NICE Future
Nuclear Innovation: Clean Energy Future

Towards a Clean and Just Energy Transition

October 2023

TerraPraxis produced this report for the Researching Impacts in Social Equity & Economic Empowerment (RISE³) — A Clean Community Transformation Campaign 2022, organized under the Clean Energy Ministerial (CEM) Nuclear Innovation: Clean Energy Future (NICE Future) initiative.

To accelerate the repurposing of unabated coal plants with new advanced nuclear technologies, and to bring about breakthrough nuclear innovations, the CEM NICE Future initiative launched an Expert Group to Researching Impacts on Social Equity and Economic Empowerment (RISE³). This campaign has enabled the discussion about how nuclear innovations can lift economies and raise the quality of life for communities and nations.

This report highlights environmental justice issues and key communication points in the transition towards a clean energy future, with a focus on the role of nuclear energy and emissions-free heat sources (such as fission) in the transition from coal. This report reflects existing research and RISE³ activities (webinars and workshops) to date.

Net Zero by 2050 Requires Climate Justice

On December 12, 2015, world leaders at the UN Climate Change Conference (COP21) signed the Paris Agreement which includes commitments from all countries to reduce their emissions, work together to adapt to the impacts of climate change, and strengthen their commitments over time.[1] The Paris Agreement is a legally-binding treaty, which went into effect on November 4, 2016, and today includes 193 States plus the European Union. It states that global temperatures should not increase more than 2°C above pre-industrial levels in this century and that efforts should be made worldwide to limit this increase to 1.5°C by 2050, to prevent permanent warming of the planet and catastrophic consequences. To limit warming to 1.5°C, global emissions from all sources need to be reduced by 45% by 2030 relative to 2010 and reach Net Zero by 2050.[2]

Surpassing 1.5°C global temperature rise means accepting severe climate impacts which may include 10 million more people being displaced by sea level rise; 65 million more people exposed to exceptional heatwaves; a doubling of biodiversity related impacts such as species loss; the elimination of Arctic Ocean sea ice; and the loss of virtually all coral reefs. Missing the 2°C target would expose half the world's population to summertime 'deadly heat', Greenland and the West Antarctic ice sheets would collapse, droughts would increase by 500%, and the Sahara Desert would begin to expand into southern Europe. Furthermore, world food supplies would be imperiled, driving major refugee flows and a growing risk of civilizational collapse.[3]

Because annual emissions accumulate in the atmosphere, it also matters how much CO_2 is emitted on the way to 2050. Intermediate targets are useful because they show us if we are making sufficient progress; however, the data indicates that we are not. The earth is already 1.1°C warmer than it was before fossil fuel combustion took off in the 19th century. At the current rate of warming, achieving the 2030 target is no longer a realistic possibility. Instead of decreasing, annual emissions have increased from 2010.

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[1] *Paris Agreement (accessed July 2022) — https://unfccc.int/process-and-meetings/the-paris-agreement*

[2] *UN Climate Change, Net Zero Coalition (accessed September 2022) — https://www.un.org/en/climatechange/net-zero-coalition*

[3] *Missing Link to a Livable Climate (2020) — https://www.lucidcatalyst.com/hydrogen-report*

Current climate commitments are insufficient. Thus far, no country is even on track to meet their commitments. In February 2022, a new report[4] published by the Intergovernmental Panel on Climate Change (IPCC) found that deep divisions between rich and poor nations and within societies will determine people's ability to withstand the worst effects of climate change — with huge implications for global politics. The divisions will worsen if countries fail to rein in greenhouse gas emissions, but there are already steep challenges. The IPCC report underscores that the countries facing the worst climate impacts are those which contributed the least to global warming — and have the fewest resources to adapt. Speaking about the report findings, Antònio Guterres, U.N. Secretary-General said: "I have seen many scientific reports in my time, but nothing like this..." He called the findings "an atlas of human suffering and a damning indictment of failed climate leadership."

