A JOURNAL FOR THE CLEAN ENERGY COMMUNITY

RISE3D

A NICE FUTURE INITIATIVE PROJECT

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The NICE Future Initiative would like to thank all authors and organizations for their submissions to support this publication. The initiative would additionally like to acknowledge the support from the National Renewable Energy Laboratory (NREL) including Jal Desai, Holly Darrow, Isabel McCan, Christopher Schwing, and Liz Breazeale in their production of the second volume of RISE3D. This report is made available by the NICE Future Initiative, a workstream of the Clean Energy Ministerial.

Funding provided by U.S. Department of State. The views expressed in this publication do not necessarily represent the views of the U.S. Government or any agency thereof.

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CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

NICE Future
Nuclear Innovation: Clean Energy Future
An Initiative of the Clean Energy Ministerial

RISE³
Research the Impacts on Social Equity and Economic Empowerment
A Campaign of the NICE Future Initiative

LANE
Leaders in Advanced Nuclear Energy
A Campaign of the NICE Future Initiative

FINDING A WAY FORWARD: CREATING OUR OWN LANE

In the face of the unprecedented effects of climate change, it is imperative that we holistically address decarbonization of the energy sector, including through incorporating innovative and groundbreaking nuclear energy solutions that work as a part of clean energy systems that reduce emissions. The Nuclear Innovation: Clean Energy (NICE) Future initiative brings nuclear expertise and solutions to the wide range of Clean Energy Ministerial (CEM) initiatives to address energy security and mitigate climate change around the world and find a clean energy future for all.

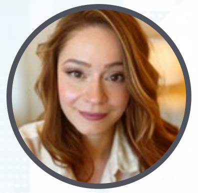
In 2022, NICE Future released the first volume of RISE3D as a product of the Campaign to Research the Impacts on Social Equity and Economic Empowerment (RISE³) and were thrilled to highlight a first wave of case studies that aim to realize the goals of our RISE³ campaign. In this second volume, we are proud to showcase a new round of visionaries and leaders who are pioneering real-world solutions that accelerate clean energy and climate goals.

To further encourage the development of leaders in nuclear energy worldwide, NICE Future is proud to announce the Leaders in Advanced Nuclear Energy (LANE) technical working group. Guided by the collaborative leadership of Canada, France, Japan, the United Kingdom, and the United States, LANE will support groundbreaking research in five key tracks:

- Messaging and Communication;
- Integrated Clean Energy Systems;
- Economic Modeling and Financing;
- Non-Electric Applications; and
- Workforce Development.

Beginning in 2024, LANE will harness the collective wealth of knowledge and resources of its members to carry out activities that develop solutions for each of the five tracks with a focus on cross-cutting projects and collaborations with other CEM initiatives.

As you read through this second volume of RISE3D, I invite you to consider the extensive possibilities and opportunities presented and reach out to us through social media or our website with any questions, or to join us. As NICE Future amplifies the work of our Participants and Partner Organizations through the RISE3D publication, we remain steadfast in our commitment to foster and sustain leaders who will champion the creation of a sustainable, equitable, and prosperous clean energy future.



Sarah McPhee Charrez
Office of International Nuclear Policy & Cooperation,
U.S. Department of Energy

Partnerships with Indigenous, Underserved, or Remote Communities

Economic Empowerment Opportunities & Workforce Development

Flexible and Integrated Systems Utilizing Both Nuclear and Renewable Energy

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Evaluation of Transition Options for Unabated Coal Sites

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FOREWORD - COMMUNITIES COME TOGETHER THROUGH RISE3D

The NICE Future Initiative recognizes there is no one-size-fits-all solution to energy and fosters collaboration among clean energy supporters in exploring diverse solutions, including nuclear energy technology solutions, both electric and non-electric, for clean, integrated, affordable, and reliable systems of the future. Canada, like many countries, is pursuing nuclear energy as part of our "all-options" approach to fighting climate change and meeting our net-zero goals.

Through the Clean Energy Ministerial, NICE Future has provided a forum for ministers and global policy leaders to explore how nuclear innovations may be integrated in clean energy systems design, implementation, and operation. As the sole nuclear energy-focused initiative of the CEM, NICE Future, founded by co-lead countries the United States, Canada, and Japan, is advancing a vision of the world in which nuclear innovations are integrated with other non-emitting technologies to accelerate progress toward clean energy and climate action goals.

Research Impacts on Social Equity and Economic Empowerment (RISE^3) campaign co-leads Canada, Japan, the United Kingdom, and the United States are proud to continue the invaluable work being done through this campaign. The RISE^3 campaign, which formally launched at CEM in July of 2023, enables communities to come together with experts, governments, and stakeholders in pursuit of effectively building a cleaner energy future to combat climate change. RISE^3 provides expert resources for these communities to build blueprints for transition while promoting social equity and economic empowerment.

The work done by the U.S. Department of Energy through their continued sponsorship of the Research Impacts on Social Equity and Economic Empowerment Demonstration (RISE3D) Case Series is a great complement to the broader work of RISE^3, and a strong method to promote the vision and success of RISE^3 participants and partners. The previous series of RISE3D case studies provided communities a place to come together. This current series demonstrates the success and progress of the RISE^3 model in shifting the conversation and bringing more stakeholders to the table to provide important perspectives as we fight against climate change, and support our communities, domestic and global, in doing the same.

I am eager to continue working with the communities and stakeholders in this case study series and look forward to working on new case studies in the future. Everyone who has contributed should be proud of their work through this campaign as it represents some of the incredibly meaningful work that has been accomplished through the NICE Future Initiative. In reading this issue of RISE3D, I hope that you become as inspired as I am about the future of nuclear energy and its critical role in addressing climate and energy challenges.

Frédéric Beauregard-Tellier
Director General for Nuclear Energy and Infrastructure Security
Natural Resources Canada

RESEARCH IMPACTS ON SOCIAL EQUITY AND ECONOMIC EMPOWERMENT RISE3D KENYA CASE STUDY

NICE FUTURE

BACKGROUND AND ENERGY PROFILE

Nuclear energy has been identified as a key technology for meeting Kenya's future energy demands, offering an opportunity for Kenya to achieve its emission reduction targets, as it is one of the cleanest energy sources with minimal life cycle greenhouse gas emissions. The adoption of nuclear power generation not only helps achieve these targets, but also provides a reliable source of baseload electricity that is resilient to climate change. Additionally, the technology has the ability, particularly with small modular reactors (SMRs) and microreactors, to meet industrial heat and electricity needs, integrate with variable renewables, and provide the energy needed for water desalination.

Kenya has ambitious plans to build 0.6 GWe of nuclear energy capacity by 2038. This is part of the country's broader goal to increase its use of clean energy sources, such as geothermal, hydro, wind, and solar power. In 2019, the Nuclear Power and Energy Agency was established under the Kenya Energy Act to accelerate the development and implementation of the nuclear power program, as well as to carry out research and development and capacity building in the energy and petroleum sectors.

The Nuclear Power and Energy Agency has been working with the U.S. Department of Energy, NREL, and Idaho National Laboratory (INL) on a model study for NICE Future to evaluate the economic benefits of nuclear power plants in Kenya and assess the impact of nuclear integration on the country's energy mix. The collaboration effort has also analyzed the potential for increased industrialization of Kenya through electric and non-electric applications of nuclear energy, focusing specifically on the potential to establish industries in manufacturing, large-scale clean water production, and the enhancement of the agriculture sector.

THE CASE STUDY

The Nuclear Power and Energy Agency, INL, and NREL will carry out modeling from existing and forecasted plants to the main load centers to determine the best scenarios to simulate based on current energy policies and forecasted demand and projected plants.

The study will cover:

1. Roles for nuclear energy alongside renewables as Kenya plans clean growth of its electricity generation capacity and grid system
2. Roles for other nuclear energy services, such as heat, synfuels, hydrogen, and desalination, as Kenya plans clean growth of its industry, transportation, and societal needs
3. The potential benefits of nuclear plant construction and operation in Kenya, including job creation, contribution to gross domestic product, and clean energy generation for both electric and non-electric applications
4. The challenges and risks associated with nuclear energy adoption in Kenya, including regulatory and licensing requirements, public acceptance, and financing.

Over the next three years, the Nuclear Power and Energy Agency will conduct multiple studies on how nuclear energy can advance renewables in integrated clean energy systems. Additionally, the studies will focus on how flexible electric and non-electric applications of nuclear energy can boost the country's economy and improve the quality of life of its citizens, aligning with Kenya's Vision 2030 goals. This will highlight the challenges and risks that must be addressed to successfully implement a nuclear power program in the country. The results of the study will be incorporated into the country's energy planning policy and industrialization road map. Furthermore, the study will be incorporated into the Nuclear Power and Energy Agency's strategic plan for the nuclear power program and shared with ministerial committees in other government sectors that implement the country's long-term development goals to ensure that cohesive policy goals and objectives are established across all sectors of the economy. This initial study will also be used to enhance ongoing studies on industrial involvement within the Kenyan nuclear power project that began in 2018. The technical skills and knowledge gained in the case study will be invaluable in these future studies.

Learn more about this project by visiting www.nice-future.org/kenya-nuclear-energy-future.

Figure 1-1. View of Nairobi, Kenya from Uhuru park (Photo from Getty Images 1299026534)

TOWARD A CLEAN AND JUST ENERGY TRANSITION

NICE FUTURE

THIS WORK WAS AUTHORED AS PART OF THE NICE FUTURE INITIATIVE IN COLLABORATION WITH TERRA PRAXIS.

To accelerate the repurposing of unabated coal plants with new advanced nuclear technologies, and to bring about breakthrough nuclear innovations, the NICE Future Initiative launched an expert group, 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 toward 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 United Nations 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 (2.1). The Paris Agreement is a legally binding treaty that 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 (2.2).

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 (2.3). Because annual emissions accumulate in the atmosphere, it also matters how much carbon dioxide (CO_2) is emitted on the way to 2050.

Intermediate targets are useful, because they help demonstrate progress; however, the data indicates that the world as a whole is 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.

Current climate commitments are

insufficient. Thus far, no country is even on track to meet their commitments. In February 2022, a new report published by the Intergovernmental Panel on Climate Change 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 (2.4). The divisions will worsen if countries fail to rein in greenhouse gas emissions, but there are already steep challenges. The Intergovernmental Panel on Climate Change report underscores that the countries facing the worst climate impacts are those that have historically contributed the least to global warming—and have the fewest resources to help themselves to adapt. Speaking about the report findings, Antònio Guterres, United Nations 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 must reduce annual emissions to net zero in less than three decades. This means we must replace all 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, which extracts CO_2 directly from the atmosphere (2.5).

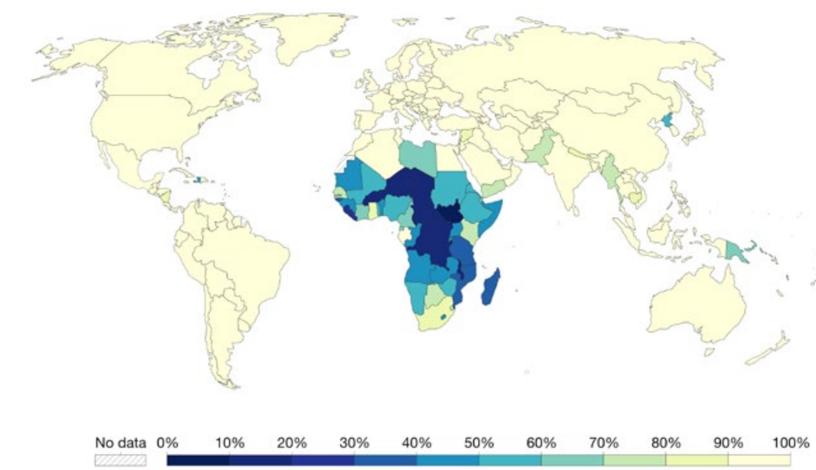

Figure 2- 1. Access to electricity in 2020 (2.12)

However, the imperative for a profound transformation requires not just a shift away from polluting energy sources toward sustainable alternatives, but also expanded access to clean energy for 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 for achieving net zero involves a massive, simultaneous infrastructure buildout in every country. An unprecedented logistical challenge, we must not only build enough clean electricity generation to power the world, but do so quickly, all 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, we must 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.

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 health care, 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 each of these societal needs (2.6). Today, most of the world's population lives in 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 (2.7).

Africa currently contributes about 3% to global emissions but is one of the regions hit worst 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% (2.8).

> "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

Global access to electricity has increased since 2010, but wide regional disparities remain (Figure 2- 1). Variations in regional and national per-capita emissions partly reflect different development stages, but emissions 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 (2.9). 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 2- 1). Closing the access gap by 2030 hinges on electrification efforts in these countries (2.10). Enhanced mitigation and broader action to shift development pathways toward sustainability are expected to have positive distributional consequences within and between countries (2.11).

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 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: Meaningfully engaging 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 considered.
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 toward net-zero emissions will lead to an overall increase in energy sector jobs (Figure 2- 2). The IEA has set out the Net-Zero Emissions by 2050 scenario, which shows a pathway to achieving 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 (2.13).

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 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.

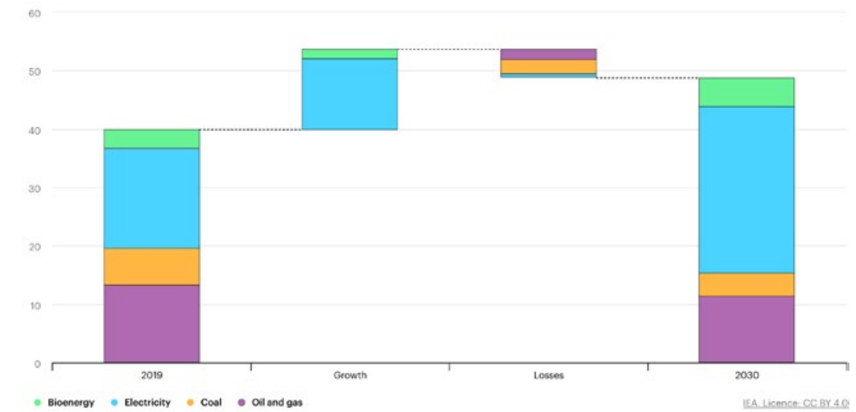

Figure 2- 2. Global employment in energy supply in the Net-Zero Emissions scenario, 2019–2030 (2.14)

TRANSITIONING COAL IS ESSENTIAL TO A JUST ENERGY TRANSITION

Coal energy is the largest component of the existing fossil fuel-based global energy infrastructure that must be reimagined as part of a just energy transition. 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 CO2 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 (2.15). 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 summer 2022, the urgent energy crisis in South Africa, which resulted 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.

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 (2.15).

An established body of knowledge exists surrounding flexible operation of nuclear plants, which the NICE Future Initiative has gathered within its Flexible Nuclear Campaign (2.16). 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. SMRs, for example, could be coupled to thermal energy storage systems or hydrogen production to further increase value and flexibility (2.17). SMRs are being designed for factory fabrication and use of modular construction techniques, which should also lead to lower costs and reduced construction schedules (2.15).

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 Figure 2- 3 and 2- 4) (2.19).

The opportunity to repurpose coal plants facing closure can contribute to a just transition. These sites offer enormous value due to (2.20; 2.21):

- Established power markets
- Existing grid connections, which reduce the need to build new transmission (access to the grid is set to become increasingly important as more distributed power generation grows with the increased penetration of solar photovoltaic 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
  - 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

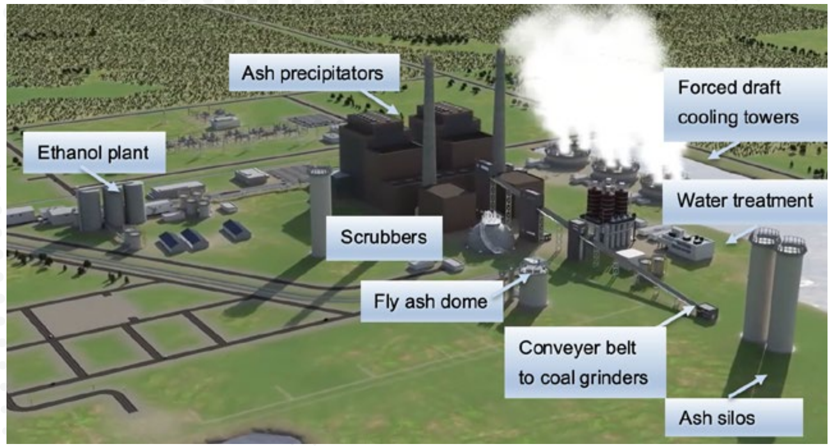

Figure 2- 3. Rendering of an existing coal plant. Graphic from Terra Praxis, 2022.

repurposed coal plant will require 250 workers for its day-to-day activities). (2.22)

- Opportunities for skilled and higher-paying jobs, such as reactor operators or radiation protection technicians that 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.) (2.23).

Several countries have started to analyze the potential to repurpose coal-fired power plants with clean heat sources 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. To determine whether Polish coal plants could be repurposed, a detailed study (2.25) 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 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 capital expenditure, and reduce construction time substantially. Furthermore, 60%–70% of the local workforce could be retained.

Figure 2- 3 shows an existing coal-fired power plant, while Figure 2- 4 shows the proposed repurposed plant with nuclear energy—retaining large parts of the existing infrastructure (Figure 2- 3 identifies the components of the existing coal power plant).

