題を克服することで初めて中東は現実に世界の脱炭素化の取組みに貢献し、自らの資源を長期的に活用していく道が開けるのである。そのためには、日本を始め、CO_2フリー水素・アンモニアの主要消費国となるアジア諸国などとの協力が欠かせない。

中東が自らの努力と国際協力を通して、CO_2フリー水素やアンモニアの大規模輸出に成功していくにせよ、その過程において、考慮すべき多様な課題が他にもある。第 1 には、CO_2フリー水素・アンモニアへの関心が高まる中、多くの資源国が輸出構想に取り組み始め、今後国際的な競争が発生していく可能性があること、第 2 に、脱炭素化の世界に対応するため、水素・アンモニアの CO_2フリー特性に関して、世界的認証を確保していくことが不可欠となること等である。もう一つ根本的な問題として、仮に CO_2フリー水素・アンモニアの輸出に成功しても、そこから得られる「レント」が石油あるいは天然ガスと比較して小さなものになる可能性が高いことである。「レント」の水準に関しては、まず、石油の場合、OPEC プラスの生産調整で市場価格が完全競争市場の価格より高位となっている点を忘れてはならない。さらに、CO_2フリー水素・アンモニアは、どうしてもその生産・供給コストが CO_2回収等のコストや輸送を含めたサプライチェーン全体のコストとしてどうしても高くなる可能性が高い。CO_2フリー水素・アンモニアの利活用で成功を収めることは、石油・ガス資源の座礁資産化回避には有効に機能することが期待されるが、「レント」収入はどうしても石油に比べれば低くなると考えられる。その場合、中東産油・産ガス国の経済・社会運営にとっては大きな問題が残り続ける可能性がある。

その意味では、中東産油・産ガス国にとって、化石燃料の脱炭素化に加え、より本格的な経済構造多角化・高度が必須となる。そのための構造改革の努力は今後一層強化していく必要があり、その面においても日本を始めとする主要国との国際協力は不可欠である。

3. おわりに：中東安定化に向けた諸課題

中東産油・産ガス国にとって、世界で加速化する脱炭素化の潮流に対する取組み以外にも課題が山積している。短期的には、将来に向けた経済高度化を進める上で必要な原資を確保するためにも原油価格を一定に保つ必要があり、激動を続ける国際石油市場での難しい生産調整を今後も継続していく必要がある。

国際石油情勢を複雑化させる要因には、中東情勢流動化もある。足下ではバイデン政権の対イラン政策の行方や、人権・民主主義等の価値観外交を重視するバイデン政権の中東政策が中東情勢安定にどのような影響を与えるかも注視していく必要がある。中長期的には、米国の中東への関与・影響力が徐々に低下していく中、中国やロシアの中東への関与の強化、とりわけ、米中対立が激化する中で、中国の中東におけるプレゼンスや影響力がどう強化され、それが中東情勢安定化にどのような影響を持つか、も注目すべきポイントとなる。

中東の安定は、今後も国際エネルギー情勢の安定における「要」の一つであり続ける。中東安定には、中東諸国自身による安定化のための努力・取組みが不可欠であり、同時に中東を取り巻く主要国との国際関係や地政学情勢が大きな影響を及ぼす。世界の脱炭素化の潮流は中東情勢をより複雑にする一面があり、中東にとっての自らの安定化と繁栄のため、さらなる努力が必要となっている。今後の中東諸国自らの取組みとそれを支援する国際的な取組みの双方がますます重要になろう。

執筆者紹介

小山　堅（こやま けん）
2001年英国ダンディ大学博士号取得。エネルギー動向分析室長、研究理事などを歴任。東京大学公共政策大学院客員教授、政府審議会委員等を多数務める。専門は国際石油・エネルギー情勢の分析、アジア・太平洋地域のエネルギー市場・政策動向の分析、エネルギー安全保障問題で、関連の著書・論文多数。2020年6月より現職。

How will the Middle East and Other Resource-Rich Countries Respond to the Global Carbon Neutral Movement?

Tatiana Mitrova*

Now, in the 21st century, humankind faces the threat of global climate change induced by anthropogenic GHG emissions. As concerns about this challenge are growing, there is increasing pressure from key stakeholders (population, representatives of civil society and NGOs, investors, etc.) on governments to ensure immediate action adequate to the scale of this threat.

To address this threat, the global community is undertaking efforts to reduce these emissions, focusing mostly on those of carbon dioxide (decarbonization), methane emissions are also a separate issue for the oil and gas industry.

Adopted internationally in 2015, the Paris Agreement aims to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels in order to improve adaptability to the consequences of climate change. The Agreement also aims to transition to low-carbon development. At the same time, the UN adopted Sustainable Development Goals, e.g., to take urgent action to combat climate change and its impacts (Goal 13) and to ensure access to affordable, reliable, sustainable, and modern energy for all (Goal 7).

