May 11, 2018

Nuclear Innovation: Clean Energy Future (NICE Future)
Executive Summary

Goal: Provide reliable and resilient clean energy to the global market by making available nuclear energy options for both electric and non-electric applications.

Approach: Initiate a dialogue among Clean Energy Ministerial (CEM) member countries on the role that clean and reliable nuclear energy can play in bolstering economic growth, energy security and access, and environmental stewardship - with a focus on innovative applications for advanced nuclear systems to enable coordinated and/or integrated clean energy systems of the future.

Nuclear energy is an important contributor to global clean energy supply, both as a primary source of clean energy and by complementing and enabling other clean energy sources. Existing and planned nuclear capacity will play a role in meeting clean energy goals in the future. At the same time, innovative applications of nuclear technologies and advanced nuclear energy systems could yield solutions that would further economic growth and support environmental stewardship in both the electric and non-electric sectors. These technologies could complement growing distributed electricity generation systems with larger shares of variable renewables -- such as by linking nuclear energy with a solar plant or a wind farm -- and provide a reliable source of clean baseload power generation. These technologies could also supply both heat and power to energy-intensive industries and increase clean energy access in remote and off-grid locations.

Recognizing that not all countries see nuclear energy as part of their national approach, there remains a need for exploration of the roles that clean, innovative and advanced nuclear technologies could play in simultaneously furthering economic growth and effective environmental stewardship. For this dialogue to be successful, it must work across sectoral boundaries to develop integrated perspectives on the complementary roles that nuclear energy could play alongside all other forms of clean energy. This activity is unique in that it addresses nuclear energy holistically within the context of broader clean energy systems, as opposed to a singular focus on specific nuclear technologies and associated issues.

To this end, the United States, Canada, and Japan have developed this initiative to bring a discussion on innovation and advanced nuclear energy systems to the CEM. Our governments invite other parties that have a need for clean reliable and resilient energy to join the initiative and pursue the potential of various nuclear energy options within the context of broader clean energy systems.

Initial Focus Areas

A central question this initiative seeks to address is how nuclear energy can increasingly contribute to energy systems of the future, such as through systems integration, innovative technologies, storage, and uses, to increase their versatility and value. Given the need to provide reliable clean energy to a growing global market, countries must urgently pursue multiple energy options—including innovative nuclear energy concepts across both large- and small-scale applications, such as small modular reactors (SMRs) and other advanced reactors. This involves understanding how nuclear energy technologies could complement other clean energy sources, for which uses and applications they are best-suited, and how they may interface with the technologies that will enable integrated energy systems of the future. For these systems to be viable, they must be based on a competitive business case in markets that appropriately value all aspects of energy supply, reliability, and resilience. It is equally important to engage all groups essential to enabling these technologies, from governments to nuclear workers and industry, universities and research centers, and the people and communities who may benefit from their development—including Indigenous groups. For advanced nuclear energy systems to succeed they must be developed with an understanding of the views of all enabling partners—their needs, and their questions and concerns across all available clean energy options.

The four initial focus areas are:

1) **Technology evaluations of integrated energy systems, innovative technologies, storage, and uses**
2) **Engagement of policy makers and stakeholders regarding energy choices for the future**
3) **Valuation, market structure, and ability to finance**
4) **Communicating nuclear energy's role in clean, integrated energy systems**

1) Technology evaluations of coordinated and or integrated energy systems, innovative technologies, storage, and uses. Integrated energy systems involve linking any number of energy sources together in a system that can serve different end uses such as heat and power applications. Coordinated nuclear-renewable energy systems are a new paradigm that could emerge as one of the options to manage a greater share of variable and distributed renewable generation on the grid. Linking a nuclear power plant with variable renewables, like a solar plant or wind farm, in a coordinated system, could allow nuclear power generation to backstop renewable energy sources when they are not available, making the grid more flexible and reliable. Excess heat could also be redirected to other processes, such as desalination, industrial and chemical processes, and district heating systems, when it is more economical to rely on renewables for electricity.

Nuclear reactors, especially high temperature reactors, can also economically produce hydrogen for fuel cells in the transportation sector or for grid storage. Some advanced nuclear systems may also lend themselves to pairing with other energy storage technologies or techniques. Innovation in technologies may be necessary to optimize the operation of diverse systems.

Initial work in this focus area will inform energy policy makers on the role that coordinated nuclear-renewable energy systems could play in boosting the deployment of clean and advanced energy. It could involve policy-relevant technology assessments of these systems and their viability, as well as other innovative uses of both large and small nuclear power plants to enable the energy systems of the future. This could include studies of how these systems enable clean energy in other sectors and end-uses, such as the use of hydrogen or electricity for transportation. Discussions regarding multilateral demonstration projects could be raised in the future if parties are interested in exploring further.

2) Engagement of policy makers and stakeholders regarding energy choices for the future: Although nuclear power plants have been predominantly deployed for large scale electricity generation, there is considerable interest in new and innovative applications, such as the development of small modular reactors that could provide heat and power for a range of applications both on- and off-grid. Innovative nuclear energy solutions may become an option to meet the energy needs of countries, regions, industries, and communities that have never before considered nuclear energy. To make effective decisions, decision-makers will need to have adequate information on nuclear energy technologies, as well as information on how to introduce or include nuclear energy in clean energy discussions.

Work in this area could involve studies or independent reviews of existing policies and programs to understand how to include innovative nuclear energy systems as an option in energy system dialogues and within future energy systems designs. This area could include efforts to better understand how to increase energy literacy (especially for nuclear energy) among policy makers and the public, including on the roles, strengths, and limitations of the various energy sources and options. This area could also include actual engagement pilot projects to explore the views of energy clients for whom innovative nuclear energy systems may be an option in the future.

3) Valuation, market structure, and ability to finance: To play a role in energy systems of the future, advanced nuclear energy systems will need to demonstrate a competitive business case relative to other forms of energy over their full life cycle. This will depend both on the costs of deploying these systems and the markets within which they are deployed. A number of advanced nuclear systems, such as SMRs which can be built for a fraction of the cost of a large-scale reactor with a lower initial capital investment, may improve economics for deployment. These systems could also provide other benefits such as reliability and resilience to an electricity grid or energy system. Part of the business case for advanced nuclear systems, therefore, will

be influenced by the extent to which market structures assign appropriate value to these benefits, as well as those provided by other sources of clean energy.

Work in this area could involve analyses of advanced reactor economics and the value of system attributes--such as reliability, resilience, flexibility, and societal benefits. It could involve sharing information on market structures that would appropriately compensate for these attributes. This focus area could also develop best practices for ensuring consistent financing opportunities are available for all technologies that exhibit specific attributes (for example, non-emitting sources of electricity) and that regulatory and policy considerations are consistent across technologies. While each country may have a unique national circumstance, the aim is to provide a factual basis for policy recommendations.

4) Communicating nuclear energy's role in clean, integrated energy systems. The role of nuclear energy in clean energy innovation is multifaceted, and touches on diverse issues, from technical science and engineering aspects, to international trade and partnerships, to human factors (including employment, skills development, and public confidence. For many countries, nuclear energy is an important part of the clean energy story, but there is more that can be done to communicate the role it currently plays, how its contributions will continue, and opportunities to add additional value to the energy systems of tomorrow.

This focus area could involve activities to raise the profile of the nuclear energy sector's contributions to clean energy priorities and systems and possibly share lessons learned regarding the negative impacts, implications, and challenges that have resulted when nuclear energy has been excluded from the clean energy mix. It could also address other dimensions of the story, such as the role of STEM education in maintaining a talented workforce capable of sustaining safe and reliable nuclear generation. This focus area could involve activities to expand the workforce in the sector by highlighting roles for youth, women, and Indigenous people, and to showcase the ingenuity and passion of the next-generation of leaders in the sector. This approach would also address the high-quality job creation that nuclear energy provides.

Conclusion

CEM offers an important opportunity at the ministerial level to make a strong case for future systems in which clean and reliable nuclear energy benefits society alongside other sources of energy. Exploring nuclear energy solutions in an integrated way across technical, economic, and social perspectives can help to identify new partners, and share information among groups who are essential to enabling these technologies. A forward-looking view that considers the full range of options available will help to increase the effectiveness of clean energy solutions, speed their implementation, and ensure they provide maximum benefits across their life cycles and value chains.

Work under this new initiative may, as appropriate, contribute to other existing CEM initiatives and campaigns, such as the 21st Century Power Partnership (21CPP), the Clean Energy Solutions Center, the Advanced Cooling Challenge and Advanced Power Plant Flexibility campaigns, and the C3E Women in Clean Energy initiative.

CEM's focus on all aspects of clean energy and its distinctive membership and outreach create opportunities for this new nuclear energy initiative to bring together a unique group of visionary business leaders, policy makers, environmental proponents, and other key decision-makers from around the world—along with innovators in technologies and energy systems. **The United States, Canada, and Japan invite countries looking to examine diverse options for maximizing their clean energy mix as well as interested organizations to join the CEM civil nuclear initiative, as partners in key discussions and collaborations.**

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