Opportunities in the U.S. and Japan to Decarbonize Energy Supplies by 2050: Roles for Renewable and Nuclear Energy

Peter B. Lyons*

In 2020, the world witnessed many climate-related disasters. An alphabetical list of names is prepared each year in the U.S. to label major storms. In 2020, the large number of storms used the entire list, and more names were added from the Greek alphabet. In California, more than 4 million acres have burned in wildfires. Colorado experienced the three largest wildfires in its history.[1] Cyclone Amphan killed many people in India and Bangladesh; its storm surge exceeded 16 feet and extended almost ten miles inland.[2] Super Typhoons Haishen and Maysak hit both Japan and Korea with major blows within a single week.[3] In 2019, the second greatest cost ($20 Billion) of extreme weather was in Japan from Typhoons Faxai and Hgibis, along with serious loss of lives.[4] The Northern Hemisphere had its hottest summer on record in 2020[5] and the atmospheric concentration of carbon dioxide established a new record of 417 ppm.[6] Thus, the world moved closer to the 430-ppm level determined by the United Nations' Intergovernmental Panel on Climate Change (IPCC) as a danger point for exceeding 1.5^{o}C in global temperature increase.

A 2019 study of 26 countries found that climate change is perceived as the greatest threat. That study reported that 75% of Japanese citizens expressed concern on climate change.[7] In 2020, in the United States, 81% believe the earth has been warming for the last 100 years and 82% of people with that belief point to human activity as the cause. However, despite the many indications above, 19% of Americans deny that global warming is happening.[8] In addition, 97% of U.S. climate scientists conclude that human-caused climate change is occurring.[9]

These divergent views trace to the politicization of the climate change issue in the U.S., the world's #2 carbon emitter, rather than respecting the consensus scientific view. The Trump Administration, elected in 2016, rejected anthropogenic climate change, strongly favored fossil fuels as the backbone of U.S. energy independence and argued that efforts to sharply reduce emissions would have devastating economic consequences. In contrast, in the November 3, 2020 U.S. election, a new Administration was elected on a platform that U.S. response to climate change is essential and that economic consequences will be positive with a net creation of jobs in clean industries. On November 4th, the Trump Administration's prior decision to withdraw from the Paris Climate Agreement became official.[10] President-elect Biden has called for 100% clean electricity by 2035 and carbon neutrality by 2050.[11] His vision includes all sources of clean energy, from renewables to nuclear. He has stated that the U.S. will rejoin the Paris Accord early in his term.[12] Despite the Trump

* Former Assistant Secretary for Nuclear Energy, Department of Energy, US

Administration's position against climate change, many U.S. states, cities, companies, and utilities have pledged to reach carbon neutrality by 2050.

A major step toward global carbon neutrality occurred when Prime Minister Suga on October 26, 2020, committed Japan, the world's #6 carbon emitter, to reach carbon neutrality by 2050. In his remarks, the PM suggested greater use of renewable energy and nuclear power.[13] Japan's Fifth Strategic Energy Plan suggests 20-22% of energy from nuclear power by 2030.[14] Japan announced on October 13 the start of deliberations for its Sixth Plan that should incorporate PM Suga's vision.[15]

Other countries have also stepped forward to achieve carbon neutrality. The European Commission, #3 in carbon emissions, has called for a climate-neutral Europe by 2050.[16] In September 2020, President Xi Jinping of China told the United Nations that China, #1 in carbon emissions, would strive to be carbon-neutral by 2060.[17] On October 28, President Moon Jae-in of South Korea, #9 in carbon emissions, announced carbon-neutrality by 2050.[18]

The importance of limiting climate-induced temperature rise to 1.5ºC is discussed in many publications including those of the IPCC[19], which also discuss the dire consequences if future temperatures exceed that level.[20] In addition, global warming is not uniformly distributed across the globe; already about 10% of the planet has warmed by 2ºC.[21]

The recent actions in Japan, China, EU, and South Korea as well as the U.S. plans for a new focus on climate change provide grounds for optimism, but all nations will have significant difficulties fulfilling their plans. For example, 80% of U.S. energy in 2019 came from fossil fuels[22] and, for the year ending in March 2019, Japan derived 77% of its energy from fossil fuels.[23]