As of today, 189 states have joined the Paris Agreement (including Russia, the USA rejoined the Agreement in February 2021).[1] All member countries are voluntarily committed to reducing net atmospheric emissions of CO_2 and other GHG. So far, more than 130 countries have stated their goals to achieve carbon neutrality (i.e., net-zero CO_2 emissions) by 2050.

Given this new environment, resource rich countries such as Russia, Saudi Arabia and other Gulf producers face new challenges. First of all, their key customers announce carbon neutrality and plans to reduce dramatically their consumption of hydrocarbons. For example, late in 2019, the European Union announced a comprehensive legislative initiative, the European Green Deal, which focuses on having all EU member states achieve 100% climate neutrality by 2050. On September 17, the European Commission presented its 2030 Climate Target Plan, in which the main objective is the reduction of greenhouse gas (GHG) emissions to at least 55% below 1990 levels by 2030[2] instead of the 40% proposed in 1990. In October 2020, the European Commission presented a new

* Professor and Research Director, Energy Center, SKOLKOVO Business School

1 https://unfccc.int/process/the-paris-agreement/status-of-ratification

2 https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=EU%20Commission%20Unveils%20EU%20Climate%20Target%20Plan%202030_Brussels%20USEU_European%20Union_09-26-2020#:~:text=On%20September%2017%2C%20as%20part,existing%20target%20of%2040%20percent.

strategy for methane emission reduction. The draft legislative policy called the Carbon Border Adjustment mechanism (CBAM), which will establish the carbon price for importing certain goods into Europe, was published in July 2021.

And it's not only EU: in September 2020, China announced its commitment to achieving carbon neutrality by 2060 and to pursuing green development.[3] In October 2020, Japan and South Korea made similar commitments to carbon neutrality by 2050. Canada in January 2021 also announced carbon neutrality by 2050.[4] The new US administration is also preparing ambitious Climate Plan and regards CBAM.

Many Paris Agreement signatories have either already launched CO_2 emissions trading systems (or some other forms of carbon pricing and taxing) or are set to do so in the near future. Many are introducing bans on the use of combustion engines, setting targets for the proportion of renewable energy sources in their national energy balance, or setting targets for the proportion of low-carbon fuels in their fuel suppliers' basket. As is clear, various decarbonization initiatives are gradually taking shape throughout the world.

Reducing GHG emissions is becoming an important objective not only for governments but also for businesses in all sectors and for the investors, who are starting to consider the climate risks of potential investments and are starting to withdraw from those that produce high emissions, in particular, the ultra-heavy oil, Arctic oil and tar sands. For instance, major global investors, such as BlackRock, the World Bank, JP Morgan, the Swedish pension fund Sjunde, the Norwegian Government Pension Fund Global, Goldman Sachs, Deutsche Bank, BNP Paribas, Societe Generale, the European Investment Bank, Allianz, and more, have all made statements saying as much and launched corresponding initiatives. Worldwide, thousands of corporate and private investors, whose joint asset control amounts to more than $14 trillion, have committed to divesting from the fossil fuel industry.

Given all this, the development prospects of the oil and gas producing countries, one of the noticeable GHG emitters that accounts for 12% of global GHG emissions, are directly dependent on their ability to decarbonize.

Decarbonization of the hydrocarbon producing economies is not an easy task: they are heavily dependent on oil and gas export revenues, many of them have "Dutch disease" and their economies (and energy sectors) are not really diversified well to be prepared for the Energy Transition. Energy sectors of the oil and gas producing countries in the MENA and CIS regions have two main options to diversify their revenues and to reducing their carbon intensity:

---

[3] China pledges to become carbon neutral by 2060. September 22, 2020. https://www.theguardian.com/environment/2020/sep/22/china-pledges-to-reach-carbon-neutrality-before-2060

[4] https://ihsmarkit.com/research-analysis/canada-upgrades-decarbonization-plan-.html

