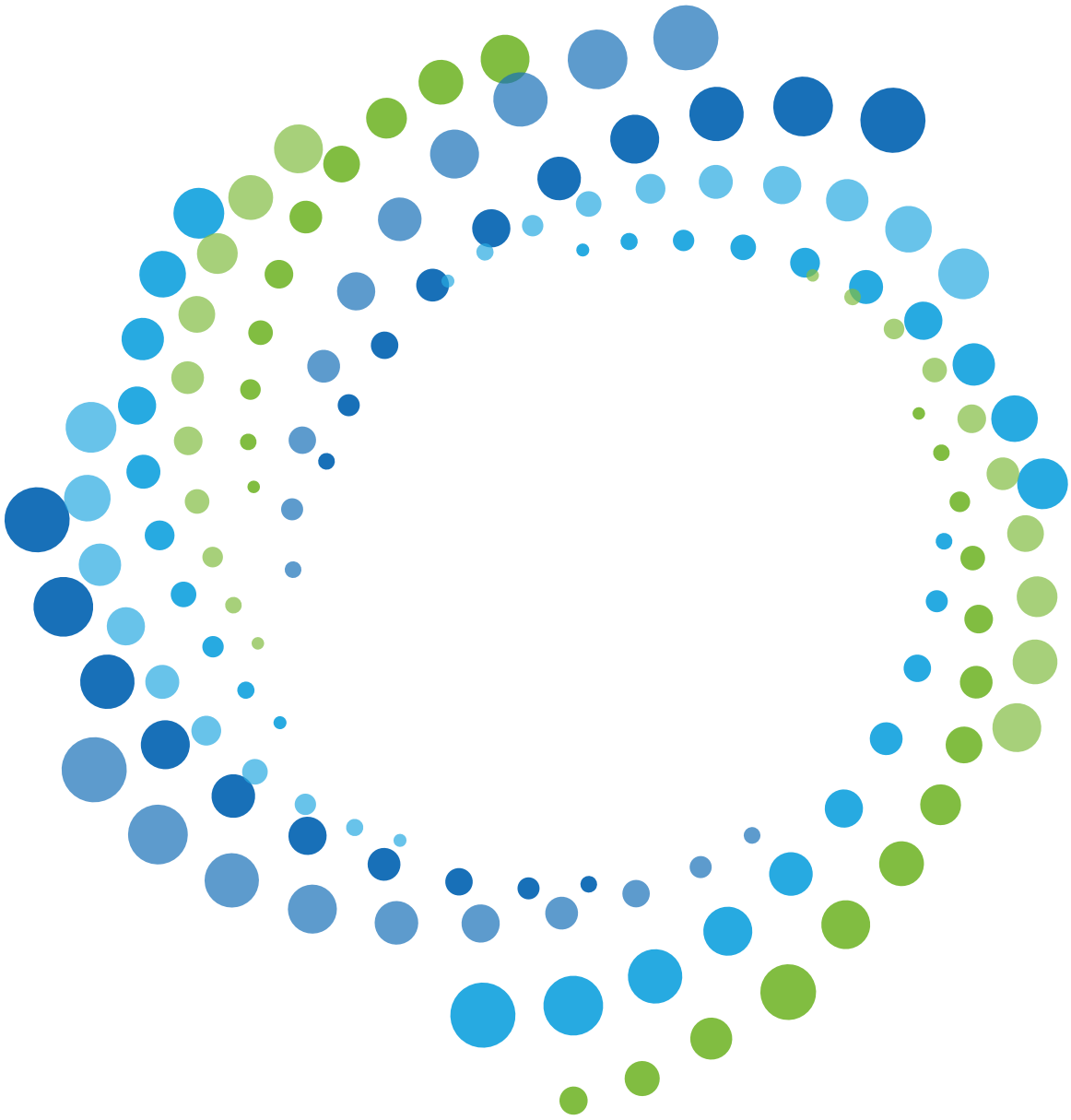
Global Nexus Initiative

Where Climate, Nuclear, and Security Meet



Nuclear Power for the Next Generation:

Addressing Energy, Climate, and Security Challenges

Meeting international climate goals of limiting temperature increases to 1.5-2 degrees Celsius will require current emission levels to be reduced by 40-80% by 2050 and near zero or negative by 2100.

Source: IPCC 5th Assessment Report

Executive Letter

The Global Nexus Initiative (GNI) was created to examine the complex challenges posed by the intersection of climate change, energy demand, and global security. It is a partnership between two important nuclear stakeholders, the Partnership for Global Security (PGS), a think tank with a long history of offering innovative solutions to global nuclear security challenges, and the Nuclear Energy Institute (NEI), a nuclear industry association that supports the beneficial use of nuclear technology and advocates for policy on issues affecting the nuclear industry. GNI brought together for the first time a diverse and distinguished working group of nuclear industry executives and climate change, energy, and global security experts. It succeeded in crafting actionable recommendations that will ensure the safe and secure use of existing and new nuclear energy sources, support economic vitality, and protect people and the environment.

Based on our first two years of work, GNI has confirmed that it will be extremely difficult, if not impossible, to meet the goal of the Paris Agreement on climate change to limit temperature increases and decarbonize the global energy sector without a significant contribution from nuclear power. But, it also determined that it will be daunting to deploy nuclear power on the scale needed and with the public confidence required unless significant changes are made in the way the technology is brought to market and governed.

Concentrations of greenhouse gases in the earth's atmosphere are at their highest level in recorded history.[1] In recognition of this, GNI has endorsed the four major approaches to decarbonize the global energy system: energy efficiency, renewable energy, nuclear power, and carbon capture and sequestration. It focused on the zero carbon output provided by nuclear power and how it can be sustained and increased in the future. The initiative supports the maintenance of the existing reactor fleet as long as it remains safe and secure. It identified a framework for the deployment of advanced reactors, including small modular types, and the importance of market forces in the decision making about these reactors. It underscored the need for rapid development of sound policy and regulation to accompany these new technologies.