BRIDGING THE GAPS

One challenge of the clean energy transition is the scale of infrastructure that must 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 (2.15):

- A market framework that adequately values both low emissions generation and the full range of electricity system services
- Electricity markets designed to ensure that the economic value of nuclear power, alongside other low-emissions technologies, is fully reflected in price signals
- Systems modeled with the whole suite of potential pathways, including repurposing coal-fired power plants
- A change from 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
- The repurposing of as much of the existing infrastructure as possible, such as transmission lines
- Consultation groups with all relevant stakeholders included from the start,

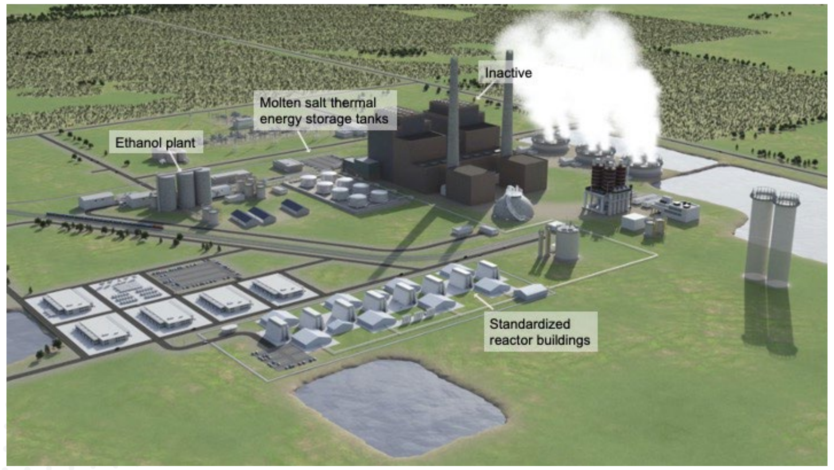

Figure 2- 4. Rendering of a repowered 1,200-MWe two-steam-unit plant (2.24). Graphic from Terra Praxis, 2022.

such as the government, regulators, industry, nongovernmental organizations, and the local and indigenous communities

- Consideration of the community's concerns and suggestions, encouraging their participation in the decision-making process and allowing them take part in the potential economic opportunities provided by a new clean energy project
- Training and education programs for new job opportunities.

Finally, we must be asking the right questions, like:

- How can we reach net zero at the required scale and speed 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?
- 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?

MOVING IN THE RIGHT DIRECTION

Several steps are being taken in the right direction. For example, when Canada started drafting its SMR road map 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 and 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 launched the Justice40 Initiative 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 (2.26; 2.27).

The U.S. Department of Energy 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 (2.28). At the same time, the Department of State launched the Nuclear Futures package, which provides $25 million to support 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 toward meeting their nuclear energy goals (2.29).

Similarly, the governments of South Africa, France, Germany, the United Kingdom, and the United States, along with the European Union, announced the launch of the Just Energy Transition Partnership to support South Africa's decarbonization efforts (2.30). 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.

Much like countries came together to address the COVID-19 pandemic by getting vaccines ready in months instead of years, these examples demonstrate 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 by bringing together new voices with different perspectives and the same sense of urgency and motivation.

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THE CASE OF ADVANCED NUCLEAR REACTORS FOR PUERTO RICO (UPDATE)

THE NUCLEAR ALTERNATIVE PROJECT

The following submission was adapted from slides presented by the Nuclear Alternative Project at the NICE Future Initiative townhall meeting on June 26, 2023. They have been included in this edition of RISE3D as a short update to their submission to RISE3D's first wave case study. You can find the first wave case study "The Case of Advanced Nuclear Reactors for Puerto Rico" at: https://www.nice-future.org/docs/nicefuturelibraries/default-document-library/rise3d-case-study-series.pdf

SUMMARY AND UPDATE

Our organization continues to educate Puerto Ricans about advanced nuclear reactors in the following ways:

- In-person presentations
- Webinars
- Technical Studies
- Podcasts
- Engagement with University of Puerto Rico Mayaguez Campus American Nuclear Society chapter
- Collaboration with College of Engineers and Surveyors of Puerto Rico
- Engagement with Justicia Energetica PR (Universidad Interamericana de Puerto Rico).

CHALLENGES

- Actual public policy calls for 100 % renewable energy by 2050
- Lack of resources for nonprofit organizations educating about nuclear energy
- First-of-a-kind reactor will have more challenges in Puerto Rico compared to a reactor that is already operating
- Spent fuel final disposal
- Emergency planning zone.

NEXT STEPS

- Site suitability study
- Preliminary economic study (expected to finish by end of 2023)
- Continue engagement with College of Engineers and Surveyors of Puerto Rico, University of Puerto Rico at Mayaguez American Nuclear Society chapter, and Justicia Energetica PR
- Continue educational campaign with webinars and in-person presentations.

Figure 3-1. Photo from the Nuclear Alternative Project

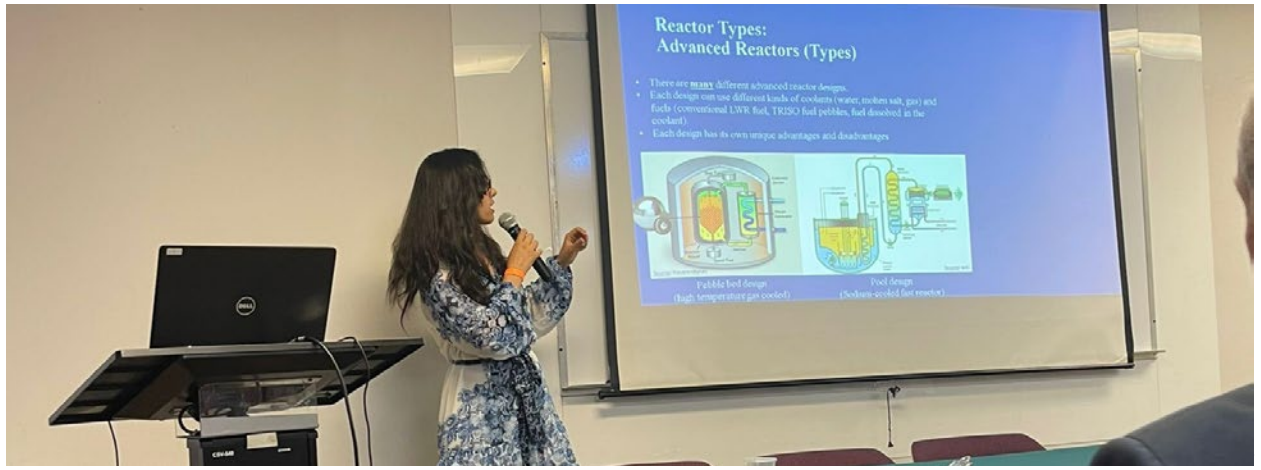

Figure 3-2. Photo from the Nuclear Alternative Project

Figure 3-3. Photo from the Nuclear Alternative Project

NUCLEAR AT THE ENDS OF THE EARTH: SMR DEMONSTRATION AT SOUTH POLE STATION, ANTARCTICA

SARAH MCPHEE, GALE HAUCK
U.S. DEPARTMENT OF ENERGY OFFICE OF NUCLEAR ENERGY POLICY AND COOPERATION

The United States maintains three year-round scientific base stations in Antarctica, with more U.S. personnel on the continent than from any other country. The largest South Pole scientific community is McMurdo Station on Ross Island, a research community operated by the U.S. National Science Foundation, consisting of up to 1,250 residents (4.1). The second-largest U.S. Antarctic base is the Amundsen-Scott South Pole Station, which houses up to 150 scientists and support staff during the summertime peak (4.2).

The environment at Amundsen-Scott is pristine and punishing, with an average annual temperature of -56°F (-49°C) (4.2). The temperature ranges from a summertime peak of 10°F (-12°C) to a wintertime low of -117°F (-83°C). The community sees only one sunrise per year—during the autumn equinox—followed by 24 hours of sunshine per day, until the sun sets on the spring equinox. This is followed by 6 months of darkness and brutal winter temperatures.

The South Pole is arguably the most remote continually inhabited location in the world.

Figure 4- 1. McMurdo Station. Image source: National Science Foundation.

Figure 4- 2. The tanker ship USNS Maersk Peary docked at McMurdo Station's ice pier and covered by a late season snowfall. Photo Credit: Laura Gerwin, The Antarctic Sun.

Once per year—usually around the last 2 weeks in January—a vessel from Port Hueneme, California, arrives at McMurdo Station on the coast of Antarctica to deliver enough food, supplies, and equipment for the entire year, and removes trash and unused or broken equipment. Everything needed to sustain life at the South Pole must then be flown or driven nearly 1,000 miles (1,600 km) inland from McMurdo Station. According to international treaty, nothing native to the continent may

Figure 4- 3. Amundsen-Scott station. Image source: Raffaella Busse (https://www.science.org/content/article/infrastructure-woes-could-slow-south-pole-telescope-plans).

be consumed and nothing left behind, especially waste. However, necessity has thus far dictated that energy for the community is supplied primarily via diesel generators. The fuel must be delivered at great expense while generating emissions and waste.

There is a precedent for nuclear energy at McMurdo Station; a reactor operated there from 1962 until it was decommissioned in 1972 due to safety issues. During its operation, this reactor reportedly replaced the need for 1,500 gallons (5,700 L) of oil per day (4.3, 4.4). As the world moves toward a clean and sustainable future, U.S. facilities in the South Pole must also consider a future without fossil fuels. SMRs, integrated with previously existing wind energy, provide the best solution for ending emissions and waste, reducing fuel shipments, and scaling up capacity for backlogged research requests while demonstrating the efficacy of nuclear integration with renewables in remote, underserved communities.

ENERGY PROFILE

Nearly all of Amundsen-Scott's energy needs are satisfied by fossil energy, primarily jet fuel, using more than 500,000 gallons (1.9 million liters) per year to run the station's 750-kW fossil energy plant (4.5). However, more energy is needed to support upgrades to existing scientific projects and the development of new ones. There is a reported backlog of requests for scientific expeditions due to infrastructure-related shortages.

Efforts to decrease McMurdo's carbon footprint include the installation of three Enercon E-33 (330 kW each) wind turbines in 2009, which help power McMurdo and New Zealand's Scott Base. The windmills have reportedly reduced diesel consumption by 11%, or 463,000 liters per year (4.6). A small wind turbine was tested at South Pole Station in the 1990s, and it can be expected that this concept will be reinvestigated as climate change and carbon emissions become of increasing concern (4.7).

THE CASE STUDY

The South Pole Station RISE3D Case Study is part of a 3-year campaign to demonstrate how nuclear energy can transform communities, advance environmental justice and equity, uplift economies, and improve quality of life for remote, off-grid, or islanded communities. The United States is responsible for environmental stewardship of three large bases in Antarctica, a continent all nations have an interest in protecting and where all territorial claims are on hold per international treaty. Furthermore, the conditions at Amundsen-Scott are the most extreme on the planet; bringing nuclear energy to this station via SMRs will demonstrate how nuclear energy can uplift remote, islanded communities and integrate with renewables to address emissions in the last pristine place on the planet.

Because Amundsen-Scott, like all Antarctic stations, falls under international treaty, the benefits of reintroducing nuclear energy must be advocated for. A proposed schedule includes a needs assessment in Fiscal Year 2024. This initial step will evaluate both current and potential future station needs, including all forms of energy such as electricity, heat, and steam. This information will allow an assessment of available technology options to meet the needs of the station.

The needs assessment will be followed by a feasibility/economic impact study in Fiscal Year 2025, and an environmental impact study and potentially a draft proposal for SMR procurement in Fiscal Year 2026.

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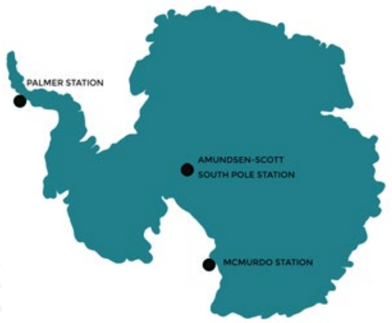

Figure 4- 4. Locations of the U.S. scientific base stations at the South Pole.

TOWARD EQUITY AND ENVIRONMENTAL JUSTICE IN THE SITING OF NUCLEAR ENERGY INFRASTRUCTURE PROJECTS

KEY FINDINGS AND RECOMMENDATIONS INFORMED BY A DISCUSSION HOSTED BY THE NICE FUTURE INITIATIVE'S RISE³ CAMPAIGN, HELD ON JUNE 8, 2022.

PANELISTS:

Dr. Rachael Budowle (Assistant Professor, University of Wyoming), Dr. Başak Saraç-Lesavre (Research Fellow, University of Manchester), and Mary Woollen (Director of Stakeholder Engagement, Ultra Safe Nuclear Corporation).

MODERATOR:

Denia Djokić (Assistant Research Scientist, University of Michigan)

This factsheet represents an ongoing area of research at the Fastest Path to Zero Initiative. The Fastest Path to Zero initiative is grateful to the panelists for contributing to this vital conversation on working toward equity and justice in the nuclear field.

To learn more, contact Dr. Denia Djokić (djokic@umich.edu).

With various nations and localities considering nuclear energy as an essential technology in their low-carbon energy futures, the global nuclear industry stands on a threshold of opportunity to reexamine approaches to siting nuclear power facilities that have been historically technocratic, top-down, and mostly based on the decide-announce-defend model. Addressing questions around institutional trust, social equity, and environmental justice in the process of siting (advanced) nuclear reactors, as well as nuclear fuel cycle facilities, is one crucial dimension in moving toward an energy future that is more just and equitable in both process and outcome.

Summarized here are the insights and recommendations of this discussion's invited experts on identifying future research, policy, action, and thought toward making the siting of nuclear energy technologies and facilities, including advanced reactor facilities, an equity-centered undertaking.

LESSONS FROM THE ENVIRONMENTAL JUSTICE LITERATURE

A classic guiding principle of environmental justice states that populations should not disproportionately incur health or environmental impacts from any industrial process. Populations that are impacted often have a range of vulnerabilities and a history of marginalization, including economic disempowerment.

In many energy facility siting contexts, including nuclear facility siting, environmental justice questions go beyond simply an equitable distribution of risks and benefits of nuclear energy technology throughout the fuel cycle. Working toward equity and justice in siting nuclear facilities also encompasses:

- A deepening of our understanding of local contexts and controversies around the siting of nuclear energy facilities and the impact on livelihoods and experiences in the present and future, which could be achieved through ethnographic and community-based participatory research
- A deliberate shifting of power and agency to historically excluded community entities as early in the siting process as possible, which could be achieved through the intentional inclusion of voices that may not have traditionally partaken in decision-making processes.

KEY ELEMENTS OF AN EQUITABLE AND JUST SITING PROCESS

Based on our historic understanding of energy facility siting, some of the fundamental elements in the successful siting of a facility are building trust, transparency, and collaboration among actors to facilitate a common understanding of the needs of communities related to the building of the facility and how the facility in question may or may not meet those needs. The willingness of government and developers to take "no" for an answer is crucial to the engagement process and, ultimately, to the potential acceptance and success of a project.

While the effectiveness of trust-building is situational and process-dependent, it is still possible to identify a set of common elements that are key to a more people-centered siting process, moving away from a technology-centered decision model.

KEY TAKEAWAYS

Trust

- Any facility siting process with meaningful community engagement moves at the "speed of trust."
- Engagement does not stop with the operating permit. It is important to plan for consistent, sustained, long-term engagement in a facility siting (and ultimately operating) process.
- Consistency is key in building trust at every level and over the long term. Let a diversity of community actors and impacted stakeholders set the agenda and shape the discussions. Embed diverse community perspectives at every step of the siting process.
- Conducting a robust and equitable engagement process is often more important than achieving an end goal (i.e., obtaining "consent" by any means necessary).
- To enhance trust and transparency, engagement may require a large degree of separation between industry and those conducting the engagement process.

Agency and decision-making

- Enabling historically marginalized voices to express their concerns and designing procedures to account for those concerns increases agency and works toward building trust.
- Meaningful engagement means aiming to reach an agreement with concerned actors about what constitutes an ethical siting process.
- A community advisory board can help inform the ethical dimensions of the siting process.
- Centering community needs necessitates moving from the community "acceptance" model (generating and obtaining acceptance) to a community "appropriateness" model (evaluating whether the facility fits the needs of this community).
- Members of potential host communities must have meaningful and diverse choices for their envisioned energy future.
- Monetary reimbursement for travel and time helps increase access to decision-making spaces to those community actors who might otherwise not be able to participate.

Research and process

- Transparency, equity, and justice are nonlinear processes. Controversies emerge as the siting process evolves, and it is important to document and learn from them.
- Ethnographic research is key to understanding how community actors understand controversies, responsible action, power dynamics, equity, and justice in the context of a local siting process.
- Conducting research on siting processes as they happen can provide feedback and observations to stakeholders in the process as it evolves in real time.
- Support and fund independent research entities at the state and/or local level and provide them with access to and data about all aspects of the siting process.

RECOMMENDATIONS TO SUPPORT COMMUNITY RESEARCH AND ENGAGEMENT PROCESSES

Fund research to deepen our understanding of the nature of controversies and actors' perspectives. The research process can illuminate power differentials and different viewpoints, shared concerns, and raise awareness about various interpretations of the controversies surrounding a facility. Ethnographic and community-based participatory research methodologies can inform community engagement and energy futures visioning processes around emerging and potential energy sources. Embed and center environmental justice-oriented principles into the research process, rather than adding them at the end.

Orient a facility siting engagement process with a "community appropriateness" framework rather than a "community acceptance" approach. Bring affected community actors into the room as early in the process as possible. Start with evaluating community needs and whether the energy facility in question adequately addresses them. Account for the ethical dimensions around siting a facility in a potential context of local historical injustices. Giving community members a sense of agency is a key element in how communities adapt and respond to environmental change. This can be partially addressed by community actors serving on an advisory board to guide the ethical dimensions of the siting process and inform it with locally appropriate knowledge.