"Climate justice is really the key dimension of the new report. The idea that clearly the most vulnerable people—just about half of humankind—are living in regions that are really highly exposed to climate impacts."

— François Gemenne, Lead Author and Director of Belgium's Hugo Observatory

The Imperative for a Profound Transformation

Climate change is, by and large, an energy problem. The energy sector (electricity, industry, and transportation) presently accounts for nearly three quarters of global emissions. The world needs to reduce annual emissions to Net Zero in less than three decades. This means we must replace all of the emitting sources of energy we use with clean, non-emitting energy sources by 2050 while also introducing CO_2 removal technologies such as direct air capture (DAC), which extracts carbon dioxide directly from the atmosphere.[5]

However, the imperative for a profound transformation requires not just a shift away from polluting energy sources towards sustainable alternatives, but also expanded access to clean energy to all of humanity and in support of socioeconomic development, especially in emerging economies. All this must happen while simultaneously limiting the impacts of climate change, pollution, and other unfolding global environmental crises.

The sequencing and time-sensitivity to achieve Net Zero involves a massive, simultaneous infrastructure build-out in every country. This unprecedented logistical challenge is not only to build enough clean electricity generation to power the world, but to do so quickly while building the infrastructure required to decarbonize end-use sectors such as heat, industry, and transport.

In addition to decarbonizing heating for residential, commercial, and industrial purposes, there is a requirement to produce hydrogen and synthetic fuels to support a transition in transport and address the difficult-to-decarbonize sectors of aviation and shipping. Furthermore, desalinating seawater in regions suffering from water scarcity and ensuring access to modern energy services in remote and developing communities are all essential components of a just energy transition.

Rapid reductions in emissions cannot come at the cost of the future prosperity of developing nations. Access to modern energy is directly related to development, quality of life, opportunity for education, increased life expectancy, and reduced maternal and child mortality rates. Higher levels of development will also make people less vulnerable to the negative effects of climate change.

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[4] *Climate Change 2022: Impacts, Adaptation and Vulnerability — https://report.ipcc.ch/ar6/wg2/IPCC_AR6_WGII_FullReport.pdf*

[5] *International Energy Agency on Direct Air Capture (April 2022) — https://www.iea.org/reports/direct-air-capture*

We are faced with an "energy trilemma" — energy not only needs to become clean, but also affordable and reliable. These three elements are critical to averting global catastrophe and meeting fundamental needs like healthcare, welfare, education, and security, while enabling every country to share in global prosperity. The United Nations Sustainable Development Goals call for rapidly and cohesively addressing all these societal needs.[6] Today, most of the world's population lives in poor countries in which more than 90% of people live on less than $30 per day (adjusted for purchasing power parity). An analysis by Our World in Data suggests that the global economy would need to increase fivefold to substantially reduce poverty.[7]

Africa currently contributes about 3% to global emissions but is one of the regions worst hit by climate change. If Africa were to use all its known reserves of natural gas, the cleanest transitional fossil fuel, its share of global emissions would rise from a mere 3% to 3.5%.[8]

"Don't tell Africa that the world cannot afford the climate cost of its hydrocarbons and then fire up coal stations whenever Europe feels an energy pinch."