With significant global interest in zero carbon emissions by 2050, many studies have explored paths to reach that goal. These studies, such as major ones by the International Energy Agency (IEA), typically depend, along with improved efficiency, on substantial electrification of all sectors including transportation, clean electricity generation, and/or use of hydrogen as a clean energy source. Renewable energy sources must increase substantially along with requirements for additional zero-carbon baseload generation, such as nuclear. Use of fossil fuels without Carbon Capture, Utilization and Storage (CCUS) drops substantially.[24] Even in a case that achieves zero emissions by 2070, 601 GW of nuclear are necessary according to the IEA, versus current capacity around 450 GW.[25] In another study, the IEA Executive Director noted that, "Without action to provide more support for nuclear power, global efforts to transition to a cleaner energy system will become drastically harder and more costly." That same study found several vital actions that are needed, such as: extend lifetimes of nuclear plants wherever it is safely possible, value the dispatchability of nuclear power, and value its environmental and energy benefits.[26] These recommendations should be followed in the U.S. and Japan!. Studies at MIT confirm that costs of decarbonizing electricity are far higher when only renewables are employed instead of inclusion of a baseload carbon-free source.[27] Another MIT study noted that using intermittent renewables for 80% of electricity might be possible, but moving to 100% would be prohibitively expensive.[28]

Neither Japan nor the U.S. is following the IEA suggestions. In the U.S., 95 reactors are now in operation but about ten have closed due to poor economics. The average age of U.S. plants is 39 years.[24] And while most U.S. reactors are now approved for 60 years of operation, leading to many expected closures in the 2030's and 2040s, only four plants to date have received approval for 80 years with another four under review. In Japan, the situation is even more dire. Only 9 plants have been approved for restart after Fukushima, and only the Genkai plant was operating in November 2020.[29] Japan also has significant reliance on coal power. In 2019, Japan had built 12 new coal plants since 2012, with 15 under construction and 10 in the planning stage.[30] Very few nuclear plants are under construction in either country and both nations will need many new nuclear plants to meet their climate goals.

New plants could use the Generation III or III+ GW-class of plant that is used in both countries or could move to alternate designs. In the U.S. there is significant interest in GenIII+ light-water-cooled small modular reactors (SMR). The NuScale GenIII+ SMR, recently certified by the NRC, offers many improvements including: rapid construction using largely factory-built assemblies, greatly improved safety with no operator actions required in any upset, no need for off-site electricity, a very small (or site boundary) emergency planning zone, and the potential for air-cooling to avoid the need for proximity to a river or ocean. Tentatively the first construction will supply the Utah Associated Municipal Power Systems. NuScale plants will consist of several modules (between 4 and 12 delivering between 307 and 924 MW_e), and their recent price estimate is $2850/kW.[31] It could be an attractive construction choice for Japan.

Gen IV plants, using alternative coolants, are under development in both nations for future deployment and offer attributes like very high levels of safety requiring no or minimal operator actions in any upset, waste re-use and disposal, and high output temperatures. Japan's High Temperature Engineering Test Reactor (HTTR) achieved criticality in 1998. It has demonstrated outlet temperature of 950ºC.[32] In the U.S. several GenIV designs are under development with gas, liquid metal, or molten salt coolants. Many private companies are involved in these development projects and the DOE has invested in a wide range of research projects. As part of the Advanced Reactor Demonstration Project, the DOE recently awarded $160 Million to two companies for demonstration of their concept, one for a sodium-cooled fast reactor with thermal energy storage and one for a high temperature gas-cooled design.[33] Several micro-reactor designs with powers below 20 MW_e are also development in the U.S.