The group believes that the global nuclear governance system must evolve and be strengthened to support nuclear power's sustained clean energy contributions and expand access to electricity in the 21st Century. GNI recognizes the significant geopolitical implications of nuclear power for international security and the global economy. It noted the importance of minimizing risks associated with the nuclear fuel cycle, and it was concerned about the challenges posed by emerging markets and new suppliers.

This report is a distillation of the issues examined in a series of workshops and three major policy memos that offered 22 recommendations. These proposals were produced through a process that had as a core principle: no artificial consensus or ideological preconceptions. So, while not all participants agreed with every proposal, there is agreement that action must be taken on the four key policy findings and recommendations that have been produced by PGS and NEI in this report.

Sincerely,

Kenneth N. Luongo
President, Partnership for Global Security

Maria Korsnick
President, Nuclear Energy Institute

Findings and Recommendations

1. Nuclear Power is Necessary to Address **Climate Challenges**

Nuclear power, in addition to other clean energy technologies, is essential to meet increasing global clean energy demands. Cutting carbon emissions while powering the 21st Century will require preserving the existing nuclear fleet, replacing many reactors by midcentury, and constructing new, advanced reactors. Deploying the next generation of technologically advanced reactors in the next 10-15 years will require three significant evolutions – new policies; an innovative, effective regulatory system; and a bold private-public financial partnership.

2. Nuclear **Governance** Needs Significant Strengthening

Nuclear governance – the global framework of international and national laws, regulations, recommendations, and operating practices that support nuclear safety, security, and nonproliferation – must be strengthened if nuclear power is to continue being a major provider of zero carbon energy. Nuclear challenges are constantly evolving and the governance system is increasingly under novel pressures from new suppliers, newcomer nations, and non-state actors. Strengthening public confidence through enhanced safety and security measures is essential. Governments, international institutions, the nuclear industry, and civil society need to work together to create effective, credible, and rapid governance responses to these new realities.

3. Evolving Nuclear Suppliers Impact **Geopolitics**

Nuclear power is a significant element of a country's geopolitical influence. There are long timeframes and deep relationships that are developed in the course of building and operating a nuclear plant and through the exchange of technologies. Traditional nuclear leaders, including the United States and its allies, need to recognize and elevate the importance of supplying the international nuclear marketplace in their geopolitical strategies to meet the economic and political ambitions of other nations that may not share their deep commitment to upholding effective nuclear norms. The control of market share translates into the power to create nuclear governance rules and prevent commercial competition from eroding vital safety, security, and nonproliferation standards.

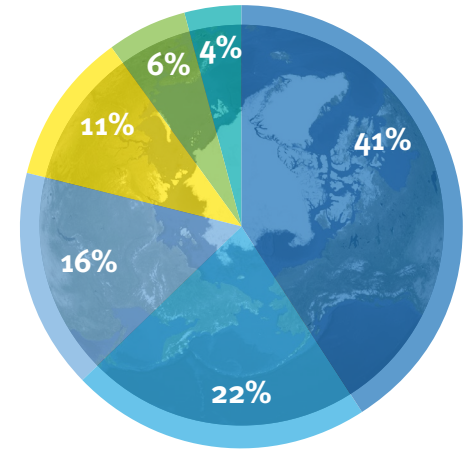
4. Innovative Nuclear Policy Requires "Break the Mold" **Partnerships**

A unique, collaborative relationship has been created between non-traditional partners – the nuclear industry and the civil society organizations that work on nuclear governance, climate change, and energy policy. GNI proved that together they can develop valuable new policies that address important issues arising from the nexus of nuclear power, climate challenges, and global security. Further progress on joint policy development – and the strengthening of public confidence that this offers – can best be served by institutionalizing and expanding this "break the mold" partnership and expanding the collaboration and financing that fuels this unique partnership.

Role of Nuclear Power

The important role of nuclear power in mitigating climate change is clear. It is a necessary component of the balanced portfolio for achieving the United Nations Framework Convention on Climate Change's Paris Agreement objectives that also includes renewable energy, energy efficiency, and carbon capture and sequestration (CCS). Operational nuclear power plants produce close to zero carbon output and are recognized as an important component of the climate change strategy of some high carbon emitting nations. In 2014, 11% of global electricity production was generated by nuclear power.[2]

World Electricity Generated by Fuel

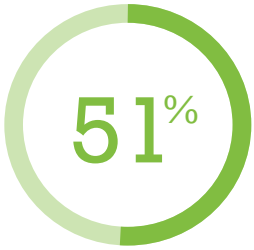


- Coal (41%)
- Natural Gas (22%)
- Hydro (16%)
- Nuclear (11%)
- Renewable and Other (6%)
- Petroleum (4%)

In some countries, including in Europe, Asia, and the United States, nuclear power produces a significantly higher portion of national electricity. According to some assessments, meeting international climate goals will require 4,000 Gigawatts of nuclear power worldwide by 2100.[3] Depending on the size of each unit, this could be 2,000-4,000 reactors.

The retirement of reactors that have reached the end of their operating life will pose a significant challenge to continuing nuclear power's contribution to the low carbon energy mix in coming decades. **Fifty-one percent of the current global reactor fleet is over 30 years old, and by 2050, those plants will be over 60 years old.**[4] In the United States alone, approximately 59 new reactors would need to be built by 2040 to maintain the 20% share of electricity that nuclear power currently contributes, if the operating reactors retire after 60 years of operation.[5] Currently, four new reactors are under construction, and several existing reactors have been or are being prematurely retired.