TOWARD EQUITY AND ENVIRONMENTAL JUSTICE IN THE SITING OF NUCLEAR ENERGY INFRASTRUCTURE PROJECTS

To facilitate community participation, fund honoraria, travel, and stipends. There may be community actors with valuable viewpoints for the siting process who might not otherwise participate, particularly if they are some of the most marginalized and vulnerable community members.

Give access to different contexts and spaces in the stakeholder engagement and community-based research processes. Do not expect stakeholder engagement experts or researchers to provide information to lay expert community members, but do invite them to institutional environments of government and industry.

Have open conversations about industry and government responsibility toward restorative and reparative justice in the local context of historical environmental injustices in communities when siting new facilities anywhere in the region. In any siting process, it is important to take into account historical trauma such as broken treaties, stolen lands, economic disempowerment, and more. Historical contexts are key to informing a potential reparative building of trust in a community engagement process that hopes to site new industrial infrastructure.

KEY GUIDING QUESTIONS:

- How does a local nuclear energy facility impact livelihoods and life experiences?
- Who has power in decision-making processes? To work toward equity in the siting process, at what critical points could deliberate shifts of power and agency strategically occur?
- What is the developer or government responsibility for restorative and reparative justice for geographically proximate communities that may have historically experienced injustices from the nuclear fuel cycle or other industrial facilities?
- How can our current and past understandings of siting processes inform future attempts at siting advanced nuclear facilities? Where are opportunities to learn from past and present siting processes (e.g., Kemmerer, Oskarshamm) and center justice and equity considerations throughout these processes in the future?
- How can trust be built between authorities, communities, and other concerned actors?
- What is considered responsible action, and how do different actors conceive differently of what is a fair and efficient distribution of responsibilities, costs, and benefits?

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TOWARD EQUITABLE DESIGN AND DEVELOPMENT OF NUCLEAR ENERGY INFRASTRUCTURE

KEY FINDINGS AND RECOMMENDATIONS INFORMED BY A DISCUSSION HOSTED BY THE NICE FUTURE INITIATIVE'S RISE³ CAMPAIGN, HELD ON MAY 31, 2022.

PANELISTS:

Kara Colton (Energy Communities Alliance), Dr. Harold Maguire, Jr. (Westinghouse), Dr. Sarah Mills (University of Michigan), Tim Kalke (Sustainable Energy Galena), Gwen Holdmann (University of Alaska Fairbanks), Dr. Katlyn Turner (Massachusetts Institute of Technology), and Andrea Morales Coto (FireHydrant). Moderator: Dr. Aditi Verma (University of Michigan).

AUTHOR:

Aditi Verma (University of Michigan)

This factsheet describes an ongoing area of research at the Fastest Path to Zero Initiative.

To learn more, contact Prof. Aditi Verma: aditive@umich.edu.

EQUITABLE AND JUST DESIGN OF NUCLEAR ENERGY TECHNOLOGIES

Several large infrastructure-based energy technologies are being considered as part of the clean energy transition. These include nuclear fission and fusion, hydrogen, and carbon capture and storage, to name a few. While the development of such large-scale clean energy infrastructure projects can be beneficial for the communities and regions in which they are sited—through the creation of high-skilled jobs, the development of local infrastructure, and potentially lower costs of energy—such projects can also create and amplify existing inequities and injustices. In the nuclear sector, for example, the creation of large-scale nuclear facilities for research, energy generation, and waste management has historically led to the displacement of (typically indigenous) communities and the amplification of existing socioeconomic inequalities.

Many of these inequities arise because communities have not typically been consulted during the technology development process, such that their desires, preferences, and even values can be accounted for in the design and development of a technology or facility. Traditional nuclear energy technologies developed in this manner include large-scale (gigawatts of electricity) plants generally sited far from population centers. However, a fundamental shift is occurring in the energy sector, from the large, centralized generation of electricity to distributed systems that are smaller, more modular, and more flexible in their output. The smaller reactor technologies are intended to be sited closer to population centers, potentially even embedded in the very communities they are intended to serve. These smaller-scale systems could support the grid, but they may also serve other functions such as providing industrial heat, district energy, water desalination, and energy for hydrogen production.

Therefore, as a result of historic inequities created by the development and use of nuclear energy as well as other large-scale energy technologies, and recognizing that new nuclear energy technologies may be embedded in and around communities, it is important to reconsider our approaches to reactor design and development specifically and energy technology development more broadly.

WHAT IS THE DIFFERENCE BETWEEN ETHICS, EQUITY, AND JUSTICE?

Ethics, equity, and justice are sometimes referred to interchangeably in discussions about socially engaged and community-centered design. These terms have different meanings, and it is important to define them while reflecting on equity and justice in a nuclear technology design and development context (6.1):

- Ethics, especially in an engineering and design context, refers to individual as well as professional ethics. It emphasizes values such as integrity, honesty, competence, safety, and social and environmental responsibility.
- Equity is about intentionally closing societal gaps instead of unintentionally exacerbating them.
- Justice focuses on proactively and retroactively creating an equitable distribution of opportunities and resources while reducing risks and harms to vulnerable communities and citizens.

Justice, in turn, has five components:

- Distributional justice, a fair distribution of benefits and burdens
- Procedural justice, the inclusivity and fairness of decision-making procedures
- Recognition justice, the acknowledgment of past harms and inequalities
- Restorative justice, using policy interventions to prevent or repair distributional, procedural, and recognition injustices
- Epistemic justice, the inclusion of diverse bodies of knowledge in decision-making criteria. Epistemic justice is especially important in the context of Native American and indigenous systems of traditional ecological knowledge. These indigenous and Native forms of knowledge have been mobilized to steward our ecosystems for thousands of years, far exceeding many Western systems of thought in their longevity.

WHAT IS EQUITY AND JUSTICE IN A NUCLEAR CONTEXT?

Centering equity and justice in the development of nuclear energy technologies involves:

- Fairly distributing the benefits and burdens of nuclear technologies
- Inclusivity in decision-making procedures about the design, development, governance, and dismantling of energy technologies
- Acknowledgment of past harms—intentional and unintentional—caused by the nuclear sector
- Using policy interventions to correct those harms and prevent more in the future
- Including local and context-specific knowledge, understandings, and meanings of equity and justice to inform technology design and development.

HOW CAN EQUITY AND JUSTICE BE OPERATIONALIZED IN THE DEVELOPMENT OF NUCLEAR ENERGY TECHNOLOGIES?

Examples of inequitable design are unfortunately all too easy to find across many technology sectors. They include, for example, facial recognition software that misidentifies dark-skinned individuals (which has criminal justice implications) (6.2). Similarly, no-touch soap dispensers frequently do not recognize darker-skinned hands and do not dispense soap. Many kitchen appliances and household tools assume right-handedness. Historically, crash test dummies for the safety testing of automobiles were not representative of women's bodies, leading to higher fatalities of women in car crashes (6.3). Security scanning systems at airports assume that bodies conform to a gender binary and sound an alarm when transgender individuals walk through (6.4).

There is a growing movement for centering individual users and communities in product and technology design, causing existing design inequities to be increasingly acknowledged and remediated. However, we have yet to see a similar shift in the energy sector and in the development of large infrastructure projects. This is because such projects lead to the development of complex sociotechnical systems that do not have a clear user. Instead, they have diffused stakeholders who, in a variety of ways, are impacted by the development of a technology, its usage, and even its failure. New nuclear reactor designs are not only significantly different from previous larger designs but are also being designed for entirely new use contexts. These new designs and applications require developers, policymakers, and researchers to renew engagements with stakeholders and nuclear communities to ensure accurate communications and understanding.

KEY TAKEAWAYS FROM THE PANEL DISCUSSION

> Design Teams Should Not Make Assumptions About What Communities Want

Many communities actively expressing an interest in nuclear energy in the United States (for example, the communities represented by the Energy Communities Alliance) are doing so because of their familiarity with nuclear energy. In many cases, these are communities who have lived adjacent to U.S. Department of Energy-run nuclear facilities. In the early stages of the development and siting of nuclear facilities prior to the establishment of the U.S. Department of Energy, the lines between weapons and energy applications were blurry, and communities were not clearly informed about the purposes of the facilities sited around them. Existing and future nuclear communities seek to clearly understand the intended uses for the technologies they will host and seek to provide early input into the development process. They are strongly opposed to the decide-announce-defend model of decision-making. Technology developers must also be willing to accept that there are communities that will simply not have an interest in nuclear technologies and will not wish to host them.

Community Expectations Vary Regionally and Have Technological Design Implications

While many communities are likely to have some shared preferences, community desires and expectations may also vary significantly within and across a country. For example, off-grid northern communities are likely to prioritize a resilient source of energy that also creates local employment opportunities. Indigenous communities are likely to prefer an energy source and technology design that aligns with their values. Still other communities are likely to prefer an ecosystem of projects—a nuclear plant that supports electric and non-electric applications—and are opposed to one-and-done projects. It is important to understand these community specificities because they have strong implications for technology and facility design. It is also important to find the right match between a community and energy technology and developing organization.

There is a tension between rapid development and the need to go slowly to understand community concerns and respond to them during the design stage. Ultimately, the latter, more deliberate and intentional approach to technology design and development, is expected to be successful, as technologies developed in this way are more likely to be well suited for their use contexts.

Communities Seek Agency and Meaningful Participation in Design-Related Decision-Making

To rebuild trust with communities, designers and developers must be careful not to overpromise and underdeliver. This is especially true in the context of first-of-a-kind projects that must be executed well from both a social and technical perspective. Successful design and development work could be aided by the appointment of community coordinators or liaisons to serve as conduits between design teams and community members. The appointment of such liaisons will facilitate mutual learning and two-way dialogue, not a one-way conversation aimed at securing public acceptance. At the center of a two-way discussion between designers and communities lies the question of risk and how to manage it (6.5). Technology developers must accept that risk is not understood purely in a quantitative and technical way by many communities. Technologies potentially sited in proximity to communities will need to be designed on the basis of community conceptualizations of risk and safety. The broad goal is to give communities agency over what is being designed and developed. This agency could be created through input and direct community participation in the design process or the use of new tools and techniques, including virtual prototyping approaches, that enable designers and communities to work together.

RECOMMENDATIONS FOR THE EQUITABLE AND JUST DEVELOPMENT OF NUCLEAR ENERGY TECHNOLOGIES

What should policymakers do?

1. Develop a sociotechnical approach to nuclear technology design and development. Given the new, potentially community-embedded use contexts for nuclear technologies, policymakers should move away from the traditional technocentric technology development paradigm to one that is sociotechnical. Such an approach can be facilitated by the development of new policy tools and assessment techniques. Traditionally, the stages of development of complex sociotechnical systems have been assessed using the Technology Readiness Level. Policymakers should instead draw on and use sociotechnical approaches to assessment; one potential model is the sociotechnical readiness level framework (6.6). An important precondition for the pursuit of a sociotechnical approach to technology development is acknowledging and repairing historic inequities created by the previous development and uses of nuclear technologies.
2. Create institutional frameworks for early community input in technology development. Policymakers can create institutional frameworks and processes to support early community input and engagement during the design process. These could take the form of a community nuclear energy advisory board at the regional or national level that offers insights into which reactor designs and technologies are community-appropriate. Such insight and advice could inform which reactor technologies are selected to receive funding, and, for funded recipients, offer insight into how to align the design and the design process with community preferences. Such community advisory boards could also provide input during the early stages of regulatory assessment of a technology, including prior to the submission of a formal application by reactor designers. The purpose of these institutional frameworks is to create community accountability, while also preventing large investments into the development of technologies that are ultimately not going to be fit for the intended purpose. Early community input and engagement will be beneficial to design teams because it will prevent expensive design changes late in the design process.
3. Build community centers of excellence and knowledge. Regional centers of excellence could facilitate the transfer of engineering and design knowledge and expertise to communities, thus empowering them to participate in design processes and provide valuable inputs to design teams more fully. Such centers would also facilitate mutual learning between communities and design teams by providing more opportunities for engagement between designers and future stakeholders.
4. Empower and facilitate citizen science and design. The institutional frameworks and community centers of excellence described previously could also facilitate citizen science and design work by empowering community members—especially youth in the community—to learn about nuclear and radiation science. A familiarity with nuclear science and technology, as well as a deep understanding of the energy needs of their communities, would allow interested community members to identify novel applications and uses for technology and design in their respective community contexts that may not be easily apparent to designers.

What should practitioners do?

5. Identify stakeholders impacted by design work. Design teams should examine how they identify users and stakeholders to whom they are accountable and whose involvement and consent is especially crucial for the development of new technologies.
6. Examine assumptions about community wants and preferences. Design teams should examine assumptions they might be making about the wants and needs of communities and, instead of making such assumptions, seek direct input. For example, many reactor designers are assuming that communities have a preference for autonomous drop-in concept designs. In reality, some communities are likely to prefer technologies requiring more hands-on support, which would also create local jobs and potentially local supply chains, thus benefiting the region and community.
7. Identify opportunities for community input and engagement early and throughout the design process. Design teams should identify opportunities for community engagement and input from the very early stages of technology design and development. Because designers have not previously engaged with communities as part of their design and development process, opportunities for community input may not be immediately apparent to design teams. Two ways to identify such opportunities are by: (a) identifying open and unanswered questions the team is facing, and (b) through direct engagement with communities in which designers explain the land-use, environmental, social, and economic implications of different design choices to community members and collaboratively explore where communities would like to offer input.

What should researchers do?

8. Uncover historic inequities. Interdisciplinary research carried out by engineering, humanities, and social science researchers working together should uncover and assess historic inequities created by the development and use of nuclear as well as other energy technologies. An understanding of these inequities is important for informing policies about repairing these inequities as well as informing practitioner approaches for engaging with communities who, while interested in the development of new nuclear technologies, are also grappling with legacy issues.
9. Develop tools and processes to support community-engaged and participatory technology design and development. Researchers, especially in academic contexts, have historically supported nuclear reactor design work through the development of new tools, techniques, software, and empirical knowledge in the areas of thermal hydraulics, reactor physics, and materials aspects of reactor design work. As reactor designers work toward reimagining the design process to include direct community engagement and input, researchers can play a similar role in supporting this new design approach by developing new tools, processes, metrics, and indicators for facilitating designer-community collaboration and interaction. Such tools and processes could, for example, support community-level decision-making and selection of energy technologies, support collaborative idea generation in design teams comprising engineers and community representatives, or they could facilitate eliciting and synthesizing community input for reactor design teams through virtual or face-to-face interactions.
10. Assess design practices and community accountability. Researchers can also facilitate community-engaged and participatory design processes by developing heuristics, metrics, and indicators that can be used to periodically assess this new type of design work, as well as identify opportunities and needs for further community input and engagement.
11. Research with communities, not on communities. It is vitally important that, in doing this work, researchers interact with communities as partners, not as research subjects. Researchers should recognize the forms of knowledge held in communities as expertise that is vital to the design process. Equitable research processes should also

emphasize community accountability (6.7). This accountability could be built into the research process and outputs. It could, for example, involve the development of community-facing research outputs such as newsletters, web tools, memos, or other formats determined collaboratively by researchers and community members working together.

12. Reconceptualize the role of engineers. Working toward community-engaged and participatory design work will require that nuclear engineers in particular think about our roles more expansively, and in addition to excelling in the traditional scientific and engineering aspects of our work, that we also develop a more nuanced and responsible conceptualization of our practices and our technologies and how they interact with communities and the environment.

NEXT STEPS: THE NEED FOR DISCUSSIONS ON EQUITABLE TECHNOLOGY DEVELOPMENT

We are in the early stages of reimagining nuclear energy practice, policy, and research to make it more community-centric. There is a need for forums, such as through NICE Future's RISE[3] campaign, to continue discussions about how to pursue a sociotechnical approach to nuclear technology development.

Such an approach to technology development is vital not just in the nuclear sector but across energy sectors if the policymaker, practitioner, and research communities hope to develop energy technologies equitably and scale their usage in time to avert the worst consequences of climate change and increase access to clean energy around the world.

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POLICY PRIORITIES FOR AN EQUITABLE TRANSITION TO NUCLEAR ENERGY

KEY FINDINGS AND RECOMMENDATIONS INFORMED BY A DISCUSSION HOSTED BY THE NICE FUTURE INITIATIVE'S RISE³ CAMPAIGN, HELD ON JUNE 21, 2022.

PANELISTS:

Lee Anderson (Utility Workers Union of America), Kirsty Gogan (Terra Praxis), Jake Kincer (Energy for Growth Hub), and Trevor McDonald (Duke Energy Corporation). Moderator: Dr. Jessica Lovering (University of Michigan).

AUTHOR:

Jessica Lovering (University of Michigan)

This factsheet describes an ongoing area of research at the Fastest Path to Zero Initiative.

To learn more, contact Dr. Jessica Lovering: lovering@umich.edu.

KEY TAKEAWAYS

In 2021, over 80% of global energy came from fossil fuels. Almost all of that will need to be replaced with clean energy by 2050 to mitigate catastrophic climate change.

Global Outlook

- •Nearly 2,000 GW of operating coal power capacity.
- Most of the existing coal capacity is in countries that are ready for nuclear power or will be by 2030: North America and Europe, but also South Africa, India, Indonesia, the Philippines, and Vietnam.
- Roughly 7 million people are employed in coal mining globally.

U.S. Focus

- From 2010–2020, nearly 100 GW of coal power plants closed, with another 25 GW expected to close in the next few years.
- Coal mining employment has decreased more than 50% in the last decade.
- An estimated $33 billion–$83 billion is needed to fairly transition U.S. coal workers.

Recommendations for a Just Transition

- Governments must develop comprehensive plans to prepare fossil-dependent communities for the energy transition.
- More research is needed on coal-to-nuclear repowering.
- Better tools are needed for community-level decision-making, as well as standard templates or modules for project development and community benefit agreements.