1. Decarbonization of oil and gas sectors. There are already plenty of methods known how to decarbonize molecules:

- Operational methods
  - Operational efficiency improvement. Although the primary objective of operational excellence is lowering production costs, in many cases those initiatives also result in carbon footprint reductions. This is a primary short-term focus with the lowest, or even zero, additional financing.
  - Recycling, reuse, and the utilization of secondary energy sources. Oil and gas companies are becoming more active in using the circular carbon economy principles. They use and process CO_2, convert the emissions into products with a smaller carbon footprint, and minimize their carbon footprint by reusing materials and resources.
  - Energy efficiency. The efficient use of energy resources by oil and gas companies is one of the cheapest methods for reducing GHG emissions. IN the short-term majority of the oil and gas companies focus their decarbonization efforts on efficient energy and resource use. According to some of the companies that participated in this research via interviews, up to 40% of decarbonization opportunities are commercially viable even without additional financing.
- Effective monetization of methane and APG. Methane leaks and APG flaring account for up to 45% of total industry emissions, which is why reducing them is a top priority, especially assuming that it is a relatively easy thing to do, for which companies have technologies available. This is also a primary focus of several syndicated initiatives, such as the Oil and Gas Climate Initiative (OGCI)[5], Global Methane Alliance[6] and Methane Guiding Principles[7], who work in conjunction with oil and gas companies. Initiatives like these often represent low, or even no, cost options for reducing GHG emissions.
- Shifting to low carbon energy sources. More and more, oil and gas companies are focusing on renewable energy and electricity storage for their own operations, biofuels as a substitute for traditional feedstock, and also low-carbon fuels for the marine transportation of their products.
- Corporate strategy methods of decarbonization
  - Optimized portfolios include divestments (removing unattractive, carbon-intensive assets), M&As allowing for resource quality improvement and diversification within the new less carbon-intensive business (first of all increasing their activities in natural gas and NGLs), restructuring, development of the petrochemical business, and creation of corporate venture capital funds focused on innovation in the fields of methane leakage

[5] https://oilandgasclimateinitiative.com/
[6] https://www.ccacoalition.org/en/activity/global-methane-alliance
[7] https://methaneguidingprinciples.org/

reduction, operational efficiency, CCUS, hydrogen technologies, and more. A few important emerging aspects of corporate decarbonization strategies include industrial cooperation on R&D, venture investments, and the piloting of deep decarbonization projects in order to increase the quality and speed of these new technologies' developments and to understand whether these tools may fit well into the longer-term plans of a company.

- Oil and gas companies are becoming increasingly interested in the petrochemical and chemical industry, as well. They see the potential for synergy through integration with oil refining systems, as well as potential for the monetization of available raw hydrocarbons, improvement of output marginality, and realization of decarbonization goals.

- Trading and offsetting carbon credits is taken with a caution, with a selective approach taken to the origin and verification of credits or offsets. "Reduce what you can, offset the rest" emerges as a prevailing approach.

- Increasingly, oil and gas companies are looking into projects focused on nature-based carbon sinks, albeit with apprehension in the selection of the project and of the project partners due to the inherent difficulty of measuring the impact of nature-based carbon sinks, as well as the negative publicity associated with not yet matured projects.

- Finally, most of the oil and gas producers have deep decarbonization visions and strategies involving carbon capture, utilization, and storage (CCUS) projects and the use of hydrogen as fuel. There are Middle Eastern and Russian companies with projects in various stages of construction and operation. These projects currently rely on extensive government subsidies and would not be feasible without such support. However, the total capacity of operating assets is far below the forecast demand for decarbonization methods. Today's operating CCUS projects have an annual CO_2 capacity of just 10 Mt. By 2050, the annual volume of CO_2 capture and storage in volumetric equivalent may reach 4,6GtCO_2 per year, which is comparable with the scale of today's global oil industry annual production. It is representing a new, major diversification opportunity for the oil and gas industry.

2. Diversification of the fuel mix and development of RES supports diversification of the whole economy, thus providing for financial sustainability of the resource-rich countries and reduction of their carbon footprint. All economies in the Middle East (which enjoy high level of insulation) as well as Russia (which has the largest wind potential in the world) are keen to develop their domestic renewable sectors. They create special programs and stimulus in order to incentivize such projects, and indeed there is a visible progress made in this direction.

Summing up, movement to net zero is irreversible and it creates an existential threat for the resource-rich countries such as Russia or Middle-Eastern oil and gas producing economies. Nevertheless, this situation is not hopeless, there are different opportunities for these countries to adapt to the new reality and to create new drivers for their economic growth and prosperity.

Writer's Profile

Tatiana Mitrova

Senior Research Fellow in the Oxford Institute for Energy Studies (OIES), Scientific advisor at the Energy Research Institute of the Russian Academy of Sciences (ERI RAS), Visiting Fellow at the Center on Global Energy Policy at Columbia University, Distinguished Research Fellow at Institute of Energy Economics, Japan (IEEJ). Leader of the annual "Global and Russian Energy Outlook up to 2040" project. Independent Director at Schlumberger Limited and NOVATEK.

・Twenty-five years of experience in dealing with global and FSU energy markets development. Profound knowledge of energy transition - new energy technologies, market organization, corporate strategies and geopolitical consequences.

・Seven years as Independent Director in international public energy companies.

・Strong focus on ESG and corporate climate strategies.

Head of Supervisory Board of "Women in Energy in Russia" Association. Dr. Mitrova is a graduate of Moscow State University's Economics Department. Visiting Professor at the Institut d'Etudes Politiques de Paris (Sciences Po) Paris School of International Affairs.