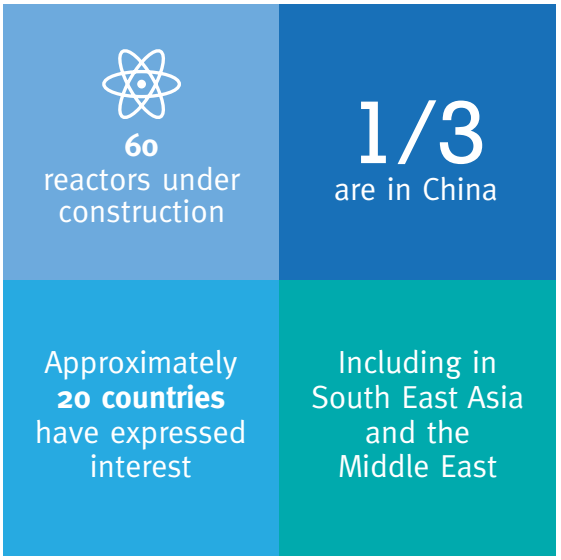
Global Reactors over 30 years old



While the operational costs are low for nuclear power and operating lives of the plants are long (40 to 80 years), construction times are long (approximately 4-10 years) and upfront capital costs high (approximately $7-9 billion for large, conventional reactor designs) when compared to other sources of electricity. As a result, nuclear power is facing formidable competition from cheaper energy sources, including natural gas, which produces more carbon emissions than nuclear power. Also, the declining cost of renewable energy is making it more attractive, although renewables face continuing technology challenges including storage, transmission, and backup capacity issues.

The future of nuclear power now appears to be in the developing world, particularly in Asia, the Middle East, and potentially in Africa. There are 1.3 billion people in the world, primarily in these regions, who lack access to electricity, and global energy demand is projected to increase 50% by 2040 as the global population and economy continue to grow.[6]

Today there are more than 60 reactors under construction – a third are in China and four are in the United Arab Emirates.[7] Approximately 20 countries that currently do not operate nuclear power plants are planning or have expressed interest in developing nuclear power programs.[8] However, even countries that are pursuing nuclear energy are planning for their programs to contribute only 20-30% of their energy by 2050.[9] Therefore, a further expansion of nuclear power should be considered, including replacing retiring nuclear power plants with new nuclear power plants.



If the clean energy benefits offered by the existing reactor fleet decline significantly, there is considerable risk in being unable to prevent global temperature increases consistent with the Paris Agreement by relying solely on renewable or other zero carbon energy options.

In addition to replacing the carbon benefits produced by the reactor fleet, these sources also will need to displace the remaining 67% of the world's electricity that today comes from fossil fuels and all future energy growth.[10] It is at a minimum uncertain at this point if, in the future, renewables with storage alone or combined with fossil fuel CCS and energy efficiency can meet these goals. In recent cases where nuclear plants have been shut down in the United States, carbon emissions have grown as the substitute power came primarily from natural gas.[11]

If non-nuclear zero carbon energy sources and related technologies cannot meet carbon reduction objectives, then falling back on carbon emitting sources of power, including natural gas or coal without CCS, will inevitably mean that aggressive climate targets will be unmet, with the attendant global consequences.

Next Generation Nuclear Power

Next generation nuclear reactors are at a critical crossroad between technology development and future deployment. Accelerating progress toward deployment of these new reactors is required if they are to meet the climate and global energy needs of the mid-21st Century and beyond.

This transition from concept to commercialization needs to occur over a fairly rapid 10-15 year period

if such reactors are to be available to replace reactors that will be retired and supply the new generation that must be accompanied by a regulatory system that ensures the safety, security, and proliferation resistance.

New reactor types – both small modular water cooled reactors and advanced non-water cooled reactors – offer a range of sizes and have the potential to be a more easily deployable and operationally flexible alternative to the large light water reactors that are dominant around the world today. Advanced reactors also offer:

- Different coolant systems that can enhance efficiency and safety
- Construction that can reduce building costs
- Fuel cycles that can reduce environmental impacts
- Potentially greater proliferation resistance and security

At present, there is more research and development than demonstration occurring, and the path to widespread commercialization needs to be clearer and better supported. To achieve this, there are a number of impediments to deployment that need to be addressed.

The most pressing challenge is the need for an efficient regulatory system for advanced non-water cooled reactor technologies that will provide certainty about their ability to be deployed in a predictable timeframe. Also, the construction and operating costs of these reactors will need to be more competitive with other energy options, particularly coal, renewables with storage, and natural gas.

Further, the technology needs to be operationally tested and demonstrated to prove its viability, safety, security, and proliferation resistance.

There also must be political and public confidence in this new class of reactors.

Achieving these goals requires institutional and cultural changes in how the next generation of nuclear power is developed, tested, regulated, deployed, and managed.

The demands on the next generation of nuclear plants, particularly in deregulated energy markets, are going to be different than in the past, including the need for increased operational and siting flexibility. The public needs to be confident that plants are safe, secure, and proliferation resistant. Advanced reactors that can minimize nuclear waste or even utilize used fuel from the existing fleet could offer waste management benefits. The market is requiring greater affordability, lower technology and construction risk, speed

of deployment, and efficient and scalable manufacturability. These expectations raise a number of issues that will need to be addressed in order for advanced reactors to proceed from concept to commercialization in a timely fashion. Therefore, it is vital to construct a framework for considering the key policy issues that will impact the deployment of advanced reactors. The central policy issues are:

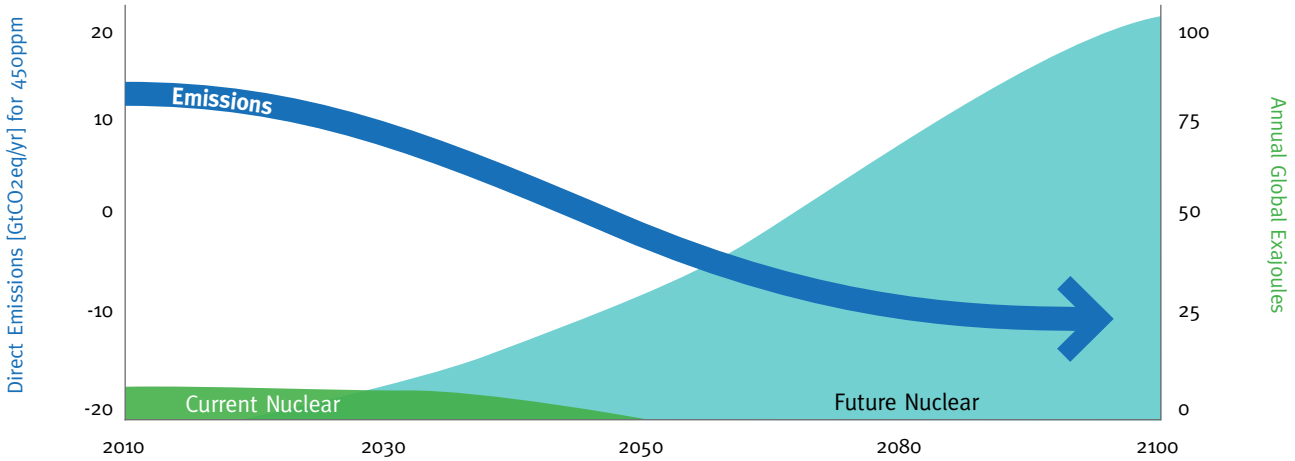
- Timeline, market, and financing
- Safety, safeguards, and security
- Regulatory reform