The next 30 years will see a radical transformation in the way we generate and consume energy, driven by parallel goals of reducing greenhouse gas emissions and expanding energy access in emerging economies. Such a clean energy transition offers numerous economic and social opportunities for new jobs, new businesses, and a healthier environment. But there will also be groups who lose out in the short term as their jobs in fossil fuel sectors scale down. What should governments be doing now to facilitate a transition to clean energy that is equitable in considering the needs of the current labor force? How can private companies incorporate equity into their plans for workforce development and community engagement?

One interesting proposal is to site new nuclear power projects at retiring coal power plants, helping transition workers directly, while also leveraging existing infrastructure. This panel included representatives from unions, academia, international nongovernmental organizations, and industry. The discussion focused on challenges and opportunities for transition equities through the lens of coal-to-nuclear repowering, although broader lessons exist for the adaptive reuse of fossil and other industrial sites.

FOUNDATIONS OF A JUST TRANSITION

The concept of a "just transition" was first developed by labor unions as a means to mitigate job losses from an energy transition. But it has now evolved into a broader framework for intentional investment in sustainable jobs and industries. Improved labor productivity has meant that fossil fuel jobs have been on a slow decline for decades in most high-income countries. But with the anticipation of an accelerated phase-out of fossil fuels, the pace of the transition could overwhelm existing support mechanisms. In the 1990s in the United States, the first proposed policies for a just transition included a superfund for workers who lost their employment due to stricter environmental regulations. By focusing new clean energy investments in communities economically affected by the shift away from fossil fuels, the benefits of a transition could be more fairly distributed, while the costs of federal programs to support these communities could be reduced.

The terms "just transition" and "equitable transition" are often used interchangeably, but the former is specifically about the process by which the decision-making and transition occur, whereas the latter refers to the distribution of outcomes, both benefits and risks. For example, while we sometimes hear proponents suggest that nuclear energy could contribute to environmental justice—because it has minimal air pollution—the reality is that the benefits of nuclear energy have tended to go to whiter, wealthier communities, while the risks from mining and fuel cycle activities are more likely to be sited in lower-income and communities of color (7.1).

A JUST TRANSITION SHOULD START WITH COAL

Looking at the challenges facing coal power plants is a good place to start when trying to understand the inequities of an energy transition. Coal consumption for power generation has been on the decline for decades in many parts of the world due to a confluence of economic and environmental factors. For example, in the United States, increased mechanization of coal mining starting in the 1960s, followed by a geographic shift toward larger mining operations in the Western United States in the 1980s, led to significant improvements in labor productivity and lower overall employment in coal mining. More recently, low fossil gas prices in the United States and liberalized power markets in North America and Europe have pushed coal out, giving a glimpse into what a future clean energy transition might look like.

The United States hosts about one-tenth of the world's coal power plant capacity, and more than half of the plants that were operating in 2015 will close before 2030. Even after productivity gains, coal power plants employ many people: close to 38,000 in 2019. In addition, around 53,000 people were employed in coal mining (7.2).

Ensuring a just transition is about much more than just replacing these jobs one-for-one with something in the clean energy sector. For example, coal power plants and mines have deep histories in these communities and are strongly linked to cultural identities (7.3).

In many communities, coal plants and mines are the primary employers. But more importantly, these are some of the best jobs available in terms of compensation and benefits. Coal workers have a long history of unionization, and collective bargaining going back more than 50 years has resulted in significant benefits: high wages, good pensions (also 401k contribution plans and social security), and top-tier health care plans.

Globally, the challenge is even bigger. Although the pipeline for new coal projects has been slowing down, especially across Africa, over 2,200 GW of coal plants operate globally (7.4). Much of this capacity was built in the last 10 years and might be difficult to close prematurely for financial reasons.

COULD NEW NUCLEAR HELP SMOOTH THE TRANSITION?

Many federal and state programs have been created to help struggling coal communities in the United States, particularly focusing on worker retraining and economic diversification. But such programs have been piecemeal, temporary, underfunded, or incentivized workers (and their families) to move away for jobs.

One option gaining attention is the potential to site new nuclear power plants—particularly SMRs—at the site of retiring coal power plants (7.5). From a technical perspective, such a coal-to-nuclear repowering could avoid a lot of greenfield development and the siting issues inherent in such processes. A project developer or utility could take advantage of some existing infrastructure such as transmission lines, rail and road networks, water intake, etc. From an energy markets perspective, coal and nuclear provide very similar energy services, making it an easier replacement than replacing with variable renewables.

Coal-to-nuclear repowering could also address many economic and social challenges for host communities. Notably, nuclear power plants employ more people than similarly sized coal or gas plants. And unlike renewable energy, nuclear employs significant permanent staff over its lifetime, not just during the construction phase. Nuclear power employees also benefit from higher salaries than average power sector workers, and plants contribute significantly to the local tax base. Most importantly, from a community perspective, direct coal-to-nuclear repowering keeps the jobs local, and could even employ the same workers with moderate retraining.

Projects are already moving forward in the United States. One company, TerraPower, has selected Kemmerer, Wyoming, as the site of the first demonstration of its sodium-cooled fast reactor. The project will be built on the site of a coal power plant where the last two coal units will retire in 2025 (7.6). And in West Virginia, the second-largest coal producer in the United States after Wyoming, the legislature overturned a 25-year prohibition on nuclear energy in February of 2022 (7.7).

The opportunity is even larger globally. 2,200 GW of operating coal plants produce about 10,000 TWh of electricity every year. If these were replaced with nuclear, that would be about 1,000 GW, which is more than twice global nuclear capacity today. Importantly, almost all of this capacity is in places that already have nuclear power, are ready for nuclear, or will be ready by 2030. Looking outside of North America and Europe, potential countries include: South Africa, India, Indonesia, the Philippines, and Vietnam. However, significant challenges remain in terms of energy policy, human resources, and financing.

RECOMMENDATIONS

It is urgent to invest in workers and communities that are at risk from the clean energy transition. According to a study by the Union of Concerned Scientists, the cost of providing comprehensive support to the roughly 90,000 people currently employed in the U.S. coal industry would cost between $33 billion and $83 billion, depending on the speed of the coal phase-out. Such comprehensive support would include:

- Five-year comprehensive wage and benefit replacement
- College education for family members
- Training programs and job placement services
- Access to mental health and counseling services.

Beyond just financial needs, these communities often have serious distrust toward outside policymakers and environmental advocates claiming to have their best interests in mind. Exacerbating this distrust, there is often a lack of capacity among local stakeholders for necessary work like applying for federal grants, performing feasibility studies and environmental impact statements, or developing worker training programs. Therefore, clean energy project developers should work with government programs, where possible, to help build local capacity and participate in genuine engagement with community stakeholders to build trust.

Focusing on the coal-to-nuclear transition, such an effort will never scale to meet the need if every project is one of a kind. Governments must invest in tools that can help coal power plant owners assess and design repowering projects. Nuclear developers should work with state and local colleges to develop curricula for worker retraining. Both in the United States and for export projects, development financing is needed, recognizing the important role that nuclear power plants can play in local economies.

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NUCLEAR PROJECTS OF ROMANIA: TODAY AND TOMORROW (UPDATE)

NUCLEARELECTRICA

The following submission was adapted from slides presented by the Nuclearelectrica at the NICE Future Initiative townhall meeting on June 26, 2023. They have been included in this edition of RISE3D as a short update to their submission to RISE3D's first wave case study. You can find the first wave case study "Nuclear Projects of Romania: Today and Tomorrow" at: https://www.nice-future.org/docs/nicefuturelibraries/default-document-library/rise3d-case-study-series.pdf

ROMANIA'S TARGETS FOR A SUSTAINABLE ENERGY AND SECURITY OF SUPPLY:

- 55% CO2ech. emissions to be reduced by 2030.
- Decreasing electricity dependence vs. increasing consumption from 20% to 18% by 2030.
- Under current geopolitical environment of today, security of supply takes a new dimension.
- Securing the nuclear fuel cycle and the advantages of natural uranium.

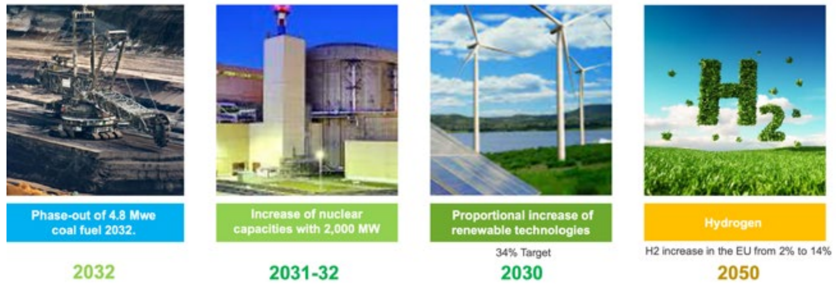

Figure 8-1. Nuclear and energy targets for Romania. Image from Nuclearelectrica.

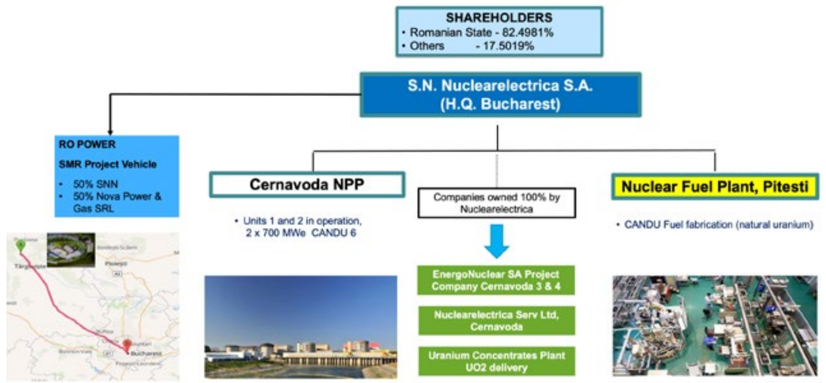

Figure 8-2. Nuclearelectrica - Snn (Group) Organization. Image from Nuclearelectrica.

Reduction CO2 ech. Units 1 and 2 commissioning	cca. 200 mil tone
Installed capacity: 1400 MWe, electricity production10.346,759 MWh, FC (de la p.i.f.): U1 – 90.41%, U2 – 94,23% - **U2 locul 1 in flota CANDU**	18-20%
Clean electricity contribution	33%
Jobs in nuclear industry	11.000
GDP Contribution	590 mil Euro
Investments by 2032	8-9 miliarde Euro

Figure 8-3. Nuclear Today in Romania

Figure 8-4. Main Nuclear Projects of Romania. Image from Nuclearelectrica.

Annual reduction of CO2 emissions with 4 CANDU and one 6 modules NuScale	cca 24 million tons
Nuclear Power production in Romania after 2931: 2800 MWe	36%
Nuclear contribution to clean energy	66%
Nuclear Supply Chain Jobs	~ 20.000

Figure 8- 5. Nuclear Energy in Romania, after 2030.

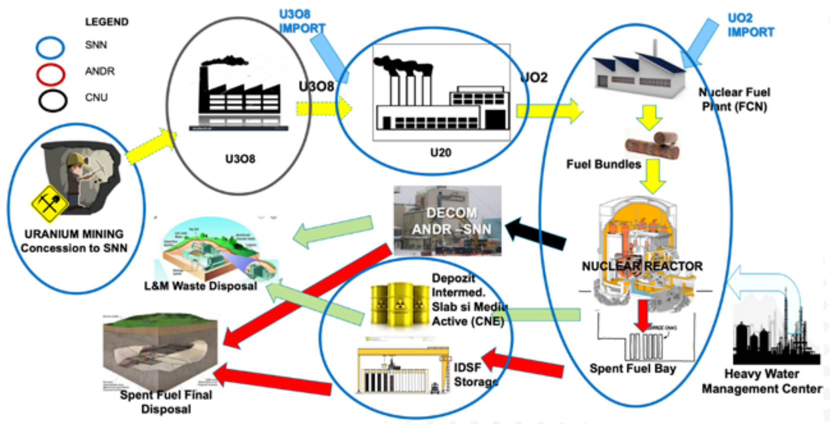

Figure 8-6. Nuclear Fuel Cycle: Driver of Energy Security of Supply. Image from Nuclearelectrica.

CERNAVODA 1 RETROFITTING

Phase 1 (2017–2022): equipment health and scope identification (retubing, design changes, consultants' recommendations, etc.) and SF finalization.

- FID–23 February 23, 2022.

Phase 2 (2022–2026): contracts and financing in force, preparing execution, licensing in force.

- On the way: long lead items contracting, renting the specific tooling, and concluding the EPC contract.

Phase 3 (end 2026–first half of 2029): LTO completed and Unit 1 commissioning.

Final Achievements:

- Operation life to be doubled (another 30 years)
- Unit 2 will be one of the cheapest electricity production capacities in Romania.

Figure 8- 8. Cernovada Tritium Removal Facility. Photo by Nuclearelectrica.

CERNAVODA TRITIUM REMOVAL FACILITY

Tritium extracting from moderator and cooling system, with significant reduction of radioactive emissions and irradiation of the exposed staff.

Cernovada Tritium Removal Facility main steps:

- OE contract in force by June 2020
- EPC contract 2023: to be signed on June

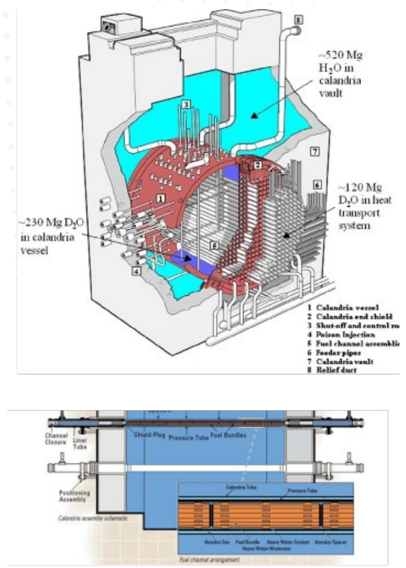

Figure 8- 7. Figure from CANDU Energy

27, 2023 (Seoul)

- Detailed engineering and procurement launched (2023)
- Environmental permit (2023)
- Construction license (2024)
- Construction starts (2024)
- Commissioning (2026)
- Turn over to operation (2027).

CERNAVODA 3 AND 4

Phase 1: Preparing etapa pregătitoare. Engineering and nuclear safety documents, in cooperation with CANDU Energy, design authority for the nuclear island original equipment manufacturer. Started 2021.

Phase 2: Preliminary works. About 30 months: critical engineering, structure and contracting financing, defining EPC contract and construction license. Process ongoing.

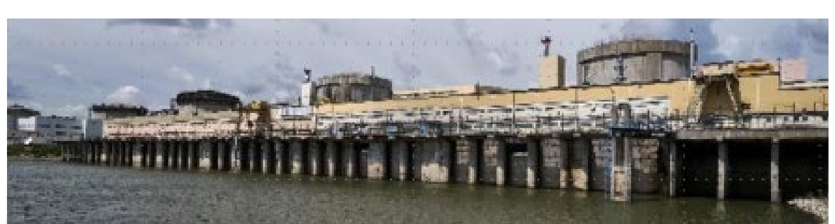

Figure 8- 9. Cernovada reactor. Photo by Nuclearelectrica.

Phase 3: Site mobilization, starting construction erection works, commissioning and turn over to operation. Unit 3 by 2030/2031 and Unit 4 by 2032.

August 2022: preliminary investment decision:

- Unit 2 CNE Cernavoda Reference Plan-
- Post-Unit 2 design modification to be implemented
- Romanian supply chain to play a visible role.

March 31, 2023: Romanian Parliament approved Law 74 regarding the Support Agreement between the Romanian State and Nuclearelectrica regarding the project:

- Sovereign Guaranies, CfD.

COP27, U.S. Exim Bank announced two letters of interest for the financing of pre-project technical services delivered by the United States, covering:

- $50 million USD for pre-project technical services from United States
- $3 billion USD for engineering and project management activities.

U.S. SMR NUSCALE VOYGR IN ROMANIA

- VOYGR-6 plant of 6 x 77 MWe (462 MWe).
- RO Power as project developer Nova Power & Gas (50%) and Nuclearelectrica (50%).
- Italian AFV Beltrame Group: potental new partner.
- Front End Engineering started to produce site licensing documentation.
- Licensing process will follow Romanian and European Union standards, regulations, and procedures.
- Module concept allows a higher flexibility and an excellent partnership with renewable and hydrogen production.
- May 2023: official inauguration of the educational NuScale simulator E2 at the Polytechica Univerityof Bucharst, as a regional center for operator training.
- Nuclearelectrica: "preferred operator" of VOYGR in Romania.

G7 HIROSHIMA

- G7 Summit, Hiroshima: Announced that two U.S. financial institutions issued letters of interest for potential of up to $4 billion USD for SMR project to be developed in Romania.
- Also, U.S. and Japanese support was expressed, as well as the South Korea and United Arab Emirates—up to $275 USD for the SMR project to be implemented in Romania (8.1).

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Photo from Getty Images 1034754006

THE POLISH NUCLEAR POWER PROGRAMME

NUCLEAR ENERGY DEPARTMENT, MINISTRY OF CLIMATE AND ENVIRONMENT, POLAND

THE RATIONALE FOR THE IMPLEMENTATION OF NUCLEAR POWER RESTS ON THREE MAIN PILLARS: ENERGY SECURITY, CLIMATE AND THE ENVIRONMENT, AND ECONOMY.

Poland's energy mix is still based on fossil fuels. Coal plays a significant role in the country's energy system, as approximately 70% of electricity is still produced from this source. In 2022, the coal sector employed roughly 75,000 people. Having this in mind, the social cost is one of the challenges facing Poland during the process of energy transition.

