Beyond Perception: Nuclear Energy's Role in the Global Green Transition

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In November 2021, the climate conference COP26 in Glasgow identified the urgent need for nations to reduce their carbon emissions more aggressively. The challenge is that demand for energy, and therefore fossil fuel power generation, remains high and is expected to grow worldwide. Given the move towards electrification, demand for electricity is expected to continue growing substantially, at a compounded rate of more than 2% per year over the next 30 years.[1] This means that the sources of energy provided by utility companies around the world will determine the rate of decarbonization in the next three decades (net zero by 2050). The International Energy Agency (IEA) expects that current and future technologies will enable grid "greenification" by 2050.[2]

One key question is whether nuclear energy can be part of the solution and whether it is a green source of energy. For example, there was a recent debate in Europe over the labelling of nuclear. France and Germany faced off over whether the EU taxonomy[3] (a system of definitions for economic activities the bloc considers environmentally sustainable) should include natural gas and nuclear as green/transition energy, with France being a vocal proponent of nuclear power. The point of contention - not just for these two nations but broadly - is how to replace constantly running and reliable fossil fuel baseload power generation with renewables that provide a more intermittent supply of energy, even with storage capacity. Baseload power is an important part of the electricity grid because it generates consistent and reliable power to meet a minimum level of demand in the grid. After much debate and despite continued pushback from several countries, in February 2022, the European Commission unveiled a Taxonomy Complementary Climate Delegated Act which included specific nuclear and natural gas activities in the EU taxonomy as "transitional" activities.[4] Some may not consider nuclear energy to be technically green as it generates highly concentrated but radioactive waste. However, it does generate extremely low greenhouse gas (GHG) emissions (none in production and low in life cycle). Therefore, we argue that nuclear should be a significant part of the solution in the quest to achieve net zero emissions by 2050 and there should be more investment in nuclear power generation.

[1] https://eneroutlook.enerdata.net/forecast-world-electricity-consumption.html
[2] https://www.iea.org/reports/net-zero-by-2050
[3] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en
[4] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_711
* Effective April 1, 2022

Environmental, Social and Governance investors can bring significant benefits by investing in nuclear power with a strong focus on and advocacy for long-term health and safety as well as social justice protocols. Nuclear can offer a viable alternative in decarbonization given that it has one of the lowest GHG emissions profiles, has made significant technological advances in scalability and safety, and is a reliable source of baseload generation.

Energy Security

The IEA defines energy security as "the uninterrupted availability of energy sources at an affordable price."[5] As renewable energy sources grow their share of total power generation, their intermittency shortcomings are becoming more noticeable. Renewables' biggest marginal cost advantage – the lack of costly feedstock – becomes their challenge as production cannot be controlled and 100% relied upon. Current storage technology does allow for short-term intraday charge/discharge cycles but cannot mitigate volatile seasonal weather patterns. Green baseload power such as nuclear can enhance grid stability and reduce reliance on fossil fuel, especially for regions where widespread usage of hydroelectric power is not possible. As the IEA's Executive Director Fatih Birol said in 2019, "Alongside renewables, energy efficiency and other innovative technologies, nuclear can make a significant contribution to achieving sustainable energy goals and enhancing energy security."[6]

Energy security is important to developed economies, and arguably even more so to emerging economies. According to the World Bank, 759 million people globally (around 10% of the world population) had no access to electricity in 2019.[7] In the quest to achieve net zero emissions while tackling inequality, it is imperative to consider the needs of emerging economies. Fossil fuels historically have supported the world's economic growth owing to their high energy density. As a concentrated power source with a negligible emission profile, nuclear energy's ability to address climate change while enabling a stable large power grid to support economic growth should not be underestimated. Rapidly growing economies such as China and India have announced massive nuclear programs in their green transition plans.

Low Lifecycle Emissions Profile

In the 2014 Energy Systems report by the Intergovernmental Panel on Climate Change (IPCC), a UN body that provides assessments on climate change, chapter 7 outlines various sources of energy, and the pros and cons of each in their potential to mitigate emissions. One key aspect of an emissions profile is life cycle analysis, which evaluates the emissions in the value chains of energy systems. The analysis starts from the extraction of minerals all the way to combustion or use of energy sources and then ultimately to the provision of electricity to end users.