Carbon Neutrality Policies in Persian Gulf Countries

Shuji Hosaka*

Ending Oil Age

In the 20th century, oil-producing Persian Gulf countries took advantage of oil resources for accumulating huge wealth. In the early 21st century when oil and other fossil fuels were criticized for causing global warming, however, their situation turned around.

Gulf countries have acknowledged their dangerous dependence on oil resources and taken various initiatives to phase out the dependence in response to internal pressure and climate change. For instance, the United Arab Emirates in 2006 launched Masdar, also known as the Abu Dhabi Future Energy Company, which seeks to exploit renewable energy for achieving zero emissions. In 2009, the UAE announced a target of boosting renewable energy's share of its total power generation capacity to 7% by 2020. It then attracted the International Renewable Energy Agency (IRENA) for commercializing renewable energy technologies and promoting the sharing of knowledge about renewables to be headquartered in its capital city of Abu Dhabi.

Saudi Arabia for its part has promoted research on renewable and other new energy sources mainly at the King Abdul Aziz City for Science and Technology (KACST,) the King Abdullah Petroleum Studies and Research Center (KAPSARC) and the King Abdullah City for Atomic and Renewable Energy (KACARE.)

Then, however, Gulf countries' energy policies responded to their energy consumption expansion amid population growth rather than climate change. They attempted to hold down their domestic oil and natural gas consumption through the introduction of renewable energy and nuclear power plants and increase oil and gas export revenue, giving priority to economic benefits.

Oil-Producing Gulf Countries' Visions

Since the early 21st century, the Gulf Cooperation Council members released their respective national visions calling for reducing their dependence on oil and diversifying their economies. In Saudi Arabia, for instance, then Deputy Crown Prince Muhammad bin Salman (now Crown Prince and known as MbS) took the initiative in launching a bold economic reform project titled "Saudi Vision 2030 (SV2030)" in 2016. SV2030 emphasized the role of renewable energy but fell short of discussing global warming or climate change in its text. It pointed out responses to energy consumption expansion accompanying rapid population growth, instead of consideration to the environment. It set the initial renewable energy power generation target at 9.5 gigawatts. Under the King Salman Renewable Energy Initiative, the National Renewable Energy Plan and other later

* Board Member, Director of JIME Center, IEEJ

initiatives, however, the target renewable energy power generation for 2030 was raised to 58.7 GW, accounting for half the total power generation.

In oil-producing Gulf countries, fossil fuels have traditionally accounted for almost 100% of power generation. Given their long sunshine hours, however, it has been natural for them to pay attention first to sunlight as renewable energy before looking to wind and nuclear energy.

Symbolizing this trend was the NEOM smart city initiative announced by MbS in October 2017. The planned 26,500-square-kilometer NEOM smart city will be built along the Red Sea coast to generate power mostly with solar and wind energy. In January 2021, THE LINE project was unveiled as the core of the NEOM initiative, envisaging an eco city that would be 170 km long, have a population of one million without cars or streets and depend only on clean energy without CO_2 emissions.

The UAE for its part announced a new energy strategy in 2017, vowing to raise clean energy sources' share of its energy mix to 50% and improve energy consumption efficiency 40%. Both Saudi Arabia and the UAE are planning large-scale government reorganizations to respond to new energy strategies. Saudi Arabia has formed the inter-ministerial Supreme Committee for Energy Mix Affairs for Electricity Production and Enabling Renewable Energy Sector as its highest decision-making body for renewables, chaired by MbS.

Projects Beginning to be Implemented

Regarding solar photovoltaics, the UAE's Emirates Water and Electricity Company in 2019 launched the 1.177 GW Noor Abu Dhabi solar power plant, then the world's largest solar PV facility. In April 2021, Saudi Arabia opened the 300 MW Sakaka solar power plant as its first commercial solar PV facility.

As for other new energy projects, the UAE launched Unit 1 of the Barakah nuclear power station built by a South Korean consortium in August 2020 and Unit 2 of the same station successfully connected to the UAE's national transmission grid in September 2021. In Saudi Arabia, KACARE in June 2011 announced a plan to build 16 nuclear power plants by 2030.

Since 2020 when the COVID-19 pandemic started its global spread, oil-producing Gulf countries accelerated their energy transition further in view of a substantial contraction in oil demand. It is no accident that hydrogen has attracted attention as a clean energy in oil-producing Gulf countries. In September 2020, Saudi Arabia's state-run oil company Saudi Aramco and the Institute of Energy Economics, Japan (IEEJ,) launched a demonstration project to produce blue ammonia through the separation and capture of CO_2 from natural gas and transport it to Japan. In January 2020, Japan's Ministry of Economy, Trade and Industry signed a memorandum of understanding with Abu Dhabi National Oil Company on cooperation in fuel ammonia and carbon recycling. In this way, cooperation between Japan and oil-producing Gulf countries in the hydrogen/ammonia area began to make rapid progress. Oil-producing Gulf countries have proactively promoted cooperation in the hydrogen/ammonia area with China, South Korea, the United States, Germany and France, as well as Japan.

