NICE Future
Nuclear Innovation: Clean Energy Future

An Initiative of the Clean Energy Ministerial

Actions to Enable Flexible Nuclear Energy

Key findings and possible actions identified by the Expert Working Group to the Nuclear Innovation: Clean Energy Future (NICE Future) initiative's Flexible Nuclear Campaign for Nuclear-Renewable Integration (FNC) held on April 19, 2021.

Flexible Nuclear Energy

Flexible nuclear energy is defined as the ability of nuclear energy plants to economically provide energy services at the time and location they are needed by end users. These energy services can include:

- **Operational flexibility:** Adjusting how much power is produced to effectively meet variable grid demand, particularly in a high renewable energy system.
- **Deployment flexibility:** Deploying nuclear on the giga, mega, or kilowatt scale that meets customer-preferred size and location of energy services.
- **Product flexibility:** Using nuclear-generated energy to support both electric and nonelectric applications, utilizing both traditional and advanced nuclear power plants and integrated systems.

Flexible Nuclear Campaign

The purpose of the FNC, a campaign of the NICE Future initiative, is to understand and clarify opportunities for the expanded roles that flexible nuclear energy can play in contributing to a clean energy system. Variable renewable energy is becoming an important part of many countries' short- and long-term clean energy plans. The FNC seeks to better understand how electric and nonelectric applications of flexible nuclear energy can complement and enable the deployment of variable renewable energy to support long-term clean energy goals.

To better understand the diverse ways in which flexible nuclear energy is being utilized and planned, the FNC has worked with experts from over 10 countries and 30 organizations to research, publish, and communicate the roles flexible nuclear energy is playing today and could play in the future.

Flexible Nuclear Workshop Takeaways

Over 50 experts from a dozen countries joined an April 2021 workshop to discuss and identify barriers to the deployment of flexible nuclear energy. Topical areas for further work identified include:

- Quantification of the value of flexibility, reliability, and resilience of dispatchable clean energy sources
- Compensation for energy system services
- Expanded modeling capabilities
- Expanded access to financing and financial products
- Innovation and harmonization in the regulatory and licensing process to accommodate novel reactor designs and configurations
- Expanded products, applications, and configurations of flexible nuclear energy
- Support for innovative reactor designs.

A landmark achievement of the FNC's first year was producing a summary report authored by over 50 contributors. These contributors shared their unique backgrounds and experiences with flexible nuclear energy in their country and organization's histories. This report was made available at the 11th annual Clean Energy Ministerial (CEM) conference in September 2020 and again at the 12th CEM in May 2021 to provide other interested countries with the background information to support evaluation of the potential value for flexible nuclear energy in their energy systems.

Key Questions on Enabling Flexible Nuclear

As part of the FNC's second year, additional research is being performed with participant country governments and partner organizations to evaluate case studies for flexible nuclear energy in the context of long-term clean energy goals. To help guide this research, an Expert Working Group of 55 experts from over a dozen countries convened in April 2021 to answer questions such as:

1. What are some of the biggest gaps in a country's clean energy goals that flexible nuclear energy could help address?
2. What are some barriers to the global deployment of flexible nuclear energy?
3. What are some misconceptions about flexible nuclear energy?
4. What research could be undertaken to help overcome the barriers and misconceptions surrounding flexible nuclear energy?

Requirements of Flexible Nuclear Energy in a Clean Energy System

The workshop's discussion highlighted key challenges and opportunities countries could address to accelerate the deployment of flexible nuclear energy applications globally. Topical areas for further work include:

1. **Quantification of value:** There is an opportunity for the value of reliability, resilience, sustainability, air quality, and emissions-free generation associated with dispatchable clean energy to be quantified and agreed upon by stakeholders and customers. This is particularly relevant to nuclear energy, where lack of monetization of these attributes is stressing the financial viability of nuclear plants in energy markets that primarily value just the near-term cost of energy. This effort would benefit from rigorous scientific communication and outreach to raise awareness of the value of flexible nuclear energy to energy system reliability and resilience.
2. **Compensation for energy system services:** In many cases, nuclear flexibility presents both economic and technical challenges. Many markets do not compensate nuclear energy for ramping down power output even when it is done to accommodate other clean energy sources. While international market structures vary widely, it will be important for the value of flexibility of nuclear energy to be recognized and compensated. In some regions, reserve capacity or ramping generation assets are compensated differently than bulk power production, and more innovation is needed to compensate nuclear energy when it ramps its output on various timescales.
3. **Expanded modeling:** Long-term clean energy plans could be informed by diverse energy system modeling that includes system-wide, cross-sectoral decarbonization and pairs variable renewable energy with dispatchable forms of clean energy. Flexible nuclear energy, geothermal, hydroelectric, energy storage, and other forms of clean energy are not currently well-represented in long-term energy planning tools. There is a great opportunity to collaborate among these technology-specific groups to establish a holistic approach to energy planning. Additionally, multisectoral energy modeling that includes analysis and representation of flexible nuclear generation across diverse sizes, operational models (e.g., load-following), and energy products (e.g., potable water, hydrogen, chemical products, industrial heat supply) could dramatically impact the economic potential of flexible nuclear technology, to include analysis of the potential economics and risk profiles of these applications.
4. **Expanded access to clean energy financing and financial products:** Given the magnitude of financing needed to support a robust contribution of nuclear energy toward clean energy/carbon reduction goals, the ability to source financing will be a valuable tool in promoting the global deployment of nuclear energy. Financial products are contractual agreements between financial institutions and recipients. For example, financial products can include loans, stocks, and bonds. Novel financial products can be designed for energy projects based on an energy project's known return on investment or estimated performance. Nuclear plants are capital-intensive projects with low operating costs. Historically, especially with large-scale plants, the increased financing costs to nuclear projects during site licensing and construction phases has been prohibitive at times and has hurt nuclear economics. In some cases, international organizations declined to finance nuclear projects due to their size and risk, instead

favoring smaller projects. Through the development of new financial products, a sustainable financial model could be created that accounts for the value of flexible nuclear energy in a clean energy system and incorporates some of the unique aspects of nuclear construction times and licensing, to include methods of addressing the high-risk construction period with the low-risk (and multidecade) operating period. The group identified that this type of innovation could enable financing that has previously been denied to nuclear projects through de-risking nuclear investment, noting opportunities for government support of these objectives. Participants also noted the importance of having international and domestic clean energy financiers recognize nuclear energy projects as clean and sustainable and, thus, including them in their portfolio of qualifying technologies.

5. **Innovation and harmonization in the regulatory and licensing process to accommodate novel reactor designs and configurations:** Establishing and maintaining safety excellence in a domestic nuclear energy program requires a strong, independent, and able regulator to license and monitor the safety of nuclear plants. These safety regulators and rigorous, science-based review practices are very important for the well-being of the global nuclear industry. These regulators are, by design, cautious in their acceptance of new nuclear technology or operating scenarios. Nuclear energy has been operated flexibly and safely in several countries, adjusting power output as needed to meet changes in net electricity demand. However, new approaches to flexibility, such as through the production of nonelectric products and flexible operation of new reactor designs, require additional analysis and demonstration to help regulators around the world more rapidly understand the technical performance and safety requirements of flexible nuclear operation.
6. **Expanded products, applications, and configurations**: Many applications of flexible nuclear energy (e.g., potable water, hydrogen, chemical products, industrial heat supply) have been proposed. The next step is to match these capabilities with plant configurations and designs to meet end-user demand. A remote mining operation, a city's district heating, and an industrial complex all require thermal energy, but the specifics of the application vary greatly. Flexible nuclear energy could be more rapidly adopted as researchers and engineers expand its applications through partnerships with potential end users.
7. **Support for innovative reactor designs:** The integration of growing variable renewable energy capacity into the electricity system necessitates the acceleration of innovation in new reactor designs and technologies that will improve operating flexibility and commercial viability of nuclear plants.

Next Steps

For the NICE Future initiative and its partners, this working meeting established an improved understanding of the diverse innovations, challenges, and opportunities for flexible nuclear energy deployment globally. Following the workshop, the NICE Future initiative will continue to work with its partners to develop additional research and analysis programs to address these challenges. Specific work is being conducted among partner countries to analyze and amplify the modeling and deployment of flexible nuclear energy. The results of this work will support other interested countries with learning the steps necessary for successful deployment of flexible nuclear energy alongside other clean energy technologies.

Learn More

Find the Flexible Nuclear Campaign report **here**.

Join our mailing list **here**.

Watch our latest webinars and webinars from our participants and partners **here**.

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As an international initiative of the Clean Energy Ministerial, The Nuclear Innovation: Clean Energy Future (NICE Future) initiative leads the global conversation on the roles nuclear energy can play in clean energy systems of the future.

The operating agent of the NICE Future initiative is the Joint Institute for Strategic Energy Analysis (JISEA) in partnership with member countries, the Clean Energy Ministerial, and stakeholders.

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