As per the IPCC report, "Nuclear energy is a mature low-GHG emission source of baseload power, but its share of global electricity generation has been declining (since 1993). Nuclear energy could make an increasing contribution to low-carbon energy supply, but a variety of barriers and risks exist (robust evidence, high agreement). Its specific emissions are below 100 gCO2eq per kWh on a lifecycle basis [TDAM note: CO2eq stands for carbon dioxide equivalent[8] and 100 gCO2eq per kWh is the threshold widely considered to be environmentally sustainable] and with more than 400 operational nuclear reactors worldwide, nuclear electricity represented 11% of the world's electricity generation in 2012, down from a high of 17% in 1993. Pricing the externalities of GHG emissions (carbon pricing) could improve the competitiveness of nuclear power plants."[9]

[5] https://www.iea.org/topics/energy-security

[6] https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system

[7] https://www.worldbank.org/en/news/press-release/2021/06/07/report-universal-access-to-sustainable-energy-will-remain-elusive-without-addressing-inequalities

[8] Carbon dioxide equivalent (CO2eq) measures the number of metric tons of CO2 emissions with the same global warming potential as one metric ton of another greenhouse gas.

[9] Bruckner T., I.A. Bashmakov, Y. Mulugetta, H. Chum, A. de la Vega Navarro, J. Edmonds, A. Faaij, B. Fungtammasan, A. Garg, E. Hertwich, D. Honnery, D. Infield, M. Kainuma, S. Khennas, S. Kim, H.B. Nimir, K. Riahi, N. Strachan, R. Wiser, and X. Zhang, 2014: Energy Systems. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf

In addition to the above report, in 2021 the United Nations Economic Commission for Europe published its report on Lifecycle Assessment of Electricity Generation Options which essentially had the same conclusion.[10] Nuclear power was identified as one of the lowest and least variable GHG-producing power sources across the globe. Lifecycle GHG emissions were studied to avoid "impact leakage" (i.e., to avoid increasing non-climate environmental pressure while reducing GHG emissions).

Based on the analysis - which assessed power sources across 12 regions in the US, Canada, Europe, Middle East, Africa and Asia - nuclear had the lowest emissions profiles compared to other electricity sources, including renewable power.

The report showed that in terms of lifecycle emissions per unit of energy produced:

- Nuclear power emits 5.1 to 6.4 g of carbon dioxide equivalent (gCO2eq) per kWh
- Hydroelectric power emits 6.1 to 11 gCO2eq per kWh
- Solar power emits 7.4 to 83 gCO2eq per kWh depending on the specific technology used
- Concentrated solar power emits 14 to 122 gCO2eq per kWh depending on the technology
- Onshore wind power emits 7.8 to 16 gCO2eq per kWh, while offshore wind power emits 12 to 23 gCO2eq per kWh
- Natural gas with carbon capture and storage technologies (CCS) emits 92 to 221 gCO2eq per kWh, while hard coal with CCS emits 149 to 470 gCO2eq per kWh
- Natural gas without CCS emits 403 to 513 gCO2eq per kWh, while hard coal without CCS emits 753 to 1,095 gCO2eq per kWh

Evolving Nuclear Technologies

Nuclear technologies have continued to evolve in the last decade. One of the most exciting innovations is the development of Small Modular Reactors (SMRs). SMRs hold promises that traditional nuclear reactors have failed to deliver, and they have the potential to produce safe clean baseload power at affordable prices to achieve a greener grid.

SMRs generally refer to reactors with power capacity of 5 MW to 300 MW, less than one-third the capacity of traditional nuclear reactors.

Advantages of SMRs include:

- Smaller size and footprint, leading to lower initial capital expenditures
- Modular components, making it possible for parts and systems to be factory-built, transported and assembled on site, thus reducing the likelihood of construction delays and cost overruns
- Passive safety features that eliminate the need for human intervention or external power to shut down and prevent core meltdowns if an extreme event occurs, similar to other advanced nuclear power plants
- Being a source of baseload power that can be deployed in remote communities away from large power grids, where the current standard fuel is diesel
- Ability of some designs to use spent fuel from traditional nuclear reactors, reducing waste

As SMRs are smaller in generation capacity, one of the keys to their future success is the ability to reach economies of scale by attracting enough demand for them from governments and utilities. Many countries have demonstrated growing support for SMRs, including the US, Canada, UK, France, China and Russia. Globally, there are about 50 SMR designs in various stages of research, development and commercialization.[11] In the US, one SMR design has already gained regulatory design approval and is being developed to reach commercial operation by the end of the decade.[12] In the UK, a private consortium has started the regulatory review process for its own design, targeting a demo unit in the early 2030s.[13]