To achieve complete decarbonization, clean energy must produce far more than electricity. The IEA has explored options for the chemical, steel, and cement industries and noted that CCUS and hydrogen are potential zero-carbon applicable technologies.[34] Of course, hydrogen is not a solution unless produced with zero emissions! Nuclear power presents another strong option for cleanly addressing these industries and studies in both countries are exploring these options using either GenIII+ or IV reactors. In Japan, both hydrogen production and steel production are under study. Japan has used their HTTR, coupled to a thermo-chemical water splitting process to demonstrate hydrogen production.[32] In the U.S. substantial research exploring coupling of nuclear and renewable energy is under way at the Idaho National Laboratory (INL), the National Renewable Energy Laboratory (NREL), and MIT. Approaches that directly generate heat, rather than electricity, are more efficient since the heat demand across all sectors far exceeds electricity use, 83% to 17%. Gen IV reactors are one source of high temperature heat.[35] Additional study has focused on the use of LWRs for these missions.[36,37] In contrast to the work in Japan using thermo-chemical processes for hydrogen production, INL has focused on high temperature steam electrolysis.[38] With the importance of utilizing hydrogen produced with nuclear energy, several demonstration projects in the U.S. are funded.[39]

The existential imperative to move to carbon-free energy should be evident. The technologies to accomplish this for electricity, intermittent renewables with some fraction of clean baseload power, are available now. Fission can provide that clean baseload power today and other technologies (hydro, geothermal and possibly concentrated solar power (CSP)) may also contribute. But of those clean baseload options available today, only nuclear can be readily expanded with favorable economics. In the future, other clean baseload technologies may become available like CCUS to enable clean use of fossil fuels, long duration storage systems, and fusion power; research programs in these areas now may prove to be vital in the future.

Extensions of renewables and nuclear into sectors beyond electricity are in the demonstration phase in several countries for clean production of hydrogen. Several studies are exploring direct utilization of clean high temperature reactor heat for industrial processes. Electrification of transportation is expanding. The optimum mix of renewables and nuclear energy will vary by location, and no one prescription will be ideal everywhere. Several regions have already developed blueprints to achieve zero-carbon goals.

Many nations have pledged carbon-free energy by dates around 2050. But the challenges to fulfill those pledges are immense. It remains to be seen if nations around the world are ready to make the commitments today that will provide that reality for future generations. Substantial construction of both renewables and nuclear energy will be needed to achieve future carbon-free societies. We can achieve this future vision, but it remains to be proven that we have the collective willpower around the globe to achieve success.

---

1 East Troublesome Fire Explodes During Wind-Fueled Nighttime Run, Colorado Public Radio, October 22, 2020.

2 The Undeniable Link Between Weather Disasters and Climate Change, Washington Post, Oct 22, 2020.

3 Super Typhoon Haishen to be One of the Most Intense Storms on Record for Japan and South Korea; Washington Post, September 4, 2020.

4 Climate Scorecard, Extreme Weather Events Affect Japan, February 12, 2020.

5 Northern Hemisphere Just Had its Hottest Summer on Record, National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, September 14, 2020.