The success of next generation reactors is highly dependent on the scale and composition of financing. The private sector is investing in the exploration and development of a variety of concepts, but government funding, for example in the United States, is considerably lower. Globally, much of the private funding available has been invested in a few programs. Also, private investment may exit early if the technologies cannot be successfully demonstrated or if a business-as-usual approach to this class of reactors impedes timely development and deployment.

The multibillions of dollars needed to bring a first-of-its-kind (FOAK) advanced reactor portfolio to deployment is far in excess of the funds that are currently being provided. In addition to significant private sector funding, there also is a need for supplementary government funding.[12]

Climate and Nuclear Technology Timeline

It is estimated that by 2050 more than 80% of the current global fleet of reactors will be retired. Potentially limiting a warming of the earth to 2° Celsius would require an increase of zero carbon energy by more than 300% from 2010 levels by 2100.



Scenarios from Electricity Sector with CCS
Source: IPCC AR5

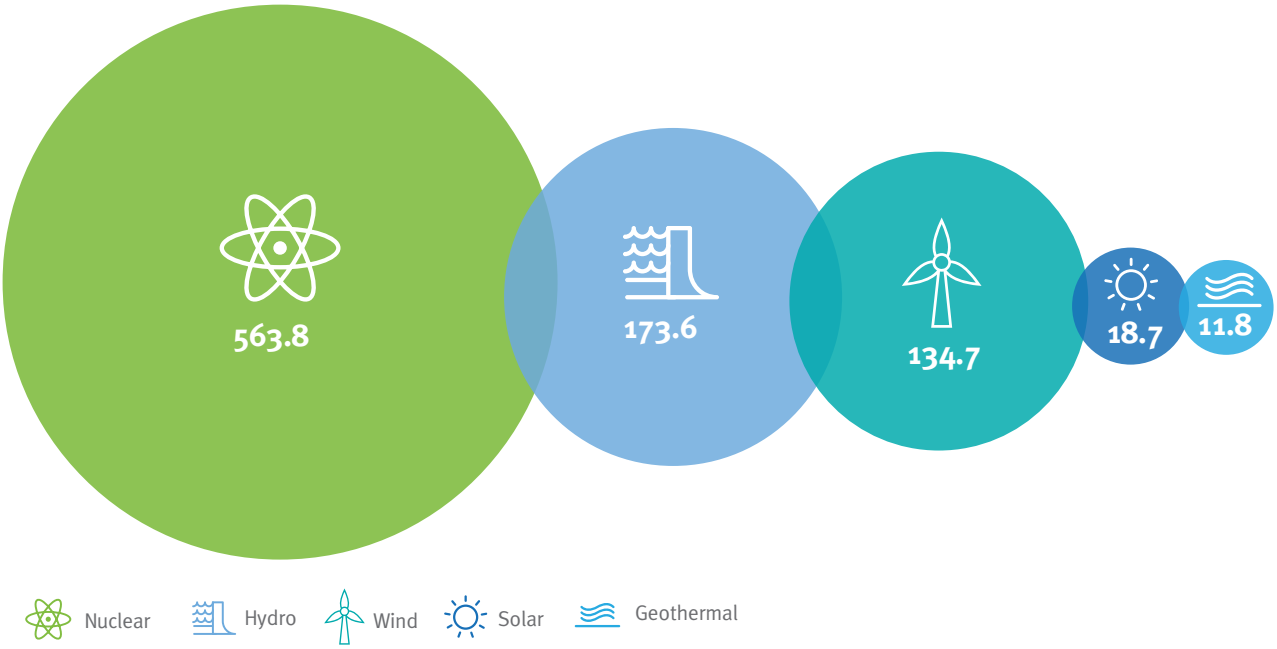
In liberalized markets, especially in the United States, it is unlikely that either governments or the private sector individually will have the resources to fully fund multibillion dollar advanced reactor efforts through design, licensing, and construction of a FOAK. Therefore, a private-public partnership is required to develop and deploy these technologies. A private-public deployment driven strategy for next generation reactors would:

- Send a signal that the reactor class is important
- Allow for robust modeling, testing, and demonstration
- Winnow the number of technologies to a handful that the market deems valuable and that also can meet international safety, security, and nonproliferation objectives

This approach, if seized on by the United States or other nations, could elevate a country into the top tier of nuclear innovating nations and reinforce its status as a major international supplier and standard setter in nuclear safety, security, safeguards, and regulation.

US Electric Power Industry CO_2 Avoided

Million Metric Tons, 2015



Source: Emissions avoided are calculated using regional and national fossil fuel emissions rates from the Environmental Protection Agency and plant generation data from the Energy Information Administration. Updated: 4/16

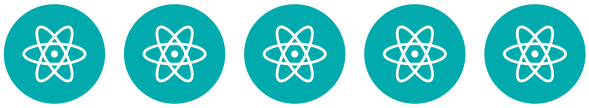
The Value of Nuclear Power

The existing nuclear fleet is a reliable, dense source of electricity. The power from five nuclear reactors is the equivalent of 16 natural gas combined-cycle plants, 7,600 wind turbines, or 3,700,000 solar photovoltaic rooftops.