— Mr. Buhari, President of Nigeria

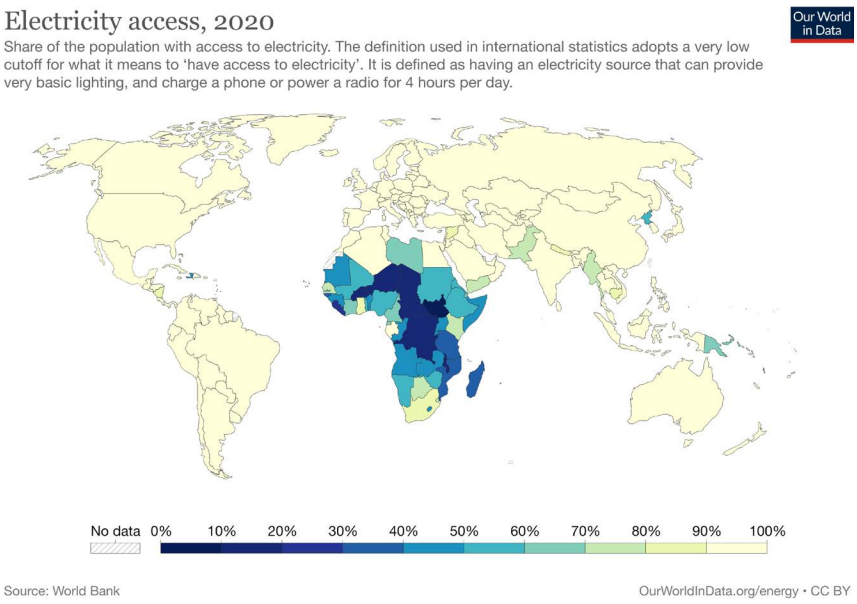

Figure 1. Access to electricity in 2020[12]

Global access to electricity has increased since 2010, but wide regional disparities remain (Figure 1). Variations in regional and national per capita emissions partly reflect different development stages, but they also vary widely at similar income levels. The 10% of households with the highest per capita emissions contribute a disproportionately large share of global household greenhouse gas emissions.[9] The 20 countries with the largest access deficits were home to 76% of the entire global population (mostly in sub-Saharan Africa) living without access to electricity in 2020 (Figure 1). Closing the access gap by 2030 hinges on electrification efforts in these countries.[10] Enhanced mitigation and broader action to shift development pathways towards sustainability is expected to have positive distributional consequences within and between countries.[11]

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[6] *United Nations' Sustainable Development Goals (accessed July 2022) — https://sdgs.un.org/goals*

[7] *Max Roser, "How much economic growth is necessary to reduce global poverty substantially?" Our World in Data, 2021. — https://ourworldindata.org/poverty-minimum-growth-needed*

[8] *Chiamaka Okafor, Climate Change: Western countries are hypocrites, can't dictate to Africa – Buhari, LA Times, November 11, 2022 — https://www.premiumtimesng.com/news/headlines/564715-climate-change-western-countries-are-hypocrites-cant-dictate-to-africa-buhari.html*

[9] *IPCC, 2022: Summary for Policymakers. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change — https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SPM.pdf*

[10] *TRACKING SDG 7: The Energy Progress Report 2022 — https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2022-executive_summary.pdf*

[11] *IPCC, 2022*

[12] *Our World in Data (Accessed 2022) — https://ourworldindata.org/grapher/share-of-the-population-with-access-to-electricity*

Enabling a Just Energy Transition

Enabling a just energy transition requires that key environmental justice and equity issues be addressed. These include:

1. **Distributional Impacts:** It is crucial to ensure that the benefits and burdens of the clean energy transition are fairly distributed. Efforts should be made to avoid exacerbating existing disparities and ensure that clean energy benefits reach all communities. Historically marginalized regions and communities, such as those in rural or remote areas, should not be left behind and should have equal access to the benefits of clean energy, including improved air quality, job opportunities, and affordable energy solutions.

2. **Access to Clean Energy:** Affordability and accessibility to clean energy technologies can be a challenge for disadvantaged communities, including those in emerging economies, islanded nations, and remote areas. Efforts should be made to address energy poverty by implementing initiatives that provide affordable and reliable clean energy solutions to these communities.

3. **Workforce and Economic Opportunities:** The clean energy transition should prioritize inclusive economic growth and job creation in all communities. This includes supporting workforce development and providing training programs and job opportunities in clean energy sectors. It is particularly important to ensure that communities reliant on traditional industries, such as fossil fuels, are not left behind and have opportunities for a just transition.