Oil-producing Gulf countries had initially given priority to green hydrogen and ammonia produced from renewable energy but have begun to focus on blue hydrogen and ammonia produced from their abundant fossil fuel resources including natural gas with CCS (CO_2 capture and storage) or CCUS (CO_2 capture, utilization and storage) technologies. They have long been interested in CCS and CCUS technologies for the effective utilization of fossil fuels. Among them, Saudi Arabia and the UAE have taken the initiative in this area.

Circular Carbon Economy

At meetings of Group of 20 leaders and energy ministers hosted by Saudi Arabia in September 2020, a Circular Carbon Economy (CCE) platform was approved to reduce, reuse, recycle and remove CO_2 emissions.

The CCE platform is seen as a decarbonization initiative communicated by Saudi Arabia to the international community. Furthermore, MbS announced the Saudi Green Initiative and the Middle East Green Initiative in March 2021, setting out ambitious targets to plant 10 billion trees in Saudi Arabia or 40 billion trees in the entire Middle East, to boost renewable energy's share of Saudi Arabia's power generation to 50% by 2030, to cut CO_2 emissions by 130 million tons through hydrocarbon technology for absorbing CO_2 and to reduce CO_2 emissions in the Middle East by 60%.

In the Middle East, Saudi Arabia and the UAE have seemingly taken a lead over others in promoting decarbonization. Among other countries in the region, Qatar has announced some energy efficiency improvements and renewable energy projects. Kuwait, though among oil-producing Gulf countries, has made no visible progress in decarbonization. Iran and Iraq may be too busy tackling serious domestic and external problems to consider full-blown carbon neutrality.

Net Zero by 2050 Roadmap

In May 2021, the International Energy Agency (IEA) released *Net Zero by 2050: A Roadmap for the Global Energy Sector* to achieve net zero CO_2 emissions by 2050 in the world. In the roadmap, the IEA cited measures required to attain net zero emissions by 2050, including an immediate halt to investment in new fossil fuel supply projects and others that are tough for the oil industry and oil-producing Gulf countries. Saudi Arabian Energy Minister Abdulaziz bin Salman branded the IEA report as a sequel to the Hollywood film "La La Land," concluding that the report was not worthy of serious consideration. This may be interpreted as indicating that oil-producing countries could fail to survive if the roadmap comes true.

Nevertheless, even the roadmap does not envisage zero oil consumption. As low-cost oil is projected to survive even though with oil consumption falling from 90 million barrels per day in 2020 to 24 million bpd in 2050, oil-producing Gulf countries are likely to increase their share of the global oil market temporarily. As a matter of course, crude oil prices are predicted to plunge to $24 per barrel in 2050 due to a substantial drop in oil demand, indicating that those Gulf countries would have difficulties in maintaining "rent."

Towards Carbon Neutrality

The problem is whether oil-producing Gulf countries could maintain their respective political regimes if they go in the direction of carbon neutrality. Excluding Kuwait, oil-producing Gulf countries are dictatorial monarchies. In this sense, their governments have a free hand in implementing large-scale political, social and economic reforms. However, the reason their governments have a free hand is that the governments or the regimes have distributed oil wealth to citizens. Oil-producing Gulf countries have already launched painful reforms including the introduction of value added tax (VAT.) In Oman, Bahrain and other financially weak countries among them, public discontent has been growing. Regimes failing to guarantee affluence for citizens could weaken.

Oil-producing Gulf countries must continue investing in fossil fuel development to maintain their oil and natural gas revenue. However, the European Union Taxonomy and other regulations are making fossil fuel investment from the West difficult. Oil-producing Gulf countries now can expect investment only from domestic players and China. They could break away from Western countries and come under growing Chinese influence.

Numerous Middle Eastern countries are trying to achieve carbon neutrality targets through technological cooperation with China as well as Western countries including Japan. They have produced no exclusive innovations for carbon neutrality, leaving their technological cooperation with advanced economies to remain important for the immediate future.

However, massive funds are required for such technological cooperation. Supported by wealth accumulated with oil and natural gas revenue, oil-producing Gulf countries have promoted various projects to phase out oil consumption and carbon emissions as described above. However, it is contradictory for them to sell fossil fuels to break away from dependence on fossil fuels. Furthermore, it is growing difficult for them to sell fossil fuels. They have reached a crucial stage.