[10] https://unece.org/sites/default/files/2021-10/LCA-2.pdf
[11] https://www.iaea.org/topics/small-modular-reactors
[12] https://www.nuscalepower.com/technology/licensing
[13] https://www.rolls-royce.com/media/our-stories/innovation/2017/smr.aspx#application and https://www.world-nuclear-news.org/Articles/Rolls-Royce-submits-SMR-design-for-UK-assessment

While SMRs have certainly taken the spotlight due to their commercialization timeline and affordability, existing nuclear technologies are improving on many different fronts. Many can be deployed as an SMR set-up to ease the path to commercialization. For example, Molten Salt Reactors are designed to use less fuel, produce shorter-lived radioactive waste, and reduce lengthy fuel loading cycles to improve operational economics. Fast Neutron Reactors can use uranium fuel much more efficiently while offering the prospect of burning long-lived components of traditional spent fuel, further reducing radiotoxicity of waste.

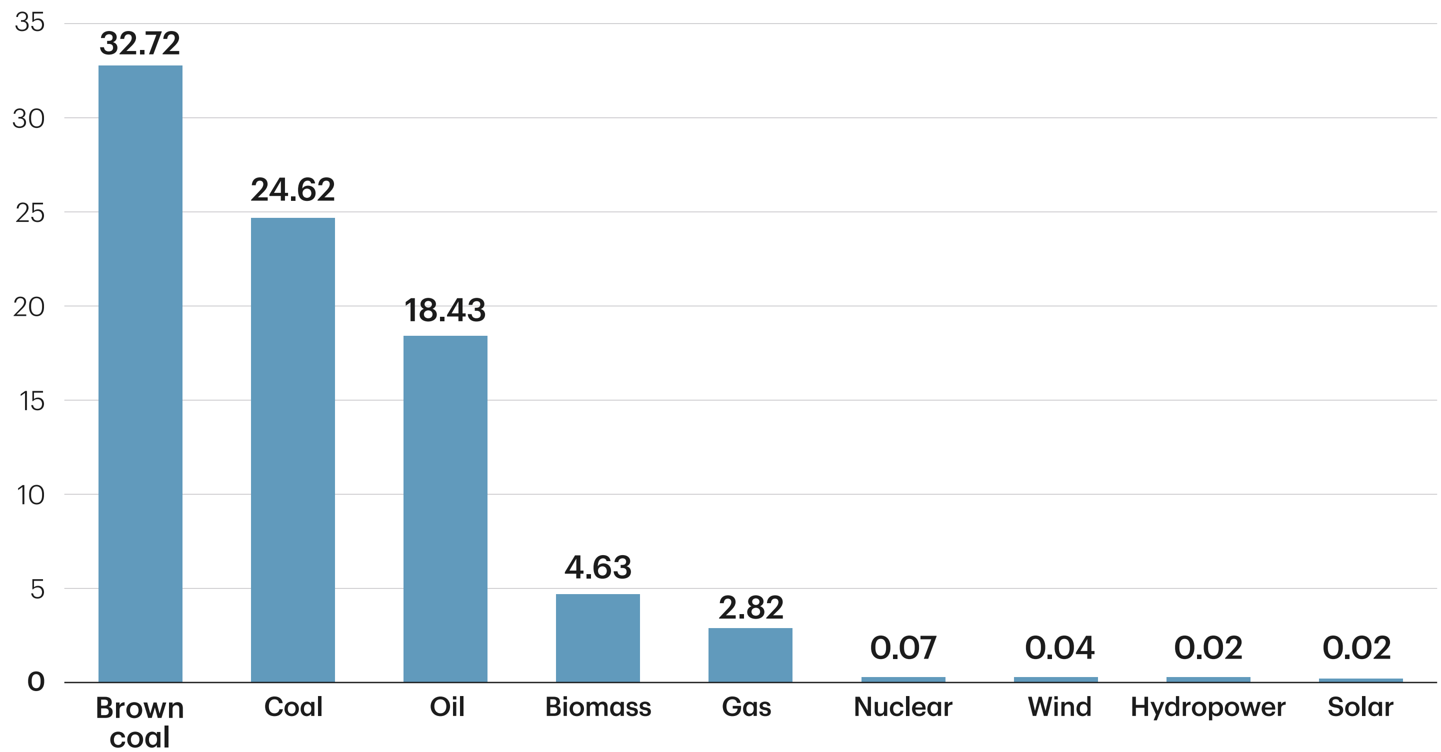
Health and Safety

Approximately 440 nuclear reactors operate globally today, generating 10% of worldwide electricity supply that is clean.[14] According to the World Nuclear Association, across the world, nuclear reactors have helped save more than 72 billion tons of carbon dioxide over the last 50 years compared to coal-fired electric generation.[15] A study in 2013 by scientists from NASA concluded that by replacing fossil fuel generation, the global nuclear fleet saved more than 1.8 million lives through reduction in air pollution between 1971 and 2009.[16]

Nuclear power continues to be safe and has one of the lowest direct deaths per unit of energy produced (Figure 1). While rare serious accidents have occurred in the past, lessons were learned, and safety parameters were strengthened further.

Figure 1: Death Rates from Energy Production per TWh (Accidents and Air Pollution)

Death rates are measured based on deaths from accidents and air pollution per terawatt-hour (TWh)



Source: Sovacool et al. (2016) and Markandya, A., & Wilkinson, P. (2007).[17]

[14] https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

[15] https://www.world-nuclear.org/press/press-statements/nuclear%E2%80%99s-contribution-to-global-climate-change-mi.aspx

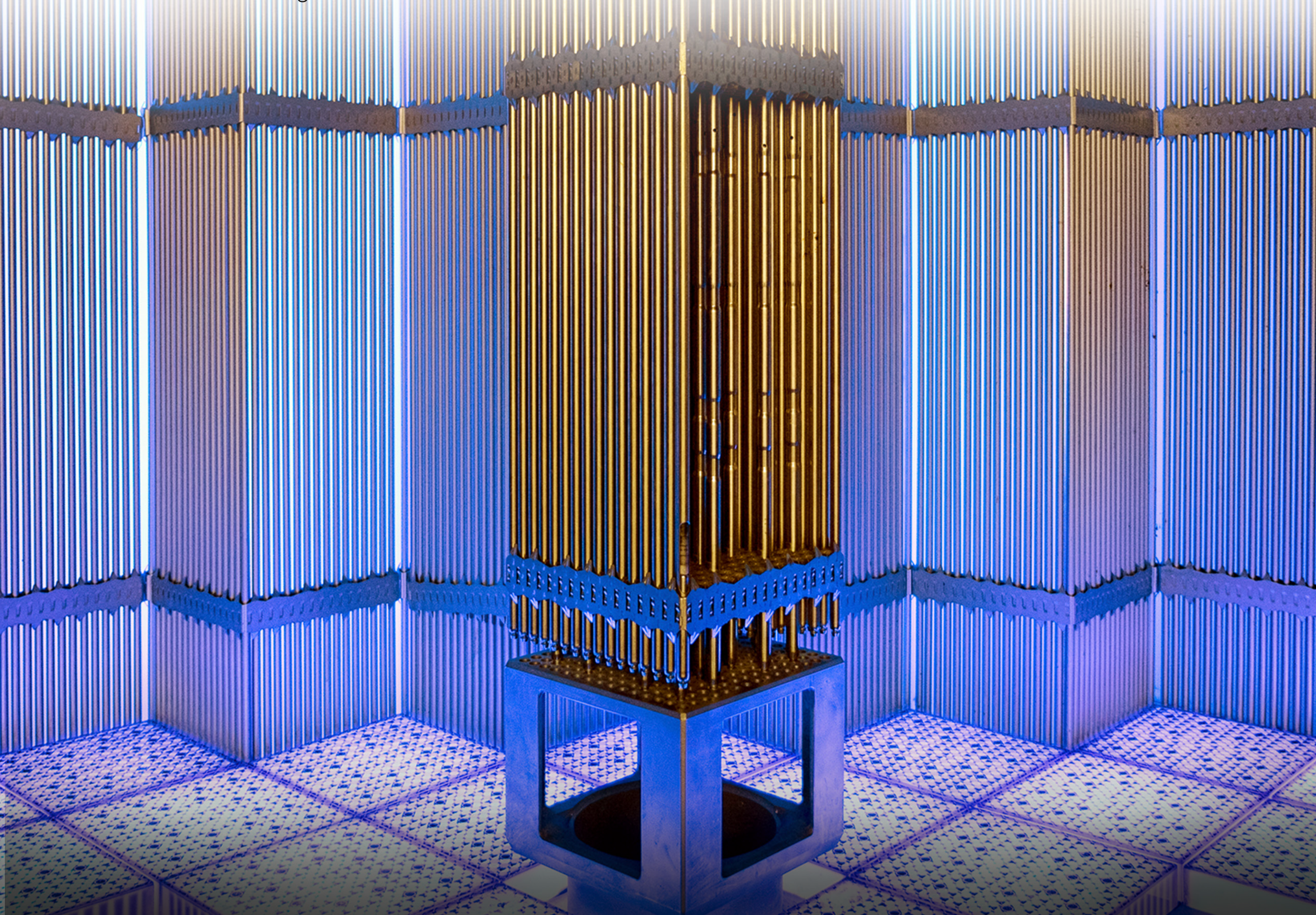
[16] Kharecha, P.A., and J.E. Hansen, 2013: Prevented mortality and greenhouse gas emissions from historical and projected nuclear power. Environ. Sci. Technol., 47, 4889-4895, doi: 10.1021/es3051197. https://pubs.giss.nasa.gov/abs/kh05000e.html

[17] https://ourworldindata.org/nuclear-energy

Stigmatization and the amplified perception of radiation risk beyond scientific facts may have caused more harm than nuclear power itself. In the decade following the 2011 Fukushima Daiichi nuclear plant accident, evidence has emerged about the health effects of leaked radiation. The United Nations Scientific Committee on Effects of Atomic Radiation concluded in 2013, and reaffirmed in 2015, that “no radiation-related deaths or acute diseases have been observed among the workers and general public exposed to radiation from the accident” and that “no discernible increased incidence of radiation-related health effects is expected among exposed members of the public or their descendants.”[18]

Despite the UN’s findings, in 2018 the Japanese government did recognize one cancer death that can be attributed to radiation exposure. By contrast, the rushed evacuation of 160,000 people from Fukushima and the resulting psychosocial impact have led to many more casualties over the long term. Some were due to the immediate toll of the evacuation, which left the elderly and the hospitalized particularly vulnerable, while other casualties were due to long-term psychological stress, which led to an increase in depression, post-traumatic stress disorder, substance abuse and suicides.[19] In 2017, a research paper studied the long-term evacuation and concluded that “no relocation was justified on scientific and economic grounds after the accident at Fukushima Daiichi.”[20]

Moreover, today’s nuclear operations are even safer. After Fukushima, governments, regulators and nuclear operators around the world have carried out stress tests to strengthen safety systems. Existing units have been upgraded to withstand extreme events. Passive shutdown systems that were already incorporated into the design of Generation III reactors - which have been around for decades - have continued to be a critical part of new builds.



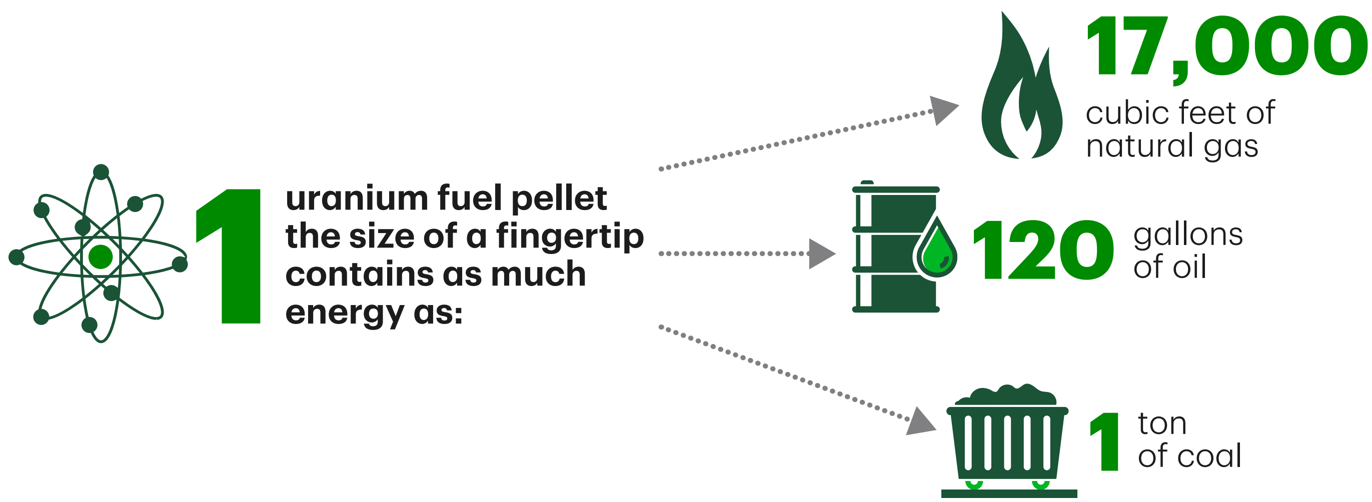
[18,19] https://world-nuclear.org/focus/fukushima-daiichi-accident/fukushima-daiichi-accident-faq.aspx

[20] I. Waddington, P.J. Thomas, R.H. Taylor, G.J. Vaughan. J-value assessment of relocation measures following the nuclear power plant accidents at Chernobyl and Fukushima Daiichi. Process Safety and Environmental Protection. Volume 112, Part A, November 2017, Pages 16-49 https://www.sciencedirect.com/science/article/pii/S0957582017300782

Waste Management and Recycling

Nuclear energy is very dense – 1 uranium fuel pellet the size of a fingertip contains the same amount of energy as 1 ton of coal, 120 gallons of oil, and 17,000 cubic feet of natural gas (Figure 2).[21] The waste it produces is also small in physical footprint and can be stored safely. According to the US Department of Energy, waste produced after 60 years of US nuclear operation can fit on a single football field 10 feet deep.[22] Most nuclear waste is stored on site with no threat of radiation to people, and solutions have been proposed for long-term deep geological repositories that require no further maintenance by future generations. While the main components of nuclear waste may remain mildly radioactive for a very long time, its radioactivity would have declined to a safe level that does not cause health problems within a few hundred years.[23]

Figure 2: Energy Density of Nuclear Fuel



Source: US Department of Energy.[24]

Mitigation efforts can also be taken to reduce waste. Today, about a third of global used nuclear fuel is reprocessed[25], and countries such as China, France, Russia and Japan all have formal policies on reprocessing. Reprocessing can reduce waste volume by approximately 80%, cut the radiotoxicity of the final waste, and recover valuable materials for use in medicine and other industries.[26] The final high-level waste can then be engineered into a stable material such as glass for final storage and disposal.

As part of nuclear reprocessing, spent fuel can also be recycled by extracting plutonium as a component of waste and blending it with depleted uranium to form mixed oxide (MOX) fuel, which can be reused in traditional reactors to obtain more energy from the original uranium. Today, MOX fuel provides 5% of the new nuclear fuel used.[27] As natural uranium prices increase, economic incentives to use reprocessed fuel will be greater. Further innovations are also underway to provide even more efficiency in fuel recycling and usage.

Innovation

[21,22,24] https://www.energy.gov/sites/default/files/2019/01/f58/Ultimate%20Fast%20Facts%20Guide-ebook_1.pdf
[23] https://world-nuclear.org/nuclear-essentials/what-is-nuclear-waste-and-what-do-we-do-with-it.aspx
[25,26] https://world-nuclear.org/our-association/publications/technical-positions/how-is-used-nuclear-fuel-managed.aspx
[27] https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/mixed-oxide-fuel-mox.aspx

Construction Costs

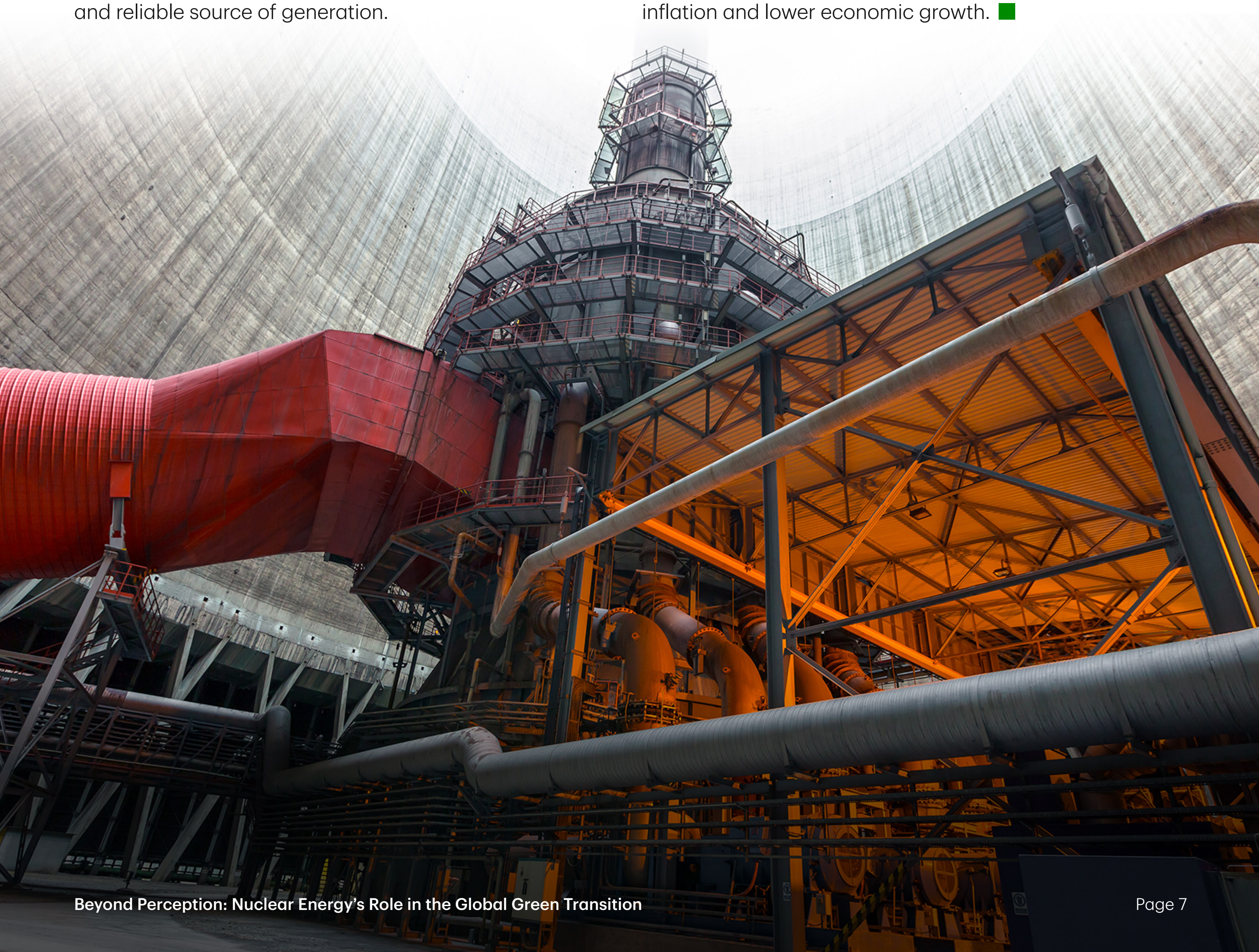
Traditional nuclear power plants are expensive to build because they are technically complex and must satisfy strict design and safety criteria. Large initial capital investments and moderate operating costs make the cost of producing nuclear energy high compared to other sources of power. Nuclear is certainly not the cheapest source of power. However, it benefits the electrical grid by providing green baseload power that complements other power sources, such as renewables, and it contributes to a stable and clean grid. As new SMR technologies gain traction, they have the potential to reduce construction costs and delays via standard factory-built components and to lower upfront investments.

Perhaps one of the biggest costs and hurdles in terms of construction time is the enormous regulatory burden to build new nuclear powerplants. This makes private investment difficult. Governments need to do their part regarding public policy to streamline the timeframe while ensuring safe operations.

In Summary

It's time to destigmatize nuclear energy and expand the definition of green investing. We cannot afford to keep overlooking nuclear power as an important energy source, given the scale of the problem we face in mitigating climate change while ensuring energy security. Nuclear energy should be on the table as a green, safe and reliable source of generation.

Energy is the engine of economic growth, and without increased investments in nuclear (and the associated infrastructure), we are likely to see higher energy prices, higher carbon prices and significant challenges for countries to meet their climate goals. That would lead to headwinds for global economies in terms of higher inflation and lower economic growth.



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