4. **Community Engagement and Decision-Making:** Meaningful engagement of communities in the decision-making processes related to clean energy projects is essential. This includes involving diverse perspectives, considering local knowledge and needs, and fostering transparent and inclusive discussions. Communities should have a say in shaping the clean energy transition to ensure their specific concerns and interests are taken into account.

5. **Environmental Health and Pollution:** The clean energy transition should prioritize improving environmental health and reducing pollution in all communities. Efforts should be made to avoid the unintended concentration of environmental hazards and ensure that all communities benefit from improved air and water quality as a result of the transition.

Addressing these environmental justice and equity issues in diverse communities, including rural, global, emerging economies, islanded nations, and remote areas, is crucial for a successful and inclusive clean energy transition that benefits all segments of society and leaves no community behind.

The energy transition presents challenges as well as opportunities. For example, in the labor market, the International Energy Agency (IEA) has indicated that the transition towards Net-Zero emissions will lead to an overall increase in energy sector jobs (Figure 2). The IEA has set out the Net-Zero Emissions by 2050 (NZE) Scenario, which shows a pathway to achieve Net Zero by 2050. In this scenario, it is estimated that 30 million new jobs could be created in clean energy, efficiency, and low emissions technologies by 2030, while 5 million jobs would be lost in fossil fuel production over the same period.[13]

Managing the clean energy transition is about much more than simply replacing one kind of energy generation for another. A massive program of reskilling, training, and professional development will be required to ensure the future workforce is ready to build, maintain, and operate the new energy infrastructure required for production, storage, transport, distribution, and end uses. Existing fossil fuel-based global energy infrastructure has been developed within complex social, political, and economic ecosystems, upon which communities, and whole economies, depend. Disrupting these complex systems to achieve large-scale change is likely to be met by intense resistance. A holistic view

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[13] *IEA, 2021, The importance of focusing on jobs and fairness in clean energy transitions, IEA, Paris —https://www.iea.org/commentaries/the-importance-of-focusing-on-jobs-and-fairness-in-clean-energy-transitions*

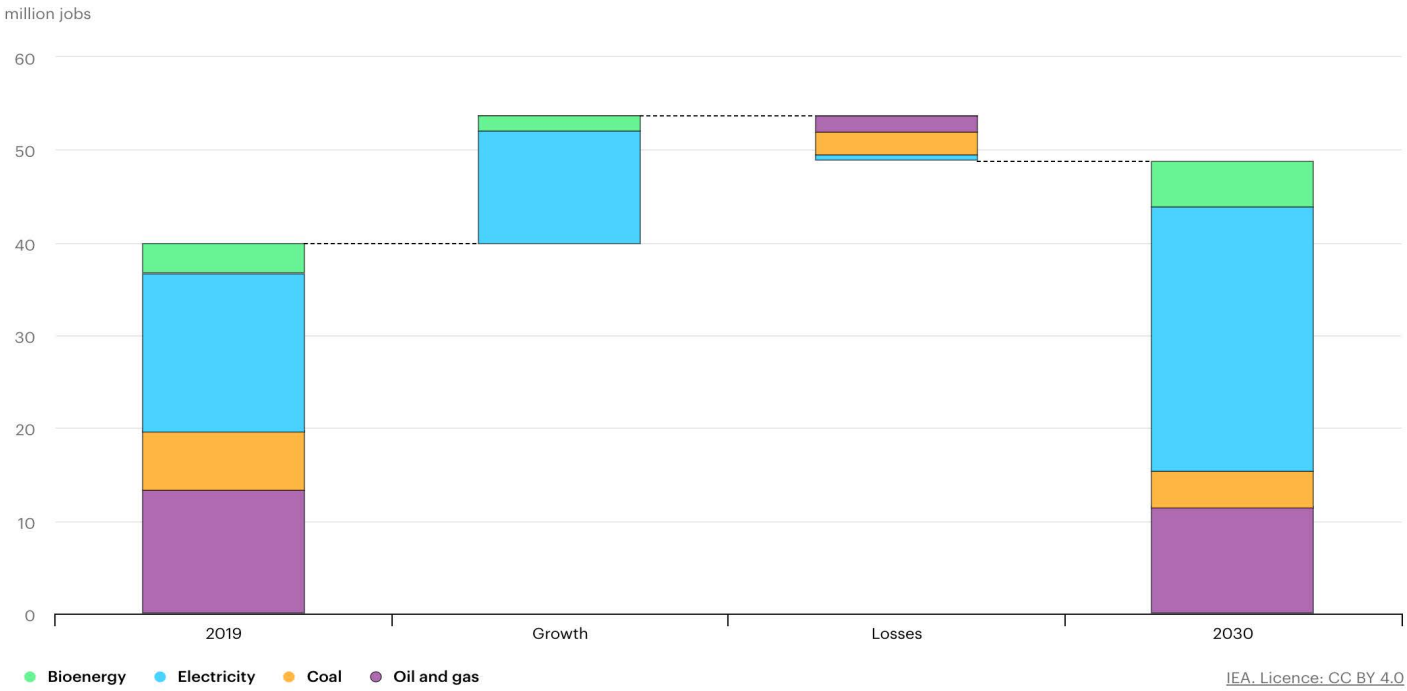

Figure 2: Global employment in energy supply in the NZE Scenario, 2019-2030[14]

will be required to understand and work with the multiple dynamics at play. With just 27 years to 2050, it is essential to mobilize our collective technological, financial, governmental, and industrial capabilities to meet the task of bringing the climate crisis under control.

Transitioning Coal Is Essential to a Just Energy Transition

The largest component of the existing fossil fuel-based global energy infrastructure that needs to be reimagined as part of a just energy transition is coal energy. Coal plants are the single largest source of carbon emissions on the planet. As of 2022, the world has more than 2 terawatts (TWe) of coal-fired electric power plants, adding roughly 12 gigatons of CO_2 emissions per year. In Europe alone (excluding countries that oppose nuclear or are phasing it out), 34 GWe of installed coal capacity, or 32% of the total, is made up of plants with 50 MW to 700 MW of capacity.[15] Countries in Africa are also heavily dependent on coal to power their economies.

It is also worth noting that coal plants are, on average, relatively young assets (14 years old) that provide reliable energy and wealth generation to local communities. Closing down these assets that have decades of usable life is challenging from an economic perspective, especially considering growing energy demand and supply shortages—even more so during the current global energy crisis resulting from Russia's war against Ukraine. There is currently $1 trillion of unrecovered capital in the global coal fleet.

In South Africa, for instance, coal-fired power plants are the primary source of energy. In the Summer of 2022, the urgent energy crisis in South Africa resulting in rolling blackouts sparked new public discourse around advanced heat sources as a potential clean energy solution. At the same time, the debate to decommission coal plants in South Africa is becoming more heated as European countries delay their decommissioning plans due to growing energy needs.

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[14] *IEA, Global employment in energy supply in the NZE Scenario, 2019-2030 (May 2021) — https://www.iea.org/data-and-statistics/charts/global-employment-in-energy-supply-in-the-net-zero-scenario-2019-2030*

[15] *IEA, 2022, Nuclear Power and Secure Energy Transitions — https://iea.blob.core.windows.net/assets/0498c8b8-e17f-4346-9bde-dad2ad4458c4/NuclearPowerandSecureEnergyTransitions.pdf*

Coal to Clean Energy with Nuclear Power

Nuclear energy's attributes, notably its low emissions, dispatchability, and flexibility, will boost its value to electricity systems as they are progressively decarbonized. In particular, dispatchability will become increasingly valuable in grids with high penetrations of variable renewables. Nuclear energy can also provide much-needed emissions-free heat as well as potentially low-cost, large-scale, emissions-free hydrogen production.[16]