In the 1930s, natural pearl industry that was life base for local people in the Gulf region was at the brink of disintegration. Oil rescued them from the crisis and has brought far greater wealth to the region. As the 21st century has started, however, the oil industry has begun to end. Ironically, however, oil is still the only remedy to the oil industry that has fundamentally supported Gulf countries.

"Saudi Arabia is no longer an oil country, it's an energy-producing country," Saudi Arabian Energy Minister Abdulaziz said in June 2021. The remark should be interpreted as indicating a hope for Saudi Arabia. If oil-producing Gulf countries fail to make a soft landing for achieving decarbonization, the entire Middle East may destabilize. To avoid such a development, Japan and other advanced economies should cooperate with the region.

Writer's Profile

Shuji Hosaka

His specialized field of research is: Modern History of the Gulf, Jihadist movements and History of Science and Technology in the Middle East. After receiving an MA (Oriental History) from Keio University, HOSAKA became a Special Assistant of the Japanese Embassies in Kuwait and Saudi Arabia. Since then, he has held various posts in the field of the Middle Eastern studies, including Researcher of the Middle East Institute of Japan, Director of the JSPS Research Station, Cairo, and Professor of Kindai University. He joined JIME Center, IEEJ in 2005. He is currently Visiting Professor of Waseda University. He became President of Japan Association for Middle East Studies (JAMES) on April 2021.

湾岸諸国におけるカーボン・ニュートラル政策

保坂　修司*

石油時代の終焉

ペルシア湾岸産油国は 20 世紀、石油によって莫大な富を蓄積してきた。しかし、21 世紀に入って、地球温暖化の元凶として石油など化石燃料が槍玉に挙がると、湾岸諸国をめぐる状況は一変する。

もともと石油依存の危険性に気づいていた湾岸諸国は、気候変動という新しい状況に対応すべく脱石油のためのさまざまな取り組みを開始する。たとえば、UAE は 2006 年、再生可能エネルギーによるゼロエミッションを標榜するマスダル（アブダビ未来エネルギー会社）を設立した。また 2009 年には、発電能力の 7%を 2020 年までに再生可能エネルギーとする目標を明らかにした。さらに同年、再生可能エネルギー技術の実用化や知見の共有を目的とする国際機関、国際再生可能エネルギー機関（IRENA）の本部を首都アブダビに誘致している。

他方、サウジアラビアではアブドゥルアジーズ国王科学技術都市（KACST）やアブダッラー国王石油研究調査センター（KAPSARC）、アブダッラー国王原子力再生可能エネルギー都市（KACARE）を中心に再生可能エネルギー等新エネルギーに関する調査・研究が進められた。

ただし、この時期の、湾岸諸国のエネルギー政策は、気候変動対策というよりは、人口増に対応する各国のエネルギー消費の拡大を意識したものであった。再生可能エネルギーや原発の導入で、国内の石油・天然ガス消費を抑え、それらを輸出に回して歳入を増大させるという経済的なメリットが重視されていたのである。

湾岸産油国の「ビジョン」

21 世紀以降、GCC 加盟国はこぞって、石油依存を減らし、経済の多角化を目指す国家ビジョンを明らかにした。たとえば、サウジアラビアは 2016 年、実質的最高権力者であるムハンマド副皇太子（現皇太子、MbS）のイニシアティブで「サウジ・ビジョン 2030（SV2030）」という経済改革プロジェクトを開始した。ここでも再生可能エネルギーの役割が重視されているが、実際には SV2030 のテキストで地球温暖化や気候変動といった文言は用いられていない。そこで指摘されているのは、環境への配慮ではなく、急激な人口増に伴うエネルギー消費の拡大への対応だ。SV2030 では再生可能エネルギーの初期目標を 9.5 ギガワットにおいた。だが、その後、「サルマーン国王再生可能エネルギー構想」や「国家再生エネルギー計画」等のイニシアティブのもと、再生可能エネルギー発電量を 2030 年までに 58.7 ギガワットにまで上げ、全発電量の半分にまで拡大すると軌道修正した。

湾岸産油国の電源構成では従来、化石燃料がほぼ全量を占めてきた。しかし、これらの国は、日照時間が長いので、再生可能エネルギーとして最初に太陽光に着目したのは当然であった。それに次ぐのが風力や原子力である。

こうした流れを象徴するのが、2017 年 10 月に MbS の発表した「NEOM」である。紅海沿岸

* （一財）日本エネルギー経済研究所　理事　中東研究センター長

に建設される2万6500平方キロメートルの巨大都市NEOMでは電力の大半を太陽光や風力発電で賄うとされる。2021年1月にはこのNEOMのなかで中核となる「The Line」と呼ばれる新規プロジェクトに着手するとの発表があった。The Lineは、全長170キロメートル、人口100万人、自動車ゼロ、車道ゼロ、動力源はすべてクリーン・エネルギーで賄い、CO_2排出もゼロのエコシティーを目指す。

また、UAEも2017年に、全エネルギー・ミックスの50%をクリーン・エネルギーとし、エネルギー消費を40%効率化するという新しいエネルギー戦略を発表した。さらに、両国ともこうした新しいエネルギー戦略に対応すべく、大規模な省庁再編を行っている。なお、サウジアラビアにおける再生可能エネルギーに関する最高意思決定機関は省庁横断的な「発電・再生可能エネルギーのためのエネルギー・ミックス問題最高委員会」となり、MbSが議長として全体を仕切ることになる。

実現しはじめるプロジェクト

太陽光発電に関しては、2019年、UAEのエミレーツ水電力公社（EWEC）が、当時単独の太陽光発電設備としては世界一となる1.177ギガワットのピーク発電量を有するヌール・アブダビ太陽光発電を稼働させた。また、サウジアラビアも2021年4月、同国初の実用規模（300メガワット）の太陽光発電所、サカーカー太陽光発電所をオープンさせている。

太陽光以外でいうと、UAEは2020年8月、韓国企業連合の建設したバラーカ原子力発電所1号機の操業を開始した。また、2011年6月にはサウジアラビアのKACAREが2030年までに16基の原発建設計画を発表している。

さらに新型コロナウイルス感染が拡大しはじめた2020年以降は、石油需要の大幅な縮減等で湾岸産油国のエネルギー転換のスピードがさらに加速した。湾岸産油国でクリーンなエネルギーとしての水素への注目がさらに高まったのも偶然ではない。2020年9月、サウジアラビアの国営石油会社サウジ・アラムコと日本エネルギー経済研究所は、サウジアラビアで天然ガスから CO_2 を分離回収して生産されたブルーアンモニアを日本に向けて輸送する実証実験を開始した。また、日本の経済産業省は2020年1月にアブダビ国営石油会社（ADNOC）と燃料アンモニアおよびカーボンサイクルに関する協力覚書に署名した。水素・アンモニア分野における日本と湾岸産油国のあいだの協力は急速に進みはじめたといえる。こうした水素・アンモニアをめぐる、湾岸諸国の協力関係は、日本のみならず、中国、韓国、米国、ドイツ、フランス等でも積極的に動いている。

なお、当初湾岸産油国は再生可能エネルギーから生産するグリーン水素やグリーンアンモニアを強調していたが、天然ガス等豊富な化石燃料からCCS（CO_2回収・貯留）、CCUS（CO_2回収・有効利用・貯留）を利用して生産するブルー水素、ブルーアンモニアへも傾注しはじめている。化石燃料の有効活用の意味からも湾岸諸国ではCCS、CCUSの利用が早くから関心を集めていたが、なかでもサウジアラビアやUAEがこの分野で先進的な取り組みを進めているといえる。

循環炭素経済

2020年9月にサウジアラビアを議長国として開催されたG20サミットではエネルギー相会合、首脳会合でそれぞれ循環炭素経済（CCE）のプラットフォームが強調され、その構成要素

たる「削減（Reduce）」「再利用（Reuse）」「再資源化（Recycle）」「除去（Remove）」が承認された。

これは、サウジアラビアが国際社会に向けて発信した、同国の脱炭素に向けたイニシアティブとも考えられる。さらに 2021 年 3 月、MbS は、サウジ・グリーン・イニシアティブと中東グリーン・イニシアティブを発表した。このなかでサウジアラビアは国内だけで 100 億本、中東全体で 400 億本の植樹を行うとともに、2030 年までに国内電力の 50%を再生可能エネルギーとし、CO_2 を吸収する炭化水素技術を活用して 1 億 3000 万トンの CO_2 排出を削減、中東における CO_2 排出を 60%削減する野心的な目標を掲げた。

現在、中東においてはサウジアラビアと UAE が脱炭素で一頭地を抜いているようにみえる。しかし、それ以外の国ではカタルが省エネや再生可能エネルギーなどでいくつかのプロジェクトを掲げている程度、同じ湾岸産油国でもクウェートではまだ具体的な進捗は見えていない。また、イランやイラクは国内外で深刻な問題に直面しているため、カーボン・ニュートラルにまで手が回らないのが現状であろう。

2050 年ネットゼロ・ロードマップ

国際エネルギー機関（IEA）は 2021 年 5 月、世界の CO_2 排出を 2050 年までにネットゼロとするためのロードマップ（*Net Zero by 2050*）を発表した。このなかで IEA は 2050 年のネットゼロ達成のために必要な措置を挙げているが、そのなかには新規の化石燃料供給プロジェクトへの新規投資の即時停止など石油業界や湾岸産油国にとっては厳しい内容が含まれていた。サウジアラビアのアブドゥルアジーズ・エネルギー相は、この IEA のレポートを「(ハリウッド映画の)『ラ・ラ・ランド』の続編」と称し、まじめに検討する価値もないと断じた。これらは、裏返せば、このロードマップどおりに事態が進めば、産油国は立ちいかなるかもしれないという焦りの表れとも取れる。

とはいえ、このロードマップでも石油消費量がゼロになるわけではない。2020 年の 9000 万 b/d から 2050 年には 2400 万 b/d へと減少するが、生産コストの低い石油が生き残ることが想定されており、したがって、湾岸産油国の石油のシェアは一時的に高まるとも考えられる。もちろん、石油の需要は大幅に減少するし、原油価格も 2050 年には 1 バレル＝24 ドルに落ち込むと予想されており、これでは湾岸諸国がレントを維持するのは困難だ。

カーボン・ニュートラルに向けて

問題は、湾岸産油国がカーボン・ニュートラルに向けて進んだ場合、それぞれの体制が維持されうるかということである。湾岸産油国は、クウェートを除き、独裁君主体制であり、その意味では、政治・社会・経済における大規模な改革でも行政府はフリーハンドをもちやすい。しかし、行政府が自由に行動できるのは、もともと体制が石油の富を国民に分配してきたからである。すでに湾岸諸国では付加価値税の導入など国民に痛みを伴う改革を開始しており、財政基盤の脆弱なオマーンやバハレーンなどでは国民の不満も高まっている。体制が国民に対し豊かさを約束できなければ、体制が揺らぐ可能性も否定できない。

湾岸諸国は石油や天然ガス収入を維持するためにも、当面は化石燃料に対する投資を継続しなければならないのだが、EU タクソノミーなどで化石燃料に対する投資は急速に困難になりつつある。資金は中東内、あるいは中国などからしか期待できなくなり、西側離れが進み、ま

すます中国の影響力が拡大するだろう。

多くの中東諸国は、技術的には日本を含む西側諸国や中国などと連携しながら、カーボン・ニュートラルの目標を達成しようとしている。カーボン・ニュートラルに向けた独自のイノベーションはまだこの地域から生まれていない。当面、技術的先進国との関係は重要になってくる。

ただ、そのためには資金が必要だ。湾岸産油国の場合、石油や天然ガス収入で蓄積した豊富な資金量を背景に、脱石油や脱炭素のさまざまなプロジェクトを進めてきたのは上述のとおりである。しかし、化石燃料への依存から脱却するために、化石燃料を売らなければならないというのは大いなる矛盾であり、しかも、化石燃料を売るための条件は年々厳しくなっている。まさに湾岸産油国にとっては正念場であろう。

1930 年代､湾岸地域の地場産業として湾岸の人びとを支えてきた天然真珠採取は崩壊の瀬戸際にあった。その危機を救ったのが石油であり、石油は天然真珠とは比較にならない莫大な富をこの地にもたらした。21 世紀になり、その石油産業にも終わりが見えてきた。しかし、今のところ、湾岸諸国を根底から支えてきた石油産業を治癒する万能薬は、皮肉なことに石油以外に、見つかっていない。

サウジアラビアのアブドゥルアジーズ・エネルギー相は 2021 年 6 月、「サウジアラビアはもはや産油国ではない。エネルギー生産国である」と述べた。この言葉には、サウジアラビアとしての希望が含まれていると見るべきだろう。いずれにせよ、湾岸産油国が脱炭素への軟着陸に失敗した場合、中東全体が不安定化する恐れもあり、それを防ぐためにも、日本を含む先進国がこの地域と協力していくことは重要であろう。

執筆者紹介

保坂　修司（ほさか しゅうじ）
専門はペルシャ湾岸地域現代史、中東メディア論。中東研究センターでは、中東全体を見渡すほか、個人的に湾岸地域を中心とする現代アラブ諸国の政治・経済をフォローしながら、ジハード主義の思想や運動、中東メディア論、ゲームやマンガ等のポップカルチャーなど、日本ではあまり注意を向けられなかった分野も研究対象とする。執筆論文、著書、講演多数。趣味は日本全国油田・ミイラめぐり。2020年6月より現職。2021年4月、日本中東学会会長に就任した。

エネルギー経済 IEEJ Energy Journal
Special Issue　October 2021

Editor : Yoshihiko Omori

Publisher : The Institute of Energy Economics, Japan
Inui Bldg., Kachidoki, 13-1,
Kachidoki 1-chome, Chuo-ku, Tokyo
104-0054, Japan
Tel:+81-3-5547-0211 (General Planning Group)
e-mail: report@tky.ieej.or.jp

Please contact the editor for inquiry
(Tel:+81-3-5547-0214) or (e-mail:yoshihiko.omori@tky.ieej.or.jp).

sunrise ohya co.

The Institute of Energy Economics, Japan