To achieve a clean system by 2050, Poland must deploy all available technologies, such as nuclear, solar, wind, and hydrogen. According to the Energy Policy of Poland until 2040l (9.1), the development of new industries and jobs related to civic energy, based on renewable energy sources, as well as promising sectors, including nuclear energy, will be supported. It is estimated that around 300,000 new jobs will be generated in this manner. Dedicated European Union and national funds will support the process of retraining workers , encouraging investments, and creating new jobs, especially in regions that are heavily dependent on fossil fuel mining.

The Polish Nuclear Power Programme was adopted by the Council of Ministers in 2014, then its updated version was approved in 2020. The objective of the Programme is the construction and commissioning of nuclear power plants in Poland with a total installed nuclear capacity from approximately 6 to approximately 9 GWe based on proven, large-scale, Generation III (+) pressurized water reactors.

The first polish nuclear power plant will be built in Lubiatowo-Kopalino in the Pomerania region. Following a decision taken by the Polish Government on November 2, 2022, the nuclear power plant will be based on Westinghouse Electric Co.'s AP1000 technology. According to the schedule, the construction work for the first unit will begin in 2026, and its commissioning is expected in 2033.

The government administration is currently working on five important tasks listed in the Polish Nuclear Power Programme to consistently and successfully implement nuclear power in Poland. The activities are carried out for human resources development, infrastructure development, support for the domestic industry, strengthening of the nuclear regulatory control system, and social communication and information.

According to a survey conducted for the Ministry of Climate and Environment in November 2022 (9.2), support for nuclear energy in Poland reached a level of 86%. It is the highest result recorded in these polls, which have taken place yearly since 2012.

The Ministry of Climate and Environment carries out various activities to disseminate information about nuclear energy. For example, in 2022, a nationwide campaign, called "The Atomicki Family. Day to Day With Nuclear Power," was launched on television, radio, and the internet. Its aim was to raise public awareness of nuclear power, while building a stable level of public acceptance.

One of the important elements of educational initiatives are activities offered for primary and upper secondary students and teachers. For example, training courses help educators enrich their skills and materials on how to teach about nuclear energy.

The Ministry of Climate and Environment also conducts activities related to human resources development to ensure qualified and highly competent personnel for the construction and operation of nuclear power plants in Poland in accordance with global standards and best practices. A comprehensive Plan for the Development of Human Resources for Nuclear Power was approved on December 7th 2023 by the Minister of Climate and Environment.

There is already an existing educational and scientific infrastructure in Poland that will play a role in developing appropriate human resources. Various programs and majors, directly linked to the field of nuclear energy, are hosted by several Polish technological schools and universities.

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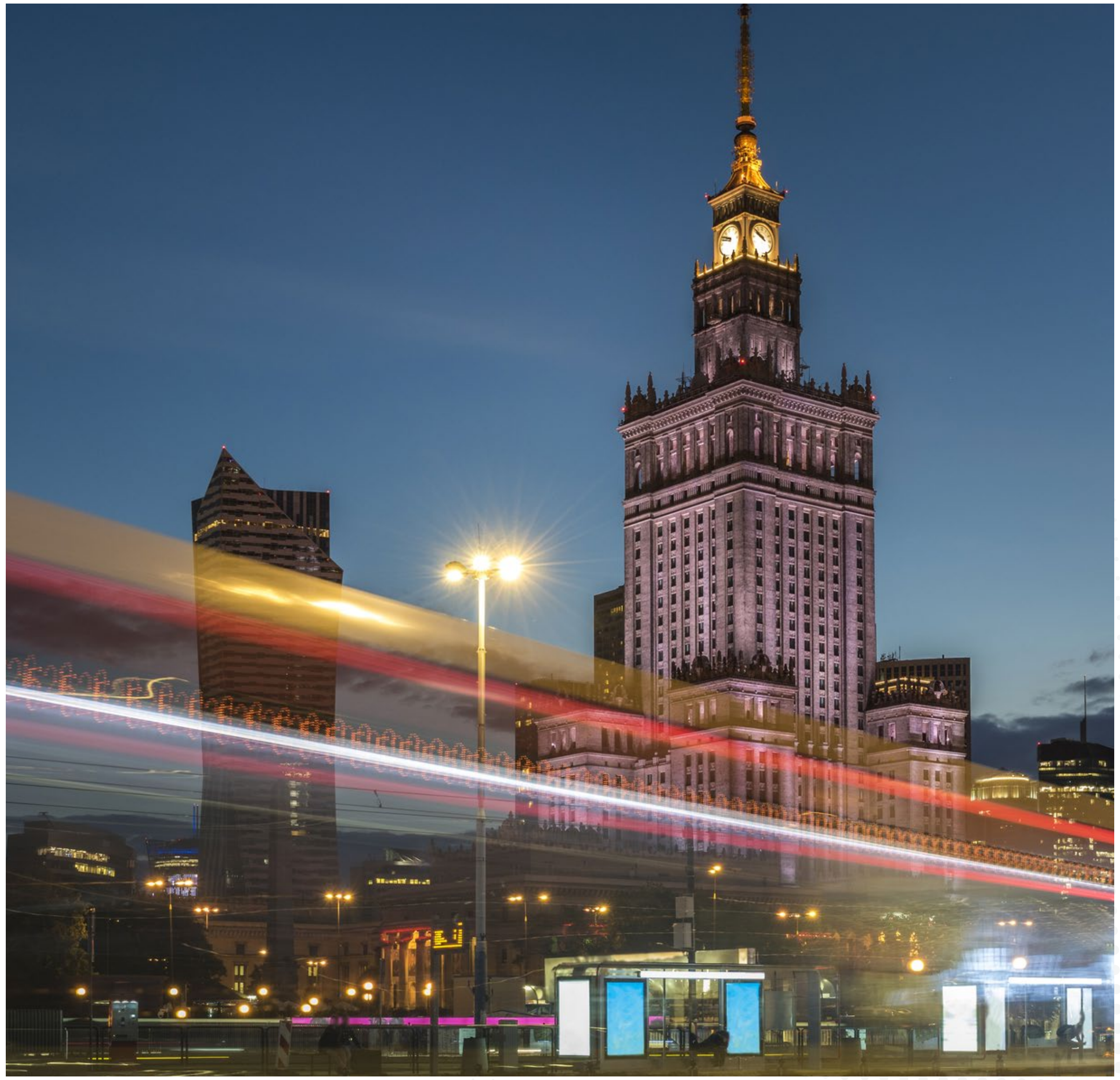

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THE MILESTONES APPROACH AND STAKEHOLDER ENGAGEMENT

INTERNATIONAL ATOMIC ENERGY AGENCY

The International Atomic Energy Agency (IAEA) plays a crucial role in promoting safe, secure, and peaceful uses of nuclear energy worldwide. As part of its mandate, the IAEA supports member states in the development and implementation of new nuclear power programs through its Milestones Approach. This approach provides a structured pathway through which to support the development of new nuclear power programs, and it consists of three phases: consideration, preparation, and implementation. Throughout these phases, stakeholder engagement is emphasized as a key infrastructure issue to support the successful implementation of the program.

Involving stakeholders in the decision-making process for new nuclear power programs can enhance public awareness, understanding, and confidence in the application of nuclear science and technology and strengthen communication among the key organizations involved. Therefore, the IAEA's approach to stakeholder engagement emphasizes a process that incorporates the perspectives and concerns of all relevant stakeholders.

Effective stakeholder engagement provides several benefits for new nuclear power programs. It promotes transparency, builds public trust, and enhances the credibility of decision-making processes. By involving stakeholders, concerns and viewpoints can be addressed, leading to improved project design, safety standards, and effective risk communication.

IAEA'S ROLE IN SUPPORTING STAKEHOLDER ENGAGEMENT

Guidance development: The IAEA provides member states with guidance documents on approaches to stakeholder engagement. These publications assist countries in establishing frameworks, methodologies, and strategies to effectively engage stakeholders.

Public information and communication strategies: The IAEA supports member states in developing effective communication strategies to disseminate accurate and accessible information about nuclear power programs. These activities help countries engage with the media, conduct public consultations, and address concerns and misconceptions related to nuclear energy. The IAEA also fosters knowledge sharing through international meetings and workshops where participants from different countries can exchange ideas and experiences.

Capacity building: The IAEA provides a diverse range of capacity building activities to support member states at all stages of a nuclear power program. This includes e-learnings, training courses, expert missions, and workshops to enhance the skills and knowledge of stakeholder engagement. These initiatives aim to empower countries to design and implement robust engagement plans, ensuring the participation of stakeholders at various levels.

During expert missions, the IAEA works closely with the relevant organizations to develop tailored strategies and approaches for engaging stakeholders. This includes supporting the development of stakeholder engagement plans and drafting communication strategies.

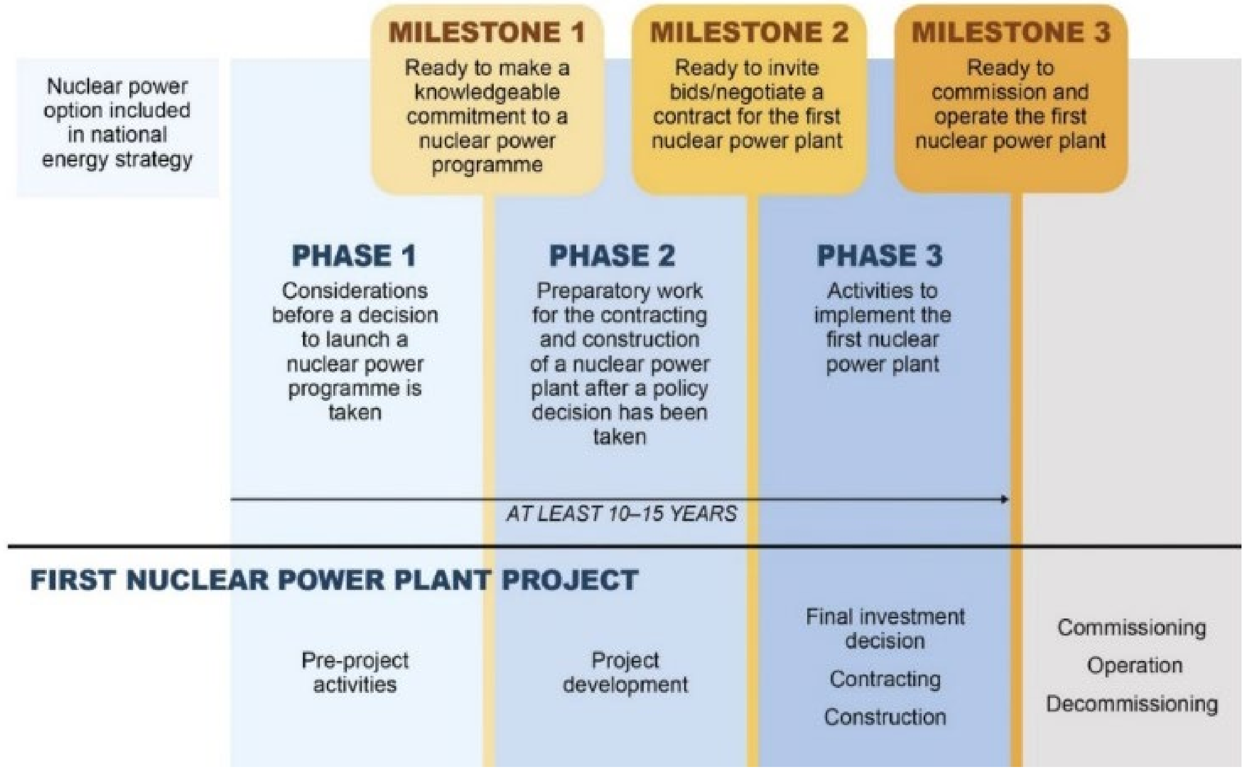

Figure 10- 1. The IAEA Milestones Approach enables a sound development process for a nuclear power program.

Figure 10- 2. Visit to the Mishkat Interactive Center for Atomic and Renewable Energy in Saudi Arabia during an expert mission on stakeholder engagement. Photo by IAEA.

PUBLIC CONSULTATION IN FRANCE'S ENERGY STRATEGY AND PROJECTS

FRENCH MINISTRY FOR ENERGY TRANSITION

PUBLIC CONSULTATION AT THE CORE OF FRENCH LEGISLATION ON ENERGY STRATEGY AND PROJECTS

Public authorities must organize public consultations on most decisions that have an impact on the environment, as stated in the French Environment Code. The laws allow everyone living in France, and in some cases beyond the French borders, to participate in these consultations. The National Commission for Public Debate (CNDP), an independent authority created in 1995, acts to implement this right on environmental protection matters.

The public participation, whether at the local, national, or international level, has become crucial in the decision-making process for energy strategy and projects in France, as evidenced by the following cases.

THE FUTURE OF THE FRENCH ENERGY MIX WENT THROUGH A NATIONAL-SCALE PUBLIC CONSULTATION

A national consultation on the future of the French energy mix was announced by the President of the French Republic in his speech in Belfort on February 10, 2022, as part of the definition of France's road map to achieve carbon neutrality by 2050. This consultation, called "Our Energy Future Is Now" and organized by the French government, intended to provide people with input on the Government's Strategy on Energy and Climate and enable them to contribute to its definition.

This process occurred between October 2022 and February 2023. An online consultation allowing all citizens to express their views on the matter was organized. Over 31,000 contributions were received on three main themes:

- Adapting our consumption to achieve carbon neutrality
- Meeting our electricity and energy needs, while ending our dependence on fossil fuels
- Planning, implementing, and financing our energy transition.

A "Tour de France of the regions" was also organized with the aim of highlighting local priorities. A youth forum also brought together, by drawing lots, over 200 young people aged between 18 and 34 from all over France (metropolitan and overseas).

Following the public consultation, the CNDP issued a report and summarized the debates. The government will respond to the report published by the CNDP. This report and the lessons learned from the public consultation will help define the government's future energy choices.

PUBLIC CONSULTATION FOR THE FRENCH NEW NUCLEAR POWER PLANTS PROGRAM

French electric utility company EDF and transmission system operator RTE have jointly referred to the CNDP the project to build six new nuclear power plants of the "EPR2" type, the first two of which will be located in Penly, Normandy. A public consultation on this program was held from October 2022 to February 2023. An online platform was created, and more than 70 events were organised (debates, topical meetings, events with young people, site visits) to meet citizens and gather their opinions. More than 4,500 opinions were collected.

Following these debates, the CNDP issued a report in September 2023. It identified 33 questions raised by the public. The CNDP requested EDF and RTE to bring further details on certain topics.

Figure 11-1. Public consultation on EDF's new nuclear power plants project, 2023. Image source: CNDP. https://www.debatpublic.fr/nouveaux-reacteurs-nucleaires-et-projet-penly/decouvrez-lavis-de-la-cndp-4603.

Figure 11-2. EDF's new nuclear power plants site, Penly, Normandy, 2023. Image source : CNDP. https://www.debatpublic.fr/nouveaux-reacteurs-nucleaires-et-projet-penly.

Figure 11-3. Consultation on the future of the energy mix, 2023. Source : CNDP's report on the future of the Energy mix, September 2023.

REPOWERING 2 TW OF PHASED-OUT COAL BY 2050 WITH CLEAN NUCLEAR ENERGY

THIS WORK WAS AUTHORED AS PART OF THE NICE FUTURE INITIATIVE IN COLLABORATION WITH TERRA PRAXIS.

THE CHALLENGE

In 2015, the world came together to sign the Paris Agreement (12.1), which states that, to limit global warming to 1.5°–2°C above pre-industrial levels and maintain Earth as a livable planet, we must reach net-zero emissions by 2050 at the latest.

More than 2,000 GW worth of coal-fired plants are operating in the world today, generating roughly 15 billion tons of CO_2 emissions per year. Should the coal fleet keep operating unabated, its emissions alone would exceed the 2°C commitment in the Paris Agreement. Mainstream climate thinking risks making an unrealistic assumption that countries will simply shut down their unabated coal plants (12.2). Most coal plants are young assets, and more than half are less than 15 years old (12.3). These plants deliver around 37% of global electricity supply and provide jobs, tax revenue, reliability to the electric power grid, and an enormous amount of electricity and industrial heat to drive economic growth. It is unclear whether these same benefits can be supplied by renewables, energy storage, or clean hydrogen. Land availability, transmission, and investment requirements also represent serious constraints to the clean energy transition being achieved at the necessary scale, cost, and speed.

THE OPPORTUNITY

Repowering coal fleets with clean generation offers a fast, low-risk, large-scale contribution to decarbonizing the world's power generation. Installing advanced heat sources, such as SMRs, to replace the coal-fired boilers at existing coal plants enables the continued use of existing infrastructure for emissions-free electricity generation. By sustaining permanent high-quality jobs for communities, repowered coal plants reduce the negative impacts on communities to help enable public and political support for a just transition. It also reduces the overall global investment required to transition to clean energy. As shown in a recent study by Scott Madden (12.3), aside from the difference in how steam is generated, a nuclear power plant is remarkably similar to a coal plant.

> "The actual transferability of skills is amazing between a coal plant and a nuclear plant. At the heart of it, what a nuclear plant does is boil water differently."
>
> – Maria Korsnick, President and CEO of the NEI4 (12.4)

The Clean Energy Ministerial's NICE Future Initiative, under its RISE^3 campaign, is convening governmental, industry, and nonprofit partners to examine practical solutions to decarbonization. The NICE Future partner organizations are looking into ways to accelerate coal plant repurposing.

For example, the nonprofit Terra Praxis is leading a REPOWER Consortium to repower coal plants with emissions-free heat sources at the speed and scale necessary to outcompete fossil fuels. REPOWER's radical innovation is a building system that consists of standardized, pre-licensed parts designed for manufacture which can be reconfigured to accommodate various regulatory requirements, heat sources, sites, and energy/heat demands. It uses a standardized heat transfer system and is designed to 'plug in' to existing plant infrastructure, reducing design work and costs. A seismic isolation system allows for multiple sites of varying seismic risk. The target cost of the system is $2,000/kWe. Target schedule is 5 years. REPOWER also includes a partnership with Microsoft

to provide AI and digital tools to quickly evaluate the business case for repowering a plant (EVALUATE); or reduce cost/time for licensing and permitting applications. The Gateway for Accelerated Innovation in Nuclear (12.6) and INL are conducting extensive research and providing support in feasibility analysis to repurpose coal plants in the United States. For example, a case study for the Colstrip site in Montana concludes that it is a potential location to transition from coal to nuclear. Colstrip (12.7) presents several attractive factors—like the benefits to the local community in terms of jobs and tax base.

This transition would provide a clean, firm, dispatchable form of electricity that can make use of the existing infrastructure, such as the grid connection and the cooling system (depending on which type of reactor design chosen).

THE BENEFITS

- Opportunity to accelerate and de-risk the clean energy transition while reducing the overall scale of investment required.
- Large public health benefits associated with eliminating coal-fired boilers and the associated pollution from toxic coal ash.
- Continued affordable, reliable, grid-scale electricity generation to support regional and national economic well-being and prosperity, without emissions.
- Advanced nuclear plants are expected to hire more professionals at a higher wage than the coal plants and with the potential to be long-lasting jobs (12.8). A case study from the U.S. Department of Energy has found that replacing 1,200 MWe of coal capacity with 924 MWe of nuclear capacity would create 650 additional and permanent jobs to the region (12.9).
- The increase in job opportunities, in turn, fosters economic growth in the local community around the power plant maintaining or even enhancing tax revenues (12.8).
- Potential for new energy services such as clean hydrogen production, heat supply, and direct air capture of CO_2.

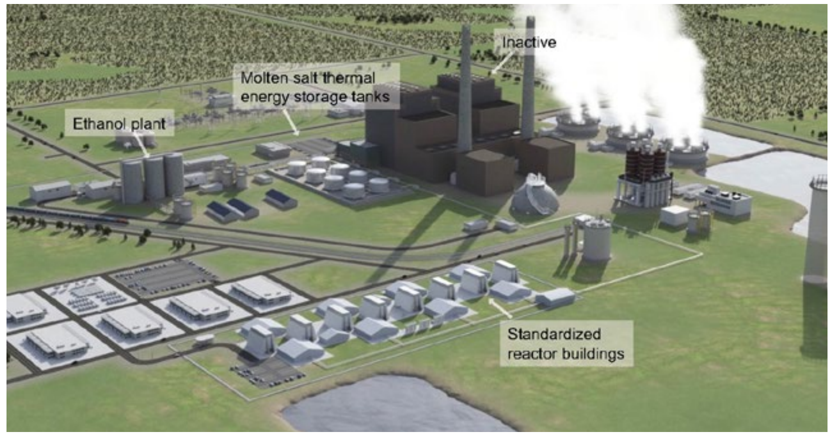

Figure 12- 1. Repowering coal case study of Coal Creek Station, conceptual repowering of a two-steam-unit, 1,200-MW electric plant with eight advanced reactors and thermal storage (turbine halls and storage units in the foreground). Image credit: Terra Praxis.

NEW DIGITAL PLATFORM

Coal-fired power stations could, depending on the case, be replaced by nuclear reactors (both large and SMRs), ensuring the equivalent production of electricity into the grid. Various initiatives can facilitate the fast, low-cost, and repeatable replacement of coal-fired plants with SMRs (12.11) such as standardized and prelicensed designs supported by automated project development and design tools with a set of purpose-driven digital applications and data exchange infrastructure for the building system to standardize and optimize:

- Site assessment and repowering feasibility
- Procurement, investment, and regulatory approval
- Construction and engineering systems
- Design, manufacture, assembly, and operation
- Increased collaborative interactions between supply chain organizations.

These applications are being developed to compress plant design and engineering from years to months or weeks and to leverage proven and demonstrated innovations in other sectors (12.12).

This large-scale solution to the world's largest single source of carbon emissions could repurpose trillions of dollars of existing infrastructure to continue supplying reliable energy without emissions and could advance ground-breaking progress toward net zero by 2050.

> "With these [advanced nuclear]

technologies now maturing, the next horizon is about their deployment, which is really a bridge to bankability for nuclear. And that's to me what we're really talking about here today, which is that we need a phased approach to the deployment of new nuclear that prioritizes speed to market."

– Jigar Shah, Director of the Loan Programs Office at the U.S. Department of Energy (12.10)

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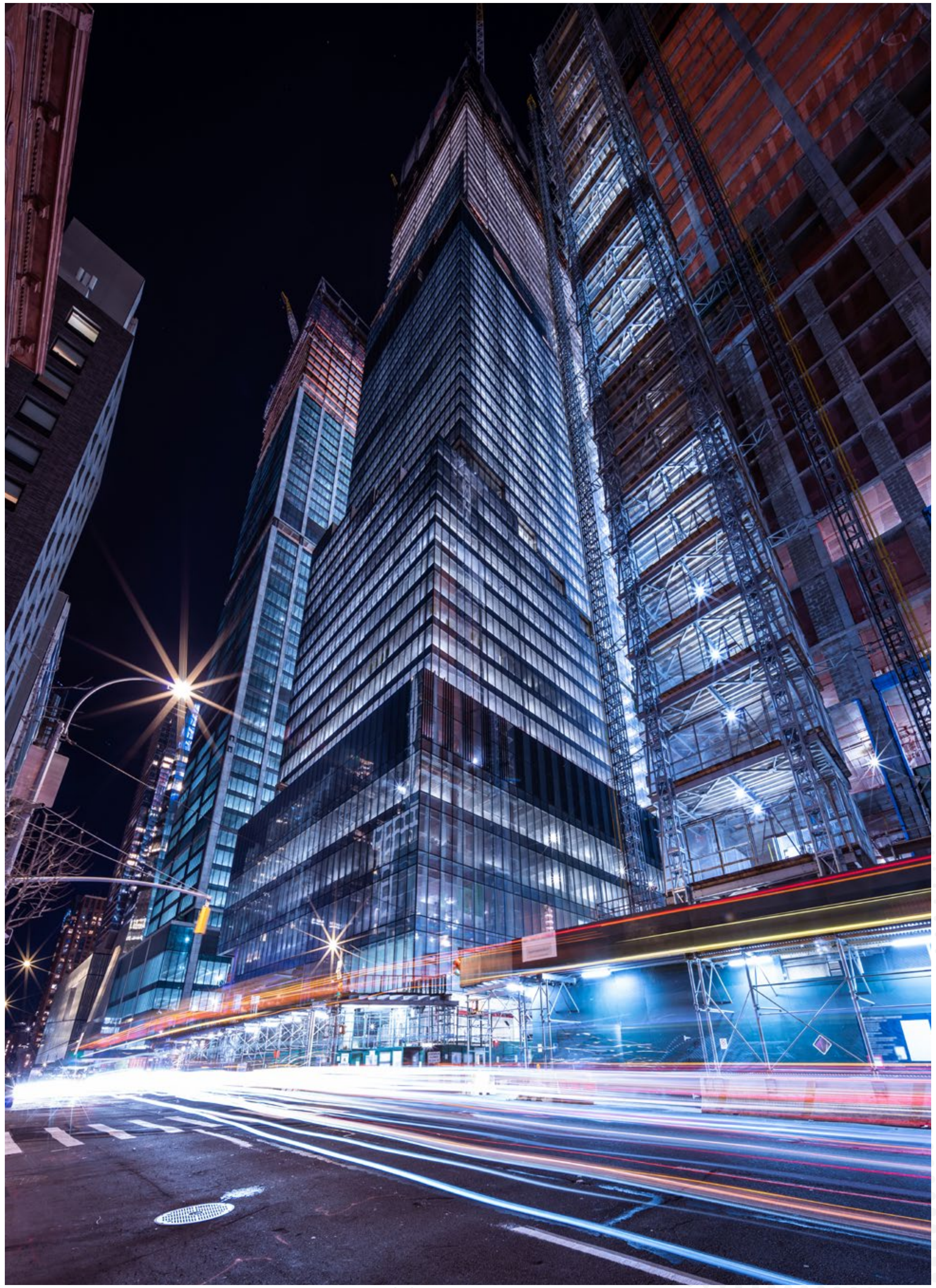

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COAL TO NUCLEAR (UPDATE)

MATT CROZAT, NUCLEAR ENERGY INSTITUTE

The following submission was adapted from slides presented by the Nuclear Energy Institute at the NICE Future Initiative townhall meeting on June 26, 2023. They have been included in this edition of RISE3D as a short update to their submission to RISE3D's first wave case study. You can find the first wave case study "Small Reactors with Big Impact: How SMRs can be a Solution for Transitioning Coal Communities" at: https://www.nice-future.org/docs/nicefuturelibraries/default-document-library/rise3d-case-study-series.pdf

COAL-TO-NUCLEAR TRANSITION

- Coal power plant shutdowns can be devastating to local communities.
- Transition to an SMR can provide carbon-free replacement power, while:
  - Capitalizing on existing infrastructure
  - Saving jobs
  - Supporting communities.
- Pursuing policy actions to encourage coal to nuclear.

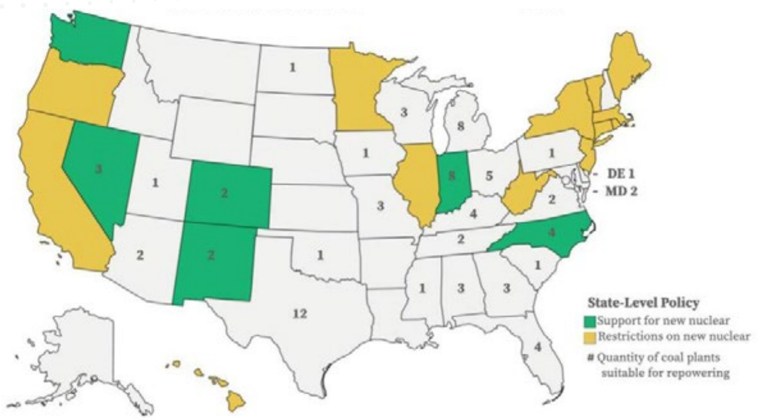

Figure 13- 1. Coal Plants Suitable for Repowering by an SMR. Source: 13.3.

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	Coal Site				NuScale SMR			
Job Type	On-Site Coal FTEs	Total Hourly Wages	Median Hourly Wage	Total Hourly Wages per MWe	On-Site SMR FTEs	Total Hourly Wages	Median Hourly Wage	Total Hourly Wages per MWe
Craft	34	$1,272.73	$37.36	$0.91	64	$2,810.65	$42.64	$3.04
Operators	25	$976.85	$37.19	$0.70	40	$1,846.60	$43.45	$2.00
Laborer	27	$681.25	$24.63	$0.49	55	$1,552.73	$25.35	$1.68
O&M Support	3	$104.09	$36.53	$0.07	49	$1,956.95	$41.74	$2.12
Supervisory	8	$403.20	$50.78	$0.29	10	$551.20	$55.12	$0.60
Professional	6	$280.25	$49.74	$0.20	14	$753.18	$52.96	$0.82
Senior Leadership	4	$263.42	$64.43	$0.19	5	$380.76	$75.62	$0.41
Total	107	$3,981.79	$37.19	$2.84	237	$9,852.07	$43.45	$10.66

Table 13- 1. New Nuclear Jobs (Source: 13.1)

COAL PLANT POSITION	# DEDICATED COAL POSITIONS	SMR POSITION	# DEDICATED SMR POSITIONS	DEGREE OF RETRAINING REQUIRED
Operations Supervisor	5	Senior Reactor Operator	5	High
Control Room Operator	10	Reactor Operator	15	High
Field Operator	15	Non-Licensed Operator	25	Low
Lab Operator/Chemistry/Scrubber	4	Chem Tech	14	Medium
Maintenance Supervisor	2	Maintenance Supervisor	3	Medium
Mechanical Craft	12	Mechanical Craft	21	Low
I&C [DB1] Craft	9	I&C Craft	10	Medium
Electrician Craft	5	Electrician Craft	11	Low
Technician	11	Technician	13	Low
Security Officer	20	Security Officer	48	Low
Subtotal	93		165	
All Other Positions	14		72	Medium
Total On-Site Positions	107		237	
Possible Centralized Positions			33	
TOTAL POSITIONS			270	

Table 13- 2. Jobs at Nuclear and Coal Plants (Sources: 13.1; 13.6)

REPURPOSING COAL PLANTS: AN INNOVATIVE WAY FOR LOCAL COMMUNITIES TO THRIVE

THIS WORK WAS AUTHORED AS PART OF THE NICE FUTURE INITIATIVE IN COLLABORATION WITH TERRA PRAXIS.

Climate change is, by and large, an energy problem. More than two-thirds of anthropogenic (human-caused) emissions come from burning fossil fuels for energy and transportation. In the 2015 Paris Agreement on climate change, most nations pledged to try to keep global warming under 2°C or even under 1.5°C (14.1).1 Left unchecked, climate change of 3°C or more will wreak havoc on the world's ecological systems, which would have enormous consequences for people and nature.

The world's energy sector is undergoing a profound transition to achieve these emissions reduction goals and expand access to clean energy in support of socioeconomic development, especially in emerging economies, while at the same time limiting the impacts of climate change, pollution, and other unfolding global environmental crises.

The urgency and scale of the needed emissions reductions cannot come at the cost of the future prosperity of developing nations. Access to energy is a fundamental requirement for socioeconomic

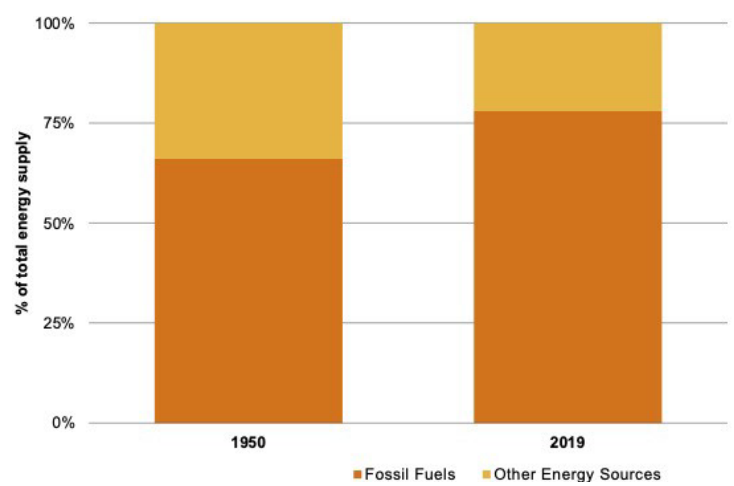

Figure 14- 1. Percentage of energy supply, fossil vs. other, 1950–2019 (14.2)

development, improved quality of life, education, longer life expectancy, and lower maternal and child mortality rates. Increased levels of wealth and development also reduce people's vulnerability to the adverse effects of climate change.

The challenge of transforming the energy sector can be described as an "energy trilemma."(14.3) It is crucial for energy to not only become clean but also affordable and reliable. These three elements are vital to preventing global catastrophe while meeting basic needs such as health care, welfare, education, and security, while enabling every country to share in global prosperity.

The United Nations Sustainable Development Goals call for a swift and unified approach to addressing societal needs (14.4). Currently, most of the world's population resides in impoverished countries, where over 85% of individuals survive on less than $30 per day (adjusted for purchasing power parity).

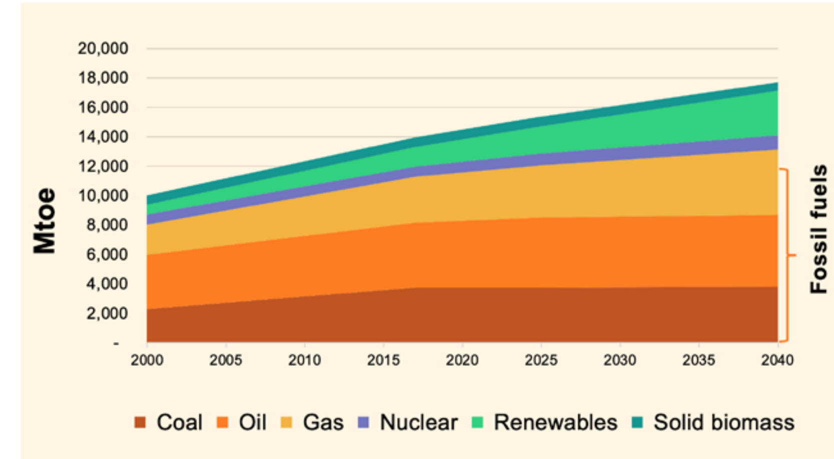

Figure 14- 2. IEA stated policies by scenario: world energy by source (14.2)

Analysis by Our World in Data suggests that the global economy would need to expand fivefold to achieve a significant reduction in poverty.

A transition from polluting energy sources to sustainable alternatives is necessary to ensure that these goals are met. According to most 1.5°C pathways, a 45% reduction in annual emissions from 2010 levels is needed by 2030.6 Annual emissions have instead increased from 2010 to 2019, making it impossible to reduce emissions rapidly enough to achieve the desired goal.

Coal-fired power plants are the primary source of global CO_2 emissions, resulting in immense pressure to close them down.

However, many of these power plants are relatively new assets (less than 15 years old) and have the potential to operate for another 50 years. In addition to providing reliable energy access, these power plants also generate employment opportunities and contribute to socioeconomic development.

Furthermore, new coal power plants are under construction or in the planning stages in several developing countries, particularly in Southeast Asia and Africa. Halting the operation or canceling the construction of these coal plants would have a significant impact on the growth and development of regional economies. Many of these countries are already exposed to the impacts of climate change and urgently need new energy infrastructure to strengthen their resilience against increasing risks.

Currently, coal remains a crucial energy source and driver of economic growth in both developed and developing countries. Despite international climate agreements to "phase down" the use of coal (14.8). Global consumption of coal has reached unprecedented levels, contributing almost one-third of global net annual CO_2 emissions.

The RISE[3] campaign within the NICE Future Initiative, under the Clean Energy Ministerial, together with its partner organizations and member countries, seeks to address these challenges.

RISE[3] is exploring the potential to repurpose retired coal plant sites with carbon-free, reliable, and resilient clean energy sources, such as nuclear energy. This would enable local communities that depend on coal plants for employment and tax revenue to continue to thrive. Closing these plants would result in job losses and economic stagnation for surrounding communities, losses of trillions of dollars of infrastructure investments, and reduce availability of reliable and resilient energy and transmission.

BENEFITS OF REPURPOSING COAL

Repurposing coal plants can enable a just transition in communities and provide many benefits, including: (14.10)

- Workforce retention due to high skills transferability
- Creation of new, well-paid jobs
- Potential developmental paths for current coal plant workers where there are no equivalent jobs nuclear power plant (e.g., reactor operators and radiation technicians)
- Higher salaries relative to coal plant job equivalents
- Establishment of long-term jobs (more than 40 years)
- Maintenance and growth of a vibrant local economy
- Growth of local tax revenue
- Encouragement of outside investment (e.g., govern-ments, corporations.

REPURPOSING COAL PLANTS FOR A JUST TRANSITION

Governments and utilities around the world are exploring the potential for emissions-free heat sources (such as SMRs) to replace coal boilers at retired coal plants. Replacing the coal boiler with a new source of heat can enable continued operation of the power plant with a new supply of clean steam, eliminating harmful air pollution and other environmental impacts from coal while maintaining employment and community benefits.

CLIMATE STRATEGIES WITH ENVIRONMENTAL JUSTICE AT THE HEART

A just transition should enhance human well-being, health, and capabilities; increase resilience; drive innovation toward a sustainable society at all levels; and spur economic growth and prosperity. Increasing access to clean, reliable, and affordable energy is fundamental for quality of life, health, and well-being and must be at the heart of global strategies to decarbonize global energy infrastructure.

Universal access to affordable clean energy is the focus of the United Nations Sustainable Development Goal 7. Despite some progress in increasing energy access, the Energy Progress Report for Goal 7 indicates that 733 million people still do not have access to energy in 2021, compared to 1.2 billion lacking access in 2010 (14.11). Ensuring a just transition with expanded access to clean energy is a key tenet of the RISE³ mission.

Repowering existing coal plant infrastructure by replacing coal-fired boilers with advanced nuclear energy offers a fast, low-risk path to decarbonizing global power generation.

Repurposing the global coal fleet could enable a just and efficient transition by offering communities that currently depend on coal-fired plants energy, jobs, and tax revenues retention or even improvement upon these critical benefits—providing them with the opportunity to prosper and become indispensable to the emerging clean energy economy.

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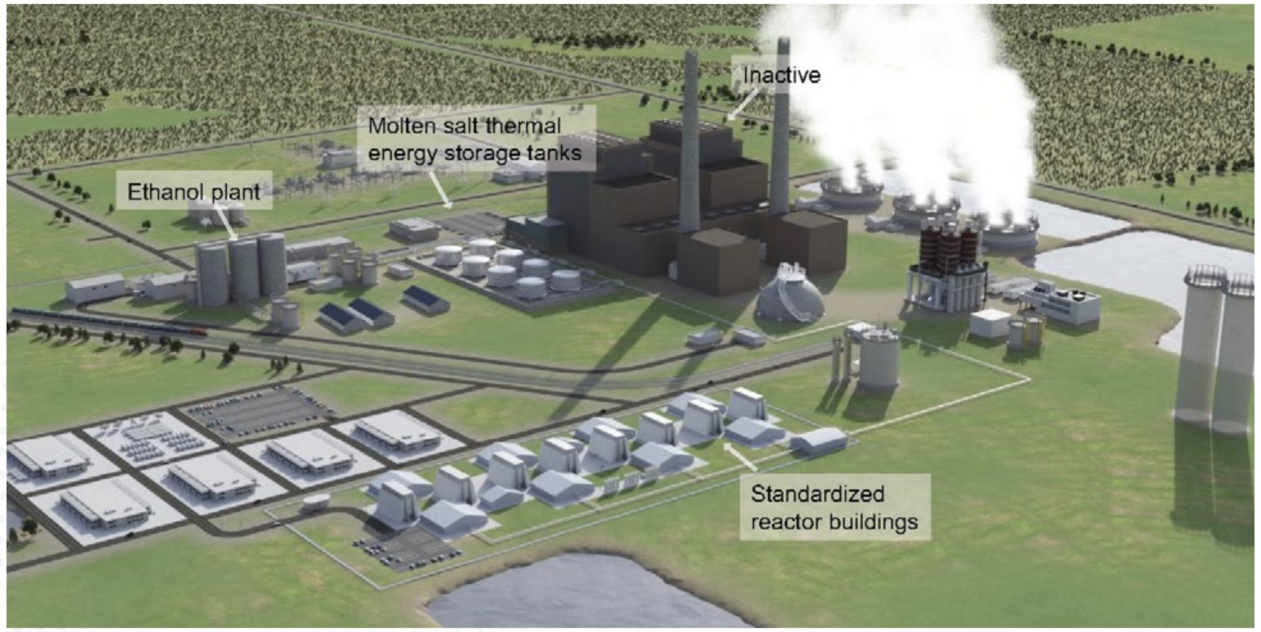

Figure 14- 3. Rendering of a repowered 1,200-MWe, two-steam-unit plant (14.9).

Photo from Getty Images 1316895024

CLIMATE SOLUTION FACTSHEET: FOUR SOLUTIONS FOR ACHIEVING NET ZERO BY 2050

THIS WORK WAS AUTHORED AS PART OF THE NICE FUTURE INITIATIVE IN COLLABORATION WITH TERRA PRAXIS.

Achieving Net Zero will be difficult, even if we use all zero-carbon energy technologies currently available. The challenge is not only to build enough clean electricity generation to power the world without associated environmental emissions, but to do so quickly while also building the infrastructure required to decarbonize end-use sectors such as heat, industry, and transport.

This NICE Future Initiative RISE³ campaign (15.1) factsheet describes four potential solutions that can help de-risk and accelerate the path to Net Zero (15.2).

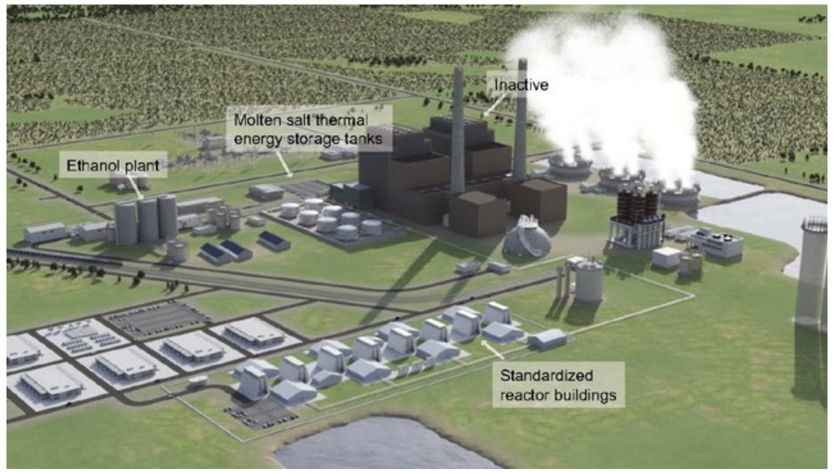

Figure 15- 1. Repowering coal case study: two-steam-unit, 1,200-MWe plant (15.5)

1. REPOWERING COAL

Repowering coal could offer a fast, large-scale, low-risk, and equitable contribution to decarbonizing the world's power generation.

Coal plants currently produce almost one-third of total global carbon emissions (15.3). Repowering the existing coal plant infrastructure is therefore the largest single carbon abatement opportunity on the planet. Repowering coal plants could also enable a just transition to clean energy by sustaining the jobs and local tax revenues associated with existing coal plants and providing larger social, economic, and environmental benefits associated with continued reliable and flexible electricity generation, as well as the continued use of existing infrastructure, including transmission lines—without emissions.

Replacing coal-fired boilers at existing coal plants with carbon-free advanced heat sources (SMRs, including small modular and advanced fission and fusion reactors) means that these power plants can generate carbon-free electricity rather than carbon-intensive electricity. This would quickly transform coal-fired power plants from polluting liabilities facing an uncertain future into jewels of the new clean energy transition—an important part of the massive and pressing infrastructure buildout needed to address climate change.

Converting 5,000–7,000 coal plant units globally between 2030 and 2050 (250–350 per year) will require a redesigned delivery model to meet this rate of deployment. To be successful, the deployment model has to de-risk the construction process, which can be the riskiest part of a project. Purpose-built automated tools can enable rapid, repeatable, and reliable project assessments to de-risk and facilitate initiation and completion of repowering projects.

Repurposing the majority of existing coal plant sites and infrastructure, including transmission, and maintaining the workforce employed today, would dramatically reduce the investments and effort required to site, plan, build, and connect new infrastructure (Figure 15- 1 shows a rendering of a repowered 1,200-MWe plant [15.5]).

Rather than closing these carbon-intensive and polluting power plants, repowering them with advanced heat sources would retain many permanent high-quality local jobs. Overall, repowered coal plants could reduce many of the negative impacts on communities to help enable public and political support for a just energy transition.

2. FLEXIBLE GENERATION

New advanced heat sources can do more than just provide reliable, clean electricity. They can offer added flexibility for power grids, decarbonize heating and industrial processes, and produce low-cost hydrogen and synthetic fuels. A helpful feature of some advanced designs is the separation of the heat source (reactor) from the turbine-generator that produces the electricity (called the power island) via a thermal energy storage and transfer system.

Thermal energy storage systems allow the heat sources to operate continuously at full capacity, while charging the thermal battery energy storage system. This enables the plant to operate flexibly, much like hydro or natural gas plants, enabling higher penetrations of variable renewable energy in support of lower overall system costs and emissions.

Decoupling the heat (nuclear) island from the power island creates other benefits, such as a smaller, more-focused scope for nuclear regulatory oversight, lower relative costs (and construction risks) for the turbine island and balance of plant, a shorter project schedule by leveraging opportunities for parallel construction, and greater overall certainty of cost and schedule.

Flexible advanced reactors—in combination with wind, solar, and hydro—can therefore make a substantial contribution to building reliable, responsive, affordable, and clean energy systems supplying clean dispatchable power-generating capacity.

3. HYDROGEN COGENERATION: ELECTRICITY, HEAT, AND HYDROGEN

Currently, 65% of the energy that nuclear power plants produce ends up in the cooling water (15.8). Cogeneration, or the production of both electricity and heat, can enable the more-efficient and flexible use of power plants.

While a normal power plant can usually turn 35% of the heat it produces into useful energy (electricity), a cogeneration plant can utilize well over 80% of the heat it produces—supplying a combination of electricity, high-quality process steam, and low-quality heat for district heating or desalination. For heat-only plants and applications, the total efficiency is almost 100%. Cogeneration increases flexibility, as it can allow a plant to switch seamlessly between electricity and other applications.

Cogeneration of power and heat, or power and hydrogen, for example, where hydrogen is an intermediate product, can increase the overall efficiency and economics of nuclear plants while decarbonizing heat that can be provided to industry and other heat users.

Heat production, in turn, can be used for other products.

Low-Temperature District Heating

Low-temperature district heating (80–120°C) is a form of cogeneration with only a relatively small effect on electricity generation. A lot of valuable heat that is otherwise rejected to the cooling system can instead be delivered to homes and businesses. Space heating and hot water represent a surprisingly large share of energy use (up to one-third in Europe). District heating offers one solution for reducing carbon emissions by providing space and water heating (and potentially cooling) for a city, town, or district from a large central heating source through a network of pipelines.

Hydrogen and Synfuels

Hydrogen-based synthetic fuels (synfuels) are economically promising "drop-in" alternatives for decarbonizing hard-to-abate sectors such as industry and heavy transport. Hydrogen-based fuels are made by combining hydrogen separated from water with carbon extracted from the atmosphere using carbon capture technology. Hydrogen derived from water electrolysis is emissions-free and entirely renewable, as it is returned to water upon combustion. Today, hydrogen is used in oil refining and ammonia manufacturing, but it is primarily produced using fossil fuels in a process called steam methane reforming, resulting in significant emissions. If clean hydrogen were used to produce synthetic fuels (hydrocarbons or ammonia) on a large scale, these could replace fossil fuels in many sectors that are difficult to electrify, such as aviation and shipping (15.6).

However, getting to costs below $1/kg hydrogen (15.7) within this decade will be a major challenge. The next section describes how new delivery models for advanced heat sources could help achieve these very low hydrogen production costs.

4. DEDICATED HYDROGEN/SYNFUELS PRODUCTION (15.7)

Two strategies are presented here for large-scale low-cost hydrogen and synfuels production with nuclear energy. The first "brings the factory to the project." The second "brings the project to the factory."

The Hydrogen Gigafactory

The refinery-scale hydrogen gigafactory is an "energy park" combined with an integrated manufacturing facility. The strategy is to bring the factory to the project to supply the needed heat and power, equipment, and facilities that can streamline manufacturing, operations, and maintenance. One gigafactory can house dozens of heat sources, which can be manufactured on-site. Each reactor could produce hundreds of megawatts of capacity used for hydrogen production.

For countries developing such refinery-scale facilities, the hydrogen gigafactory represents an opportunity to establish a world-class domestic supply chain capability, the potential to export synthetic fuels, and the potential to achieve affordable decarbonization. Simplified heat source designs and factory setting minimize installation labor costs and enable the application of fast, high-quality manufacturing techniques; streamlined licensing is enabled by reusable designs and repeatable processes in a standardized factory, managed by fixed teams, operating continuously enabling the hydrogen gigafactory to deliver large quantities of very low-cost hydrogen, eventually enabling a path to ultra-low-cost hydrogen at the target price of less than $1/kg (Figure 15- 2).

Figure 15- 2. Rendering of a hydrogen gigafactory. Image by Terra Praxis.

Shipyard-Manufactured Production Platforms

The second strategy for producing cost-competitive hydrogen is the shipyard-manufactured production platform, which brings the project to the factory. This route builds hydrogen production facilities in the form of a ship—at a shipyard. Such ships would be called floating production, storage, and offloading facilities. The proposed form uses onboard high-temperature nuclear reactors to generate heat and electricity, which are integrated with onboard hydrogen production equipment.

The hydrogen produced on the ship can be used to make synthetic hydrocarbons or ammonia, which can be used to fuel marine vessels or transported for other uses. The key innovation is transforming the currently unproductive, risky, and expensive construction-at-place method of delivering facilities to a highly productive shipyard environment.

Floating production ships come with the benefit of offshore siting (Figure 15- 3), adding flexibility. This bring-the-project-to-the-factory approach dramatically improves productivity; adds innovation, modularity, and state-of-the-art manufacturing methods; lowers costs; and makes quality control easier due to the streamlined factory production process, creating easy-to-manage quality checkpoints at different stages while maintaining strict regulation of nuclear power components. Currently, idle shipyard capacity is high around the world. These idle shipyards could provide critical economic development by serving as the basis of a new industry that attracts investment, boosts employment, generates clean energy, and contributes to decarbonization. Floating production, storage, and offloading facilities close to shore could also be configured to produce electricity and desalinated water—enabling low-cost and low-carbon energy services for countries that still lack the necessary institutions and expertise to have domestic nuclear programs.

Decarbonizing Oil and Gas

The rapid achievement of low-cost hydrogen via these innovative delivery models could accelerate deep decarbonization across sectors currently using oil and gas. By 2050, low-cost clean hydrogen could help avoid cumulative emissions on a scale measured in the hundreds of gigatons, equal to years, if not a decade's, worth of current global emissions.

The floating production, storage, and offloading facility model could also be used to produce other liquid fuels, including jet fuel, gasoline, and diesel. These scenarios utilize existing and proven chemical technologies and production processes; no further discovery or innovation is needed,

although some technologies, such as high-temperature steam electrolysis, would need to be brought to commercial scale. The resulting commodities would be drop-in substitutes—not requiring major changes to existing supply chain infrastructure, regulations, or behavior.

CONCLUSION

Current and emerging advanced nuclear reactors can do more than just provide reliable, clean electricity. They can offer added flexibility for power grids, decarbonize heating and industrial processes, and produce low-cost hydrogen and synthetic fuels. The next decade will be critical for dramatically increasing clean energy generating capacity by applying innovative deployment models such as the ones described in this section.

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Figure 15- 3. Conceptual ammonia bunker offloading ammonia from a production platform. Lucid Catalyst Graphic.

CLIMATE SOLUTION FACTSHEET: ENERGY SYSTEMS MODELING 2.0

THIS WORK WAS AUTHORED AS PART OF THE NICE FUTURE INITIATIVE IN COLLABORATION WITH TERRA PRAXIS.

The NICE Future Initiative launched its RISE³ campaign in 2022, building a partnership amongst governments and the nuclear energy, renewables, nonprofit, and academic communities to accelerate the adoption of environmentally just clean energy solutions. This report section proposes a way of modeling the clean energy transition that includes all carbon-free alternatives—renewables and nuclear energy.

In 2021, Aurora Energy Research published a report (16.1) summarizing a modeling effort that showed how renewables and nuclear cost effectively produced the hydrogen needed to achieve a U.K. Net Zero economy. The results highlighted the remarkable cost-effectiveness of using nuclear energy to produce hydrogen, which led to a dramatic reduction in the amount of land and infrastructure needed. At the same time, it eliminated dependence on fossil fuels, lowered emissions, and reduced the overall system cost of achieving U.K. net zero. Using the same nuclear-plus-renewables modeling approach, this study can be extended to other regions.

This Aurora Energy Research model is one of the first energy system modeling efforts to fully represent the potential for nuclear energy (also referred to as "advanced heat sources") to supply clean, flexible generation, cogeneration of heat, and hydrogen production using high-temperature steam electrolysis. The findings show the transformative potential of using advanced heat sources to de-risk and lower the cost of achieving net zero. Importantly, the Aurora Energy Research model also highlights a path to full decarbonization that does not require full electrification of end uses by 2050.

The results of Aurora Energy Research's modeling exercise reveals three ways in which nuclear energy can complement the mainstream strategy of using renewables to decarbonize the electricity sector and end-use electrification:

1. Advanced heat source generators provide flexible, load-following dispatch, which complements variable output from renewables. This enables higher penetrations of wind and solar while reducing (or eliminating) the need for energy storage or natural gas-fired generation.
2. Electrolytic hydrogen is often considered a use of electricity that competes with electrification of various end uses. The Aurora Energy Research study highlighted the benefit of using advanced heat sources to flexibly produce electricity when needed by the grid and produce hydrogen when grid electricity is not needed.
3. Using advanced heat sources exclusively to produce large quantities of hydrogen and synthetic fuels can decarbonize existing end uses that are currently difficult to electrify and parts of the system lagging in the electrification process.

Together, these pathways can enable a cost-effective, timely transition to a net-zero economy and substantially reduce the existential risks to the energy transition that most mainstream modeling efforts are failing to capture.

INNOVATIONS FOR MODELING 2.0

Most mainstream energy models are optimized based on cost and do not include concepts related to deployment feasibility or the performance of innovative technologies across the whole energy system (e.g., large dedicated hydrogen production facilities powered by advanced heat sources).

Four major innovations in energy modeling could help improve the utility of the results and highlight alternative pathways to achieving net zero that are smaller in scope, less risky, and lower-cost. We have dubbed this evolution in modeling "Modeling 2.0." Incorporating these innovations could lead to a profound shift in the discourse on how we think about the risk, cost, and probability of decarbonizing by midcentury. The following list presents five shortcomings in current modeling approaches and offers related recommendations or possible innovations.

Innovation 1: "Feasibility Guardrails" To De-Risk the Transition

Current energy models offer critical guidance about the quantities of generation capacity and related infrastructure by certain dates. However, these models are only optimized on cost and ignore real-world risks and challenges related to project development (e.g., public acceptance, raw materials availability). The magnitude of infrastructure needed in a relatively short time demands that energy models expand beyond cost optimization to include factors that can substantiate achievable deployment rates and scenarios that can be prioritized by risk.

Recommendation 1: Modeling net-zero scenarios should include feasibility measures to anticipate and mitigate risks to achieving deployment at the required speed and scale. All proposed deployment assumptions should be subject to feasibility guardrails related to cost, speed, scale, space, and supplies.

Innovation 2: "Flexgen" Power, Heat, Hydrogen

We must decarbonize every sector of the economy, not just the electricity sector. The next generation of advanced reactors are being designed for flexible cogeneration (flexgen), to enable the highly economical production of multiple energy services (16.2). Flexible cogeneration—resources capable of producing hydrogen, heat, and power—enables low-cost hydrogen production and load-following/grid-balancing services, which improves plant economics and lowers the cost of energy to the system. Flexible advanced heat sources—in combination with wind, solar, and hydro—can make a substantial contribution toward reliable, responsive, affordable, and clean energy systems.

Figure 16- 1. Rendering of a hydrogen gigafactory. Image by Terra Praxis.

Recommendation 2: Modeling should represent the potential for flexible and cost-effective cogeneration of power, heat, and hydrogen in support of full decarbonization across the whole energy system.

Innovation 3: High-Temperature Steam Electrolysis

Hydrogen production via high-temperature steam electrolysis can produce as much as 30% more hydrogen for the same electrical input as low-temperature water electrolysis—even when using "low-temperature" nuclear (e.g., light water) reactors. Furthermore, it can be produced at approximately half the cost of low-temperature water electrolysis systems. Larger plant sizes also enable dramatic cost reductions for electrolyzer plants. Nuclear energy's high-capacity factor results in higher utilization of the electrolyzer facility, which is a major contributor toward lowering costs. Keeping the system hot when not in use is easy for a nuclear plant and enables operational flexibility and efficiency. Several companies are now demonstrating and commercializing high-temperature steam electrolysis technology (16.3; 16.4).

Recommendation 3: Modeling should represent the transformative role of large, low-cost, high-capacity factor, high-temperature electrolysis to eliminate risks to the clean energy transition related to needed cost and scale of hydrogen supply.

Innovation 4: Dedicated Large-Scale Hydrogen Production

Large-scale hydrogen production is needed to reduce the cost to the clean energy transition and lower emissions and dependence on fossil fuels. An example: large-scale hydrogen production is possible with the potential emergence of gigafactories. These factories are designed to be replicated quickly in new locations and are a useful high-volume, low-cost manufacturing model that can be applied to hydrogen production. A hydrogen gigafactory, powered by advanced heat sources, could be built, and integrated with a large, liquid fuels production facility.

The gigafactory model enables a highly integrated manufacturing, assembly, installation, and production process on one site—enabling high-quality, repeatable processes with quality assurance designed into every step of the process. Capital and operating costs are radically reduced by streamlining manufacturing, operations, and maintenance. At full production rate, a factory could be designed to produce twelve 600-MWth reactors per year, equivalent to approximately 3 GW of electricity to power hydrogen production. The hydrogen produced by the gigafactory could be either supplied directly to the gas networks or to a synthetic fuels plant on an adjacent site. The hydrogen gigafactory technology is proposed as a next-generation refinery located on brownfield sites, such as large coastal oil and gas refineries.

Recommendation 4: Modeling should represent the transformative role of refinery-scale, low-cost giga-scale hydrogen and synthetic fuels production utilizing advanced heat sources manufactured at scale.

CONCLUSIONS

Modeling often focuses on narrow issues that reflect the modeler's expertise or on-hand data. Modeling 2.0 seeks to emphasize modeling's goal of informing policymakers. Policymakers must contend with all interrelated matters, upstream and downstream, of the energy transition. A particularly salient and challenging aspect that NICE and RISE[3] asks modelers to consider and research is assessing and including the relative feasibility of paths forward.

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AMR RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM: BUILDING A NET-ZERO FUTURE USING THE PAST

UK DEPARTMENT OF ENERGY SECURITY AND NET-ZERO

The United Kingdom has a rich nuclear heritage, and as humanity collectively looks toward how to build a net-zero world, the Department for Energy Security & Net Zero is using the lessons from the past to drive the future. The Advanced Modular Reactor (AMR) research, development, and demonstration program is looking to drive deep decarbonization across the breadth of the U.K. economy by developing an AMR demonstration by the early 2030s. The United Kingdom defines AMRs as technologies that utilize novel coolants and fuels, defined as Generation IV reactors internationally.

Funded through the Department's £1 billion Net Zero Innovation Portfolio (17.1), the AMR program is focused on high-temperature gas reactors, based on a call for evidence from industry within the United Kingdom, as well as modeling and analysis by the Nuclear Innovation Research Office, which laid out that high-temperature gas reactors are the optimal solution for the United Kingdom (17.2).

Development of this technology is not new to the United Kingdom; the DRAGON Reactor in Winfrith was completed in 1964 and operated from 1965 until 1975 (17.3). The site is currently in the final stages of decommissioning, but there are valuable lessons to learn and apply to the next generation of reactor designs.

The United Kingdom is harnessing this nuclear heritage, as well as the latest developments, to accelerate the demonstration program, which aims to showcase three key aspects to advance the development of high-temperature gas reactors at the commercial level:

- Modular build alongside advanced manufacturing techniques
- Safe and secure operation
- Ability to safely offtake high-temperature heat.

The program also aims to leverage the wealth of experience within the United Kingdom about gas-cooled reactor systems. High-temperature gas reactor designs are capable of safely producing high-temperature heat in the range of 750–950°C, which may help decarbonize hard-to-abate sectors of the economy—a key global challenge on the road to net zero. The elevated temperature means that AMRs could be a key part of industrial decarbonization.

Phase B of the AMR research, development, and demonstration program is now running, with two design developers. Ultra Safe Nuclear Corporation U.K. and the U.K.'s National Nuclear Laboratory secured funding until March 2025 to develop front-end engineering designs, identify key research and development, and grow capability and skills for a future Phase C. Phase C, which is subject to a future funding decision, envisages a down-selection for a demonstrator to license, construct, and commission by the early 2030s. The National Nuclear Lab was also awarded funding to continue the development of U.K. coated particle fuel, which is a key factor in the enhanced safety of high-temperature gas reactors. To ensure the knowledge from legacy programs such as DRAGON are not lost, Ove Arup has been awarded funding to undertake a knowledge capture program, which will support the acceleration of both the AMR research, development, and demonstration program and coated particle fuel.

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ALFRED: THE LEADING FAST REACTOR TECHNOLOGY DEMONSTRATOR (UPDATE)

DR. DANIELA DIACONU, ILIE TURCU, RATEN-ICN (REGIA AUTONOMA TEHNOLOGII PENTRU ENERGETICA NUCLEARA – INSTITUTUL DE CERCETARI NUCLEARE/TECHNOLOGIES FOR NUCLEAR ENERGY STATE OWNED COMPANY – INSTITUTE FOR NUCLEAR RESEARCH, ICN IS A SUBSIDIARY OF RATEN)

The following submission was adapted from slides presented by RATEN-ICN at the NICE Future Initiative townhall meeting on June 26, 2023. They have been included in this edition of RISE3D as a short update to their submission to RISE3D's first wave case study. You can find the first wave case study "The ALFRED Project" at: https://www.nice-future.org/docs/nicefuturelibraries/default-document-library/rise3d-case-study-series.pdf

HIGH-LEVEL SUMMARY AND UPDATES ON CURRENT CASE STUDY: SUPPORT INFRASTRUCTURE

- ATHENA: Lead thermal hydraulic research and testing facility under construction (deadline December 2023):
  - First significant involvement of domestic/local industry: 35%–40%
  - Operation team assignment and training: 18 people.
- Remaining planned support infrastructure (HELENA-2, ELF, Hands-ON, Meltin'Pot): funding approved (European Union structural funds), contractual documentation under preparation; deadline for commissioning 2026–2027:
  - Local and national contributions for completion of the feasibility studies, project management configuration.
- Research activities on lead fast reactor technology:
  - Refining research agenda for support infrastructure and lead fast reactor technology
  - Ongoing RATEN research program
  - Cooperation in the frame of the European and international initiatives, networks, and projects
  - Safety-related research
  - Education and training of young researchers; cooperation with universities
  - Licensing framework preparation:
  - Lead fast reactor technology familiarization webinars (10) with Romanian regulatory body (CNCAN).
- Investigations and initiatives for enlarging FALCON consortium
- Continuous support from Mioveni local community and beyond.

CHALLENGES

- Long-term project
- Major investment
- International environment
- Needs for human resources and competence-building
- Licensing process complexity.

NEW DOCUMENTS/CASE STUDIES

RATEN is involved in the Romanian nuclear power program with research topics and specific support services needed for highly demanding objectives related to:

- Life extension of Unit 1
- Construction of Unit 3 and 4 at Cernavoda
- SMR development.

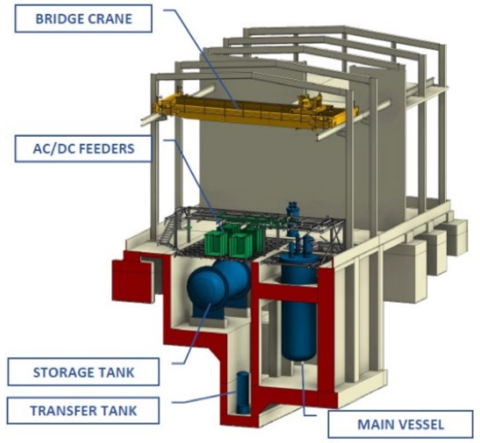

Figure 18-1. Rendering of the ATHENA facility. Graphic provided by Ilie Turcu.

Figure 18-2. Installation of the main vessel of the ATHENA facility. Photo provided by Ilie Turcu.

Figure 18-3. Construction of the ATHENA facility. Photo provided by Ilie Turcu.

Figure 18-4. Construction of the ATHENA facility. Photo provided by Ilie Turcu.

"For the UK, as for a growing number of other countries, it is clear that nuclear power will have a key role to play in our future energy mix as it is one of the most secure, reliable and low-carbon sources of power in the world. We are proud to be a member of the NICE Future Initiative and Co-lead of the Leaders in Advanced Nuclear Energy (LANE) Technical Working-Group, to drive tangible action and meaningful conversations on the role of nuclear energy in integrated energy systems. Not only is nuclear power able to produce electricity at such a small footprint, when you consider the potential of Small and Advanced Modular Reactors, which could revolutionise the transport system or industrial sectors that have been difficult to decarbonise historically, it is clear that nuclear must be part of our Net Zero strategy. And to do this successfully, we must look across national and sectoral boundaries to truly leverage the atomic potential of nuclear power. The UK stands ready to work with Participants and Partner Organisations to make this vision a reality.

Chris Heffer
Director of Nuclear Power, Infrastructure, and Decommissioning at the Department of Energy Security and Net-Zero, United Kingdom

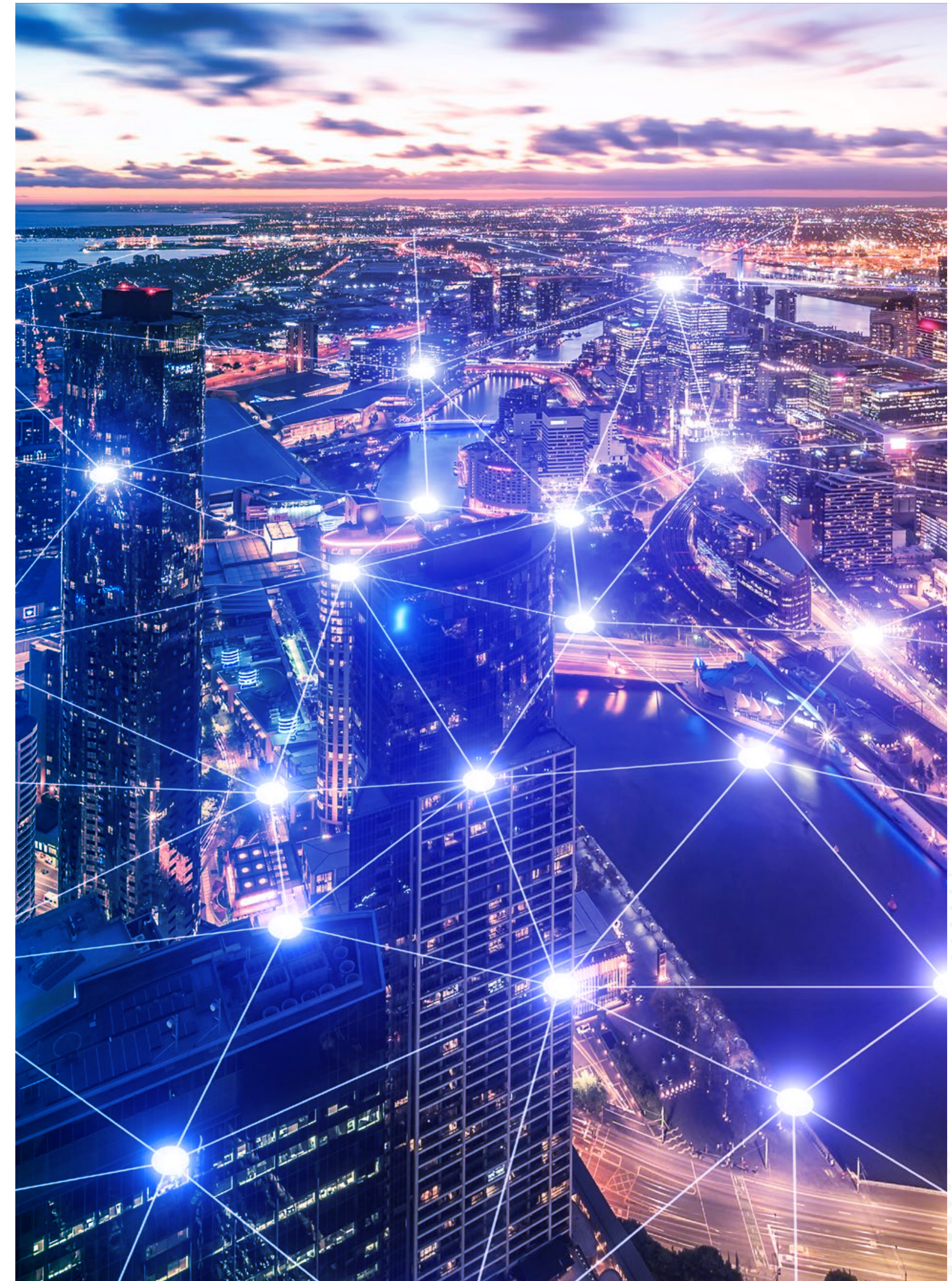

Photo from Getty Images 1135549238

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ISBN: 979-8-9887248-1-0