5

Nuclear
Power Reactors

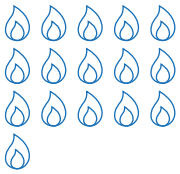
1.28 GW each



Equals

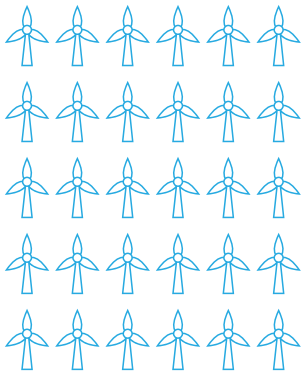
16 *Or* **7,600** *Or* **3,700,000**

400 MW natural gas combined-cycle power plants

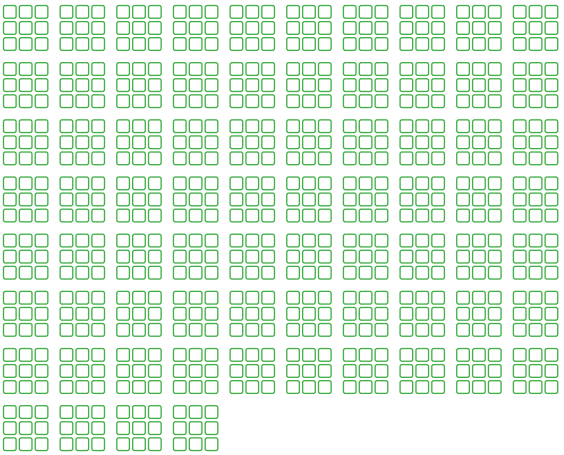


These plants would emit a total of 12 million metric tons of CO_2 per year.

1.5 MW wind turbines



250 wind turbines



50,000 panels

1,000,000 Kilowatt (kW) = 1 Gigawatt (GW)
1000 Megawatt (MW) = 1 Gigawatt (GW)
Source: Center for Climate and Energy Solutions

Nuclear Governance

Strengthening the global nuclear governance system is essential to sustaining nuclear power's vital role in addressing climate change; maintaining safety, security, and nonproliferation obligations; and effectively addressing new challenges.

Nuclear governance is a complex national and international legal and technical system that requires continuous improvement to adapt to the evolving international environment.

Its effectiveness has a direct impact on the safety and security of nuclear power operations and expansion as well as on the global public's confidence in nuclear power.

The current governance system encompasses the critically important nuclear safety, security, and safeguards regimes and essential issues related to environmental impacts. It covers a wide range of national regulations and laws, international agreements, guidance and recommendations, and facility operations and practices. At the global level, the primary institution responsible for nuclear guidance is the International Atomic Energy Agency. At the national level, it is governed by domestic laws and regulatory authorities.

Over the past six decades, the nuclear governance system has adapted to new requirements and events, but this process has been more episodic and reactive than strategic. This system now faces technical evolutions, systemic stresses, and threat vectors unlike those of previous eras. Responses need to be more proactive, rapid, and effective.

A particular challenge is being posed by the evolution in the nations seeking to add nuclear power and those that seek to supply them. Nuclear power is most rapidly growing in tense regions of Asia and slowly emerging in the stability-challenged Middle East.

It is projected that China will overtake the United States as the world's top nuclear power generating nation by 2026, making it the largest global nuclear operator and market.[13]

By contrast, western countries are building few new reactors and are focused on preserving existing plants and preparing for a possible bow wave of decommissioning at midcentury.

The nuclear supplier situation also is changing rapidly, and it has the potential to impact the effective application of established international norms and their evolution. Along with its domestic nuclear expansion, China is seeking to sell and build nuclear plants to emerging economy nations and long-standing nuclear states.

An aggressive and effective response to these new realities – strengthening, unifying, and when necessary, expanding the nuclear governance system – is essential for nuclear power to continue to play a vital role in meeting the increasing global need for carbon-free energy in the 21st Century.

An evolution of the nuclear governance system will require significant changes in a number of areas. New policies will need to be developed. Governments and international institutions will need to be more receptive to strengthened governance. The nuclear industry will need to be an active partner in achieving progress. And, relationships among diverse stakeholders that are based on cooperation in support of a common agenda will need to be strengthened and institutionalized.

The improvement and universalization of nuclear governance cannot effectively be achieved by any one stakeholder community in isolation or by any institution alone.

It requires a strong coalition among governments; the nuclear industry and its professional associations; and the nuclear nonproliferation, security, and safety expert communities. Together they can assess the requirements for improvement and formulate balanced, realistic, and effective responses. This integrated approach to strengthening the nuclear governance system can improve the chances that the necessary changes will be made, that they will not have unintended impacts, and that they will advance global safety and security. The foundation for this strategic alliance has been created, but significant additional work is required to institutionalize it and overcome past divisions (real and artificial) among these communities. An important part of that effort is the need to improve communication on nuclear governance issues and messaging effectively on its value.