There is an established body of knowledge surrounding flexible operation of existing nuclear plants which the NICE Future initiative has gathered within its Flexible Nuclear Campaign.[17] Off-grid applications, such as providing heat and power to remote communities and industries (e.g., mining), are examples of additional high-value applications for nuclear energy. Small modular reactors (SMRs), for example, could be coupled to thermal energy storage systems, or to hydrogen production, to further increase value and flexibility.[18] SMRs are being designed for factory fabrication and use of modular construction techniques, which should also lead to lower costs and reduced construction schedules.[19]

Another attribute of both traditional and advanced nuclear is the potential to repurpose coal plant sites. Coal-fired power plants can be repowered with advanced nuclear heat sources to ensure the equivalent production of electricity for the grid, with a similar footprint as the existing plant (see Figures 3 and 4).[20]

The opportunity to repurpose coal plants that are facing closure can contribute to a just transition. These sites offer enormous value due to:[21,22]

- established power markets;
- existing grid connections, which reduces the need to build new transmission (note that access to the grid is set to become increasingly important as more distributed power generation grows with the increased penetration of solar photovoltaic [PV] and wind power);
- cooling water access;
- real estate holdings;
- experienced site personnel (i.e., leverage the established skills and workforce available).

Plus, these repurposed power plants and their surrounding communities would benefit from:

- continued use of existing energy storage distribution and end-use infrastructure to produce drop-in substitute fuels, leveraging the enormous skills and capability within the global oil and gas sector to de-risk our approaches;

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[16] *IEA Nuclear Power and Secure Energy Transitions (June 2022) — https://iea.blob.core.windows.net/assets/0498c8b8-e17f-4346-9bde-dad2a-d4458c4/NuclearPowerandSecureEnergyTransitions.pdf*

[17] *NICE Future initiative Flexible Nuclear Campaign (June 2022) — https://iea.blob.core.windows.net/assets/0498c8b8-e17f-4346-9bde-dad2a-d4458c4/NuclearPowerandSecureEnergyTransitions.pdf*

[18] *Flexible Nuclear Energy for Clean Energy Systems, NREL/TP-6A50-77088 (September 2020) — https://www.cleanenergyministerial.org/content/uploads/2022/06/flexiblenuclear-energy-for-clean-energy-systems-2020.pdf*

[19] *IEA, 2022, Nuclear Power and Secure Energy Transitions — https://iea.blob.core.windows.net/assets/0498c8b8-e17f-4346-9bde-dad2ad4458c4/NuclearPowerandSecureEnergyTransitions.pdf*

[20] *IEA, 2022*

[21] *IEA, 2022*

[22] *RISE³ Webinar, Nuclear Energy Innovations — Supporting Global Communities, March 22, 2022 — https://www.youtube.com/watch?v=fSk4B-Glkm34*

- expansion of the energy services around that plant attracting other industries;
- retaining jobs with the opportunity for skills transfer;
- new job opportunities (e.g., a repurposed coal plant will require 250 workers for its day-to-day activities);[23]
- opportunities for skilled and higher paying jobs, such as reactor operators or radiation protection technicians which do not have a coal-fired power plant equivalent (e.g., the median hourly wages for on-site SMR jobs would pay a premium of approximately 17% relative to the equivalent position at a coal plant).[24]

Several countries have started to analyze the potential to repurpose coal-fired power plants with clean heat sources in order to avoid the consequences of phasing them out. Poland, for example, is considering the use of nuclear power to repurpose its coal assets as they begin planning their nuclear program. In order to determine whether Polish coal plants could be repurposed, a detailed study[26] was undertaken to characterize Polish coal units in terms of age, steam conditions, sites, site sizes, and the kind of retrofit that would be suitable. The study concluded that about half of the coal fleet in Poland could be suitable for repurposing and that the most effective way would be to replace the coal burner itself with a zero-carbon heat source. The most appropriate technical fit for that would be a high-temperature nuclear reactor or a high-temperature geothermal heat source.

The study also shows the feasibility of retaining much of the equipment on site, which would save about one-third of the cost of a new nuclear plant, a 30-35% reduction in total plant CAPEX, and reduce construction time substantially. Furthermore, 60-70% of the local workforce could be retained. Figure 3 pictures an existing coal-fired power plant while Figure 4 shows the proposed repurposed plant with nuclear energy—retaining large parts of the existing infrastructure. (Please refer to Figure 3 which identifies the components of the existing coal power plant.)

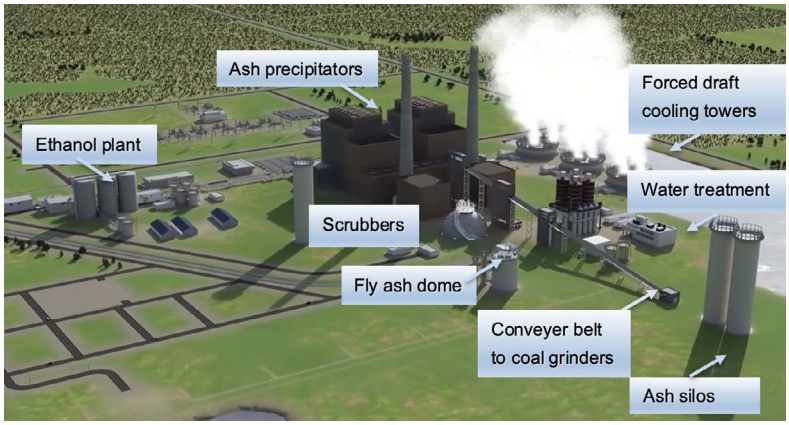

Figure 3. Rendering of an existing coal plant

Figure 4. Rendering of a repowered 1,200 MWe, two-steam-unit plant[25]

[23] *TerraPower website (November 2021) — https://www.terrapower.com/natrium-demo-kemmerer-wyoming/*

[24] *Scott Madden, Gone with the Steam White Paper (October 2021) — https://www.scottmadden.com/insight/gone-with-the-steam/*

[25] *Renderings in Figures 3 and 4 provided by TerraPraxis, 2022 — www.terrapraxis.org*

[26] *Qvist et al, "Retrofit Decarbonization of Coal Power Plants—A Case Study for Poland" Energies 2021, 14(1), 120; Supplementary Materials — https://www.mdpi.com/1996-1073/14/1/120/s1*

Bridging the Gaps

One challenge of the Clean Energy Transition is the scale of infrastructure that has to be built with respect to supply chain, materials, land use, and public acceptability.

Reducing emissions while ensuring a just transition, providing energy security, and increasing access to electricity requires:[27]

- a market framework that adequately values both low emissions generation and the full range of electricity system services;
- electricity markets need to be designed to ensure that the economic value of nuclear power, alongside other low emissions technologies, is fully reflected in price signals;
- rethinking systems modeling with the whole suite of potential pathways, including repurposing coal-fired power plants;
- changing the usual nuclear development and deployment models—moving from bespoke design engineering and a traditional construction project each time to a standardized manufacturing-based product.
- repurposing as much of the existing infrastructure as possible, such as transmission lines;
- creating consultation groups with all relevant stakeholders from the start, including government, regulators, industry, NGOs, and the local and indigenous communities;
- listening to the community's concerns and suggestions, making them part of the decision-making process and allowing them take part in the potential economic opportunities provided by a new clean energy project;
- setting up training and education programs for new job opportunities.

Finally, we must be asking the right questions:

- How can we reach Net Zero at the scale and speed that is required while considering constraints in terms of existing infrastructure, land availability, weather conditions, technology availability, financing mechanisms, and workforce readiness?
- What zero-carbon emission solutions are available or under development, including all technologies rather than focusing only on renewable energy?
- What are the risks to the deployment for each technology option towards the clean energy transition?
- How can we make the most of the existing infrastructure, rather than building from scratch and decommissioning young assets?
- How can we leverage the huge investments and enormous infrastructure, skills, human resources, capabilities, and capital we already have in our system to transform it, rather than focusing on demand-side changes?

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[27] *IEA Nuclear Power and Secure Energy Transitions (June 2022) — https://iea.blob.core.windows.net/assets/0498c8b8-e17f-4346-9bde-dad2a-d4458c4/NuclearPowerandSecureEnergyTransitions.pdf*

Moving in the Right Direction

There are several steps being taken in the right direction. For example, when Canada started drafting its SMR roadmap in 2019, it involved all the stakeholders from the start. Together, they developed several targets, goals, and objectives that would enhance the engagement and amplify potential economic opportunities. This created a safe ethical space, based upon traditional values and knowledge where indigenous viewpoints and worldviews were not only accepted but valued and integrated into the decision-making process and follow-on development processes. Canada offers many collaboration opportunities concerning funding for indigenous participation in SMR projects.

The U.S. government has launched Project Justice 40 to ensure that disadvantaged communities receive the benefits of new and existing Federal investments to advance environmental justice. Specifically, 40% of investment benefits and 40% of jobs must go to local communities, and community stakeholders must be meaningfully involved in determining program benefits.[28,29]

The U.S. Department of Energy (DOE) has also issued several announcements regarding funding for the energy transition. In November 2021, the Loan Program Office indicated that $11 billion is available in loan financing to repower existing coal infrastructure with advanced nuclear reactors to accelerate the transition.[30] At the same time, the DOE launched the Nuclear Futures package, which provides $25 million in support of expanding access to clean nuclear energy for capacity building, equipment, feasibility and siting studies, demonstration projects, study tours, site visits, and technical collaboration. This package includes support for partnerships with Poland, Kenya, Ukraine, Brazil, Romania, Indonesia, and others to help countries make progress on meeting their nuclear energy goals.[31]

Similarly, the governments of South Africa, France, Germany, the United Kingdom, and the United States of America, along with the European Union, announced the launch of the Just Energy Transition Partnership to support South Africa's decarbonization efforts.[32] The program includes an initial commitment of $8.5 billion for the first phase. It is expected to prevent as much as 1 to 1.5 gigatons of emissions over the next 20 years as it supports South Africa's move away from coal and accelerates its transition to a low emission, climate resilient economy.

These examples bring hope—much as the way in which countries came together to address the COVID-19 pandemic by getting vaccines ready in months instead of years—demonstrating that when matters are addressed with the urgency they require we are able to organize and find solutions by working together.

It is high time we address climate change with the global-scale urgency it requires, and by bringing together new voices with different perspectives and the same sense of urgency and motivation.

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[28] *Justice 40 covers Federal investments in climate change, clean energy and energy efficiency, clean transit, affordable and sustainable housing, training and workforce development, remediation and reduction of legacy pollution, and the development of critical clean water and wastewater infrastructure — https://www.whitehouse.gov/environmentaljustice/justice40/ (accessed July 2022).*

[29] *Jerome Foster II at TerraPraxis Energy Day, November 2021 — https://youtu.be/Lq1ow-nF0t0*

[30] *Jigar Shah at TerraPraxis Energy Day (November 2021) — https://www.terrapraxis.org/events/de-risking-the-terawatt-transition*

[31] *IEA, From today's challenges to tomorrow's clean energy systems, 2022 — https://www.state.gov/the-united-states-announces-25-million-to-support-access-to-clean-nuclear-energy/*

[32] *European Commission press release: France, Germany, UK, US and EU launch ground-breaking International Just Energy Transition Partnership with South Africa, November 2, 2021 — https://ec.europa.eu/commission/presscorner/detail/en/IP_21_5768*

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