6 Earth System Research Laboratories, Global Monitoring Laboratory.

[7] Climate Change Still Seen as the Top Global Threat...", Pew Research Center, February 10, 2019.
[8] Climate Insights 2020: Overall Trends, Resources for the Future, August 24, 2020.
[9] The Consensus Handbook, J. Cook, S. van der Linden, E. Maibach, and S., March 2018.
[10] U.S. is Officially out of Paris Climate Accord that Trump Quit 3 years Ago, New York Times, November 4, 2020.
[11] A Biden Victory Positions America for a 180-degree Turn on Climate Change, Washington Post, November 7, 2020.
[12] Biden-Harris Transition website, Restoring American Leadership, Climate Change: The Biden-Harris plan to create union jobs by tackling the climate crisis.
[13] Japan's New Climate Goals Lift Prospects for Crippled Nuclear Industry, Reuters Business News, October 29, 2020.
[14] Government's Strategic Policy Committee Starts Deliberations Toward Revision of Strategic Energy Plan, Atoms in Japan, Japan Atomic Industrial Forum, October 16, 2020.
[15] Deliberations Begin on Sixth Strategic Energy Plan, Japan Atomic Industrial Forum, October 16, 2020.
[16] The Commission Calls for a Climate Neutral Europe by 2050, EU press release, November 28, 2018.
[17] China's Net-Zero Ambitions: The Next Five-Year Plan will be Critical for an Accelerated Energy Transition, IEA, October 29, 2020.
[18] South Korea's Moon Targets Carbon Neutrality by 2050, Reuters, October 28,2020.
[19] IPCC, 2018: 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, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [M.-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)].
[20] IPCC, 2014: Summary for policymakers in: Climate Change 2014: Impacts, Adaptation, and Vulnerability-Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the IPCC on Climate Change [C. B. Field., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)].
[21] 2°C Beyond the Limit: This Giant Hot Spot Is Robbing the West of its Water, Washington Post, August 21, 2020; and 2°C Beyond the Limit: Extreme Climate Change Has Arrived in America, Washington Post, August 13, 2019.
[22] U.S. Energy Facts Explained, U.S. Energy Information Agency, May 20, 2020.
[23] Japan Launches Energy Policy Review Amid Global Push for Greener Power, Reuters, October 13, 2020.
[24] Achieving Net-Zero Emissions by 2050, World Energy Outlook, IEA, October 2020.
[25] World Energy Outlook 2020, Nuclear, IEA, October 2020.
[26] Nuclear Power in a Clean Energy System, IEA, May 2019.
[27] Adding Power Choices Reduces Cost and Risk of Carbon-free Electricity, MIT News, September 2018.
[28] Relying on Renewables Alone Significantly Inflates the Cost of Overhauling Energy, MIT Technology Review, February 2018.
[29] Japan Left with Only One Nuclear Reactor Working due to Shutdown, The Asahi Shimbun, Japan News, November 4, 2020.
[30] Japan Seeks Climate Leadership at G-20 Summit but Can't Kick its Coal Habit, Washington Post. June 26, 2019.
[31] NuScale Announces an Additional 25 Percent Increase in NuScale Power Module Output and Additional Power Plant Solutions, NuScale press release, November 10, 2020.
[32] K. Kunitomi, R&D Activities in JAEA for HTGR Developments, speech at the joint JAEA-DOE Symposium, October 21,2020.
[33] U.S. Department of Energy Announces $160 Million in First Awards under Advanced Reactor Demonstration Program, DOE Office of Nuclear Energy press release, October 13, 2020.
[34] The Challenges of Reaching Zero Emissions in Heavy Industry, IEA, September 19, 2020.
[35] Maximizing Clean Energy Use: Integrating Nuclear and Renewable Technologies to Support Variable Electricity, Heat, and Hydrogen Demands, C.W. Forsberg and S. M. Bragg-Sitton, The Bridge, National Academy of Engineering, Fall 2020.
[36] Study Finds LWR Electricity-Hydrogen Hybrids May Improve Profitability, R.D. Boardman, Newsletter of the Light Water Reactor Sustainability Program, October 2019, www.lwrs.inl.gov.
[37] Sustaining the Industrial Sector with Nuclear Energy, R.D. Boardman, Newsletter of the Light Water Reactor Sustainability Program, March 2020, www.lwrs.inl.gov.

[38] Evaluation of Hydrogen Production Feasibility for a Light Water Reactor in the Midwest, K. Frick, P. Talbot, D. Wendt, R. Boardman, C. Rabiti, S. Bragg-Sitton (INL); D. Levie, B. Frew, M. Ruth (NREL); A. Elgowainy, T. Hawkins (ANL); INL/EXT-19-55395 Revision 0, September 2019.

[39] US DOE Provides Funding for $26 Million in Nuclear Plant Hydrogen Projects, Electric Power, October 8, 2020.

Writer's Profile

Peter B. Lyons

Dr. Lyons led the Office of Nuclear Energy in the U.S. Department of Energy while serving as the primary policy advisor to the Secretary of Energy on issues involving U.S. and international civilian nuclear energy research, development and demonstration activities. He was a Commissioner of the Nuclear Regulatory Commission and served as Science Advisor on the staff of U.S. Senator Pete Domenici and the Senate Committee on Energy and Natural Resources, where he focused on military and civilian uses of nuclear technology. He now acts as a consultant to several corporate and laboratory boards, is a member of the Board of Directors of the American Nuclear Society (ANS) and received the 2020 Dwight D. Eisenhower Medal from the ANS and Dr. Susan Eisenhower.