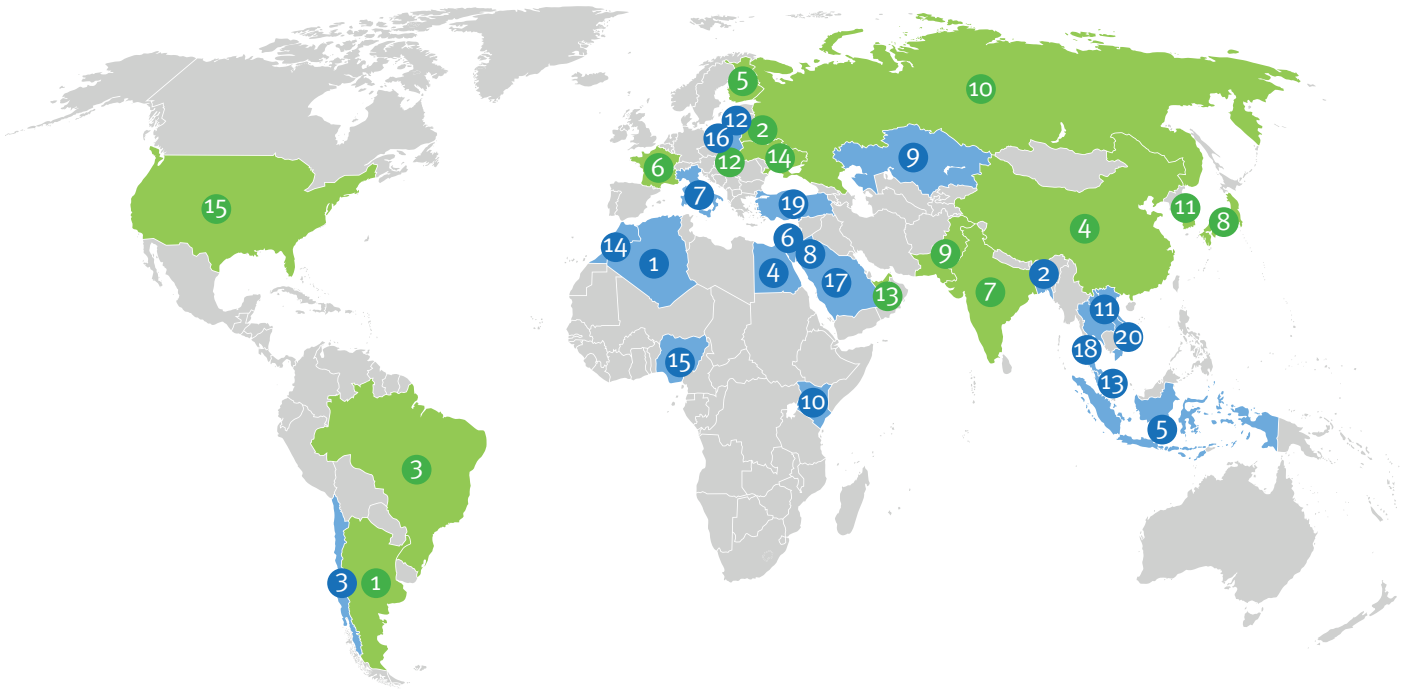
Public confidence is critical to the use of nuclear power, and the strength of the nuclear governance regime is a significant contributor to the level of public trust. This confidence can be impacted by events. The Fukushima nuclear accident, for example, negatively impacted this confidence with lasting social and political consequences in some parts of the world. Most people do not actively seek information about the detailed technical elements of the governance regime, but rather rely on governments and nuclear regulators to assess safety and security needs and responses. They also rely on media reporting and that in turn is dependent on the perspectives and analyses of various non-governmental and nuclear industry experts. In order to enhance public trust, the reliability and transparency of the information provided is essential.

As the nuclear landscape evolves, it is critical to avoid a "race to the bottom" by undermining nuclear governance to pursue sales.

With the supply chain under significant pressure, suppliers may be willing to undertake sales to countries that haven't developed strong nuclear credentials in order to increase market share. This can lead to a worrisome trend of declining standards. The main concerns are the adequacy of: nuclear safety and security, liability law, weapons proliferation prevention, infrastructure development, waste management, and personnel training and replacement.

Nuclear Growth

There are 60 civil nuclear power reactors under construction around the world, and approximately 20 countries that currently do not operate nuclear power programs have expressed interest in developing them.



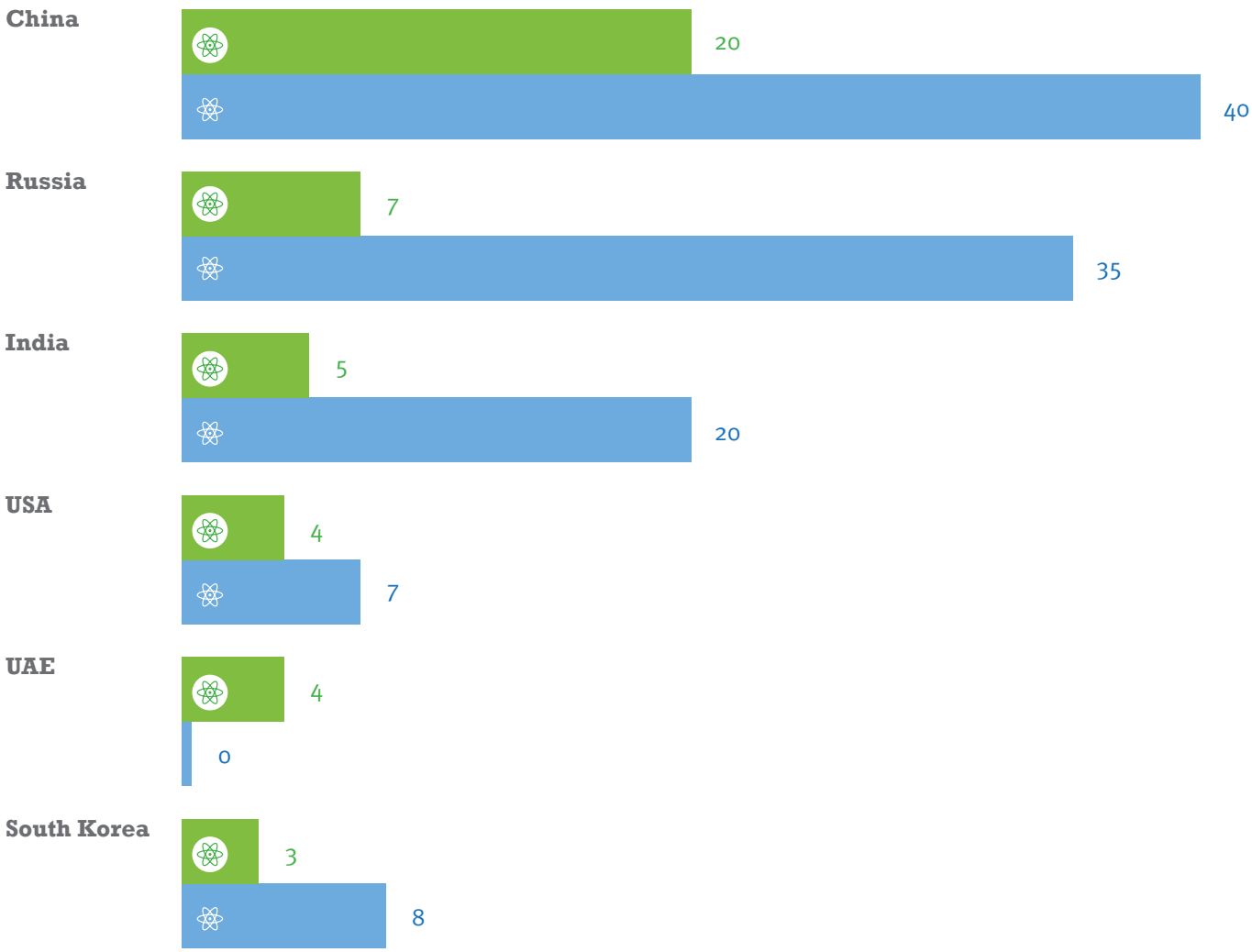
Countries with reactors under construction

Countries that have expressed interest

1	Argentina	1	Algeria	16	Poland
2	Belarus	2	Bangladesh	17	Saudi Arabia
3	Brazil	3	Chile	18	Thailand
4	China	4	Egypt	19	Turkey
5	Finland	5	Indonesia	20	Vietnam
6	France	6	Israel		
7	India	7	Italy		
8	Japan	8	Jordan		
9	Pakistan	9	Kazakhstan		
10	Russia	10	Kenya		
11	South Korea	11	Laos		
12	Slovakia	12	Lithuania		
13	UAE	13	Malaysia		
14	Ukraine	14	Morocco		
15	USA	15	Nigeria		

Source: IAEA and WNA

Countries with the Most Civil Nuclear Power Reactors under Construction



Source: IAEA, WNA, NEI

Nuclear Power Is a Strategic Geopolitical Asset

Nuclear power is an important instrument of geopolitical influence. It impacts the struggle to ensure that all nations and the international system move toward security, stability, and prosperity – three essential conditions for global progress. The locus of nuclear activity is moving to the developing world and into new regions where nuclear power is not currently operating and where political tensions are high, including the Middle East and potentially South East Asia.

Traditional nuclear suppliers, including the United States and its allies, are losing ground on nuclear commerce to Russia and South Korea, who are aggressively marketing their nuclear technologies and services, and perhaps soon to China.[14] In addition, Russia and China are moving ahead rapidly with new, non-water cooled advanced reactors, and a race is developing to dominate that emerging market.[15] Because many of these reactors are much smaller than traditional light water reactors, they can be widely distributed and placed in remote locations in a number of countries. Some of these nations will not have had previous or in-depth experience with the operation of nuclear technologies. A number of them also may have serious governance challenges and weak histories of independent oversight.

This evolution of nuclear suppliers could undermine the influence of the nations that historically have been most active in building and improving the global nuclear governance system.

The emerging suppliers do not have a deep record of initiating improvements to the global nuclear governance system that the traditional suppliers have created. And, in pursuit of commercial gain, there is the potential for risky sales to countries that lack strong nuclear credentials and experience.

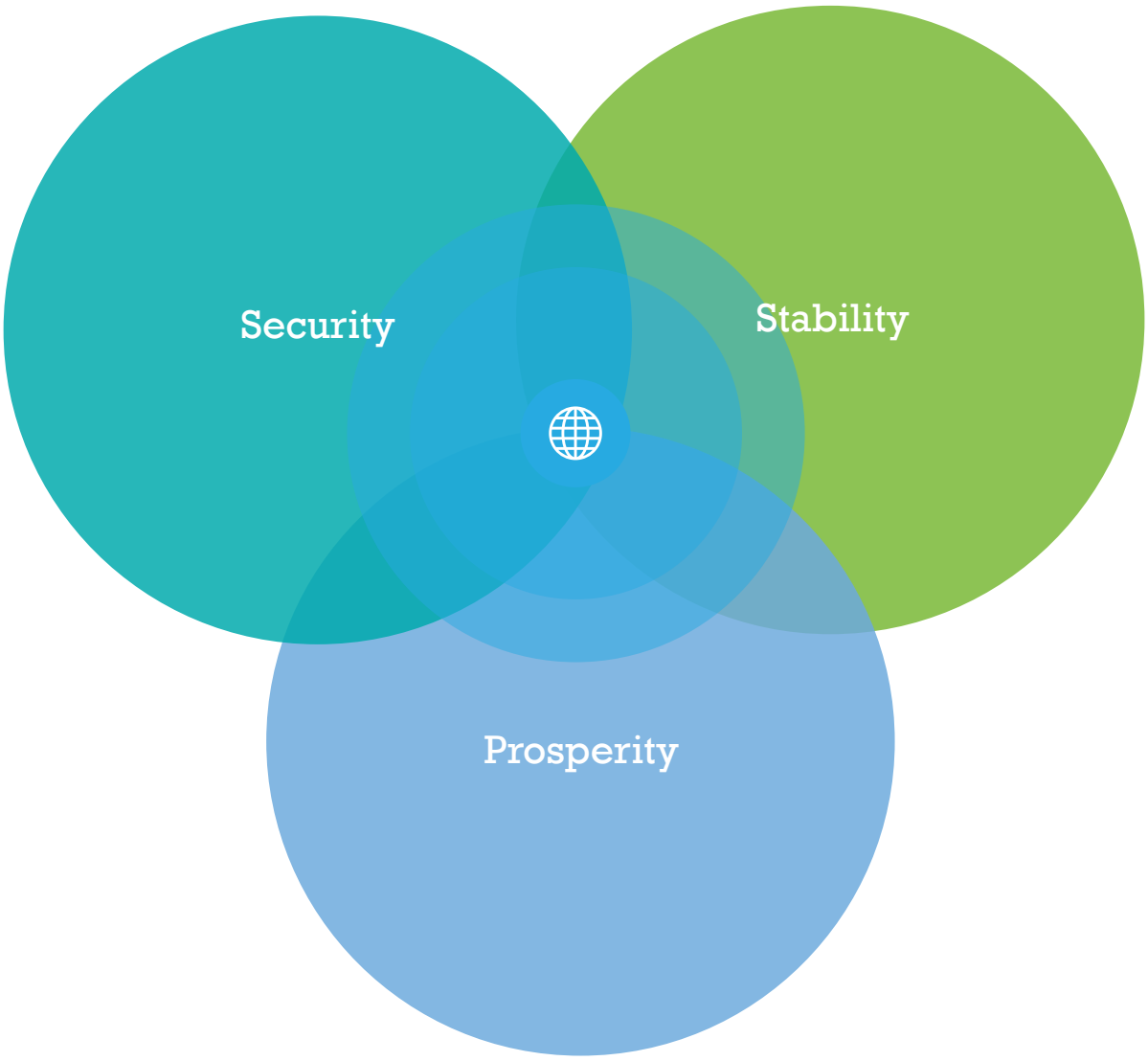
Historically, influence over the nuclear rules of the road has been exercised by those with the greatest market share. Therefore, a race to the bottom that undercuts effective nuclear governance must be avoided. The nuclear governance system must be strengthened to support the potential growth of nuclear power worldwide. However, it is at risk of being eroded. There needs to be a greater appreciation of the positive impact and importance of the United States and allied nations aggressively participating in the global nuclear energy market. There needs to be a stronger effort to ensure that China and Russia are active supporters of strong nuclear governance.

Cooperative relationships between suppliers and recipient nations can last for a century – through the creation of commercial relationships, reactor building, operation, and decommissioning.

These long-term relationships should be valued and nurtured because they can make an important contribution to the achievement of a wide range of vital foreign policy, security, and economic objectives.

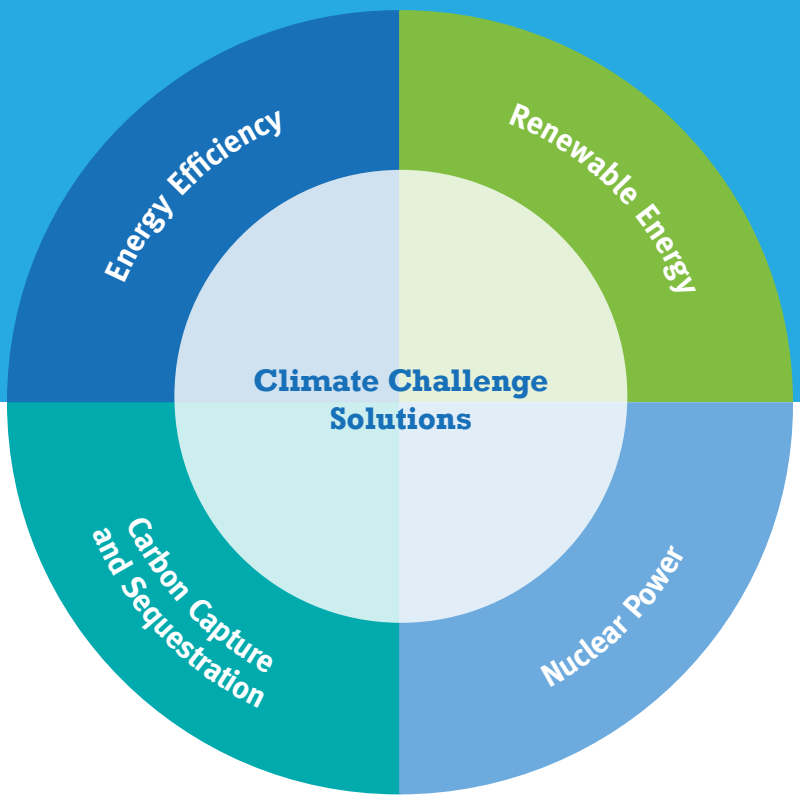
Global Progress

Nuclear power impacts a wide range of vital foreign policy and economic issues and objectives. Historically, influence over the nuclear rules of the road has been exercised by those with the greatest market share.



Effective Responses to Today's Challenges

As the number of nuclear reactors grows worldwide in response to the need for carbon-free energy and economic development, its governance system will be taxed with ensuring the safety and security of a larger number of nuclear plants and materials. It also will have to address emerging and mutating threats like cybersecurity. Effective governance in this evolving environment will require a greater willingness to identify and rapidly remedy safety, security, and proliferation vulnerabilities and acceptance of increased transparency and comprehensiveness by the international community. It is in the interest of all nations to ensure that stringent safety, security and nonproliferation systems are in place in every country operating, expanding, and pursuing nuclear power programs.



GNI Results

GNI held a series of workshops from 2015-2017 to explore the intersection of nuclear power, climate, and security issues and develop smart policy responses to today's challenges. These meetings involved dozens of experts from around the world and resulted in 22 policy recommendations which are detailed in three policy memos. This report is a distillation of those memos. For additional details on the ideas and proposals discussed in this report, please visit **www.globalnexusinitiave.org**.

The Role and Responsibility of Nuclear Power in a Carbon Constrained World (December 2015)

Achieving the international community's goal of limiting global temperature increases to 2° Celsius will require a significant transformation in the way the world produces and consumes energy. GNI urges policymakers to recognize the existing and potential contribution of nuclear power in reducing global carbon emissions. Policy changes simultaneously should enhance public support, safety, and security and strengthen international confidence in nuclear power programs.

A Framework for Advanced Nuclear Reactor Development: Policy and Issues (September 2016)

The next generation of nuclear reactors are at a critical crossroad between technology development and deployment. GNI explains that near-term demonstration projects, advanced licensing procedures, and enhanced safety, security, and safeguards measures are critical if the next generation of reactors are to inspire public confidence, enable commercial success, and meaningfully contribute to climate goals.

Evolving Nuclear Governance for a New Era (April 2017)

The global nuclear governance system is facing a series of new challenges that require effective responses from a strong coalition of governments, the nuclear industry, professional associations, and the nuclear nonproliferation, security, and safety expert communities. GNI calls for a strengthening of the system through realistic continuous improvement, a demonstrated commitment to norms and standards by nuclear suppliers and users, and a greater appreciation of nuclear power as a geopolitical tool.

GNI Working Group members met for a series of four workshops in Washington, D.C. from 2015-2017.

Guest experts attended each workshop to provide targeted insights on key issues.

Working Group Members

We gratefully acknowledge the members of the GNI working group, a distinguished panel of 17 experts from the nuclear industry, environmental and energy communities, and global security organizations with decades of first-hand management and policymaking experience on these critical issues.

- Amb. Hamad Alkaabi, UAE Permanent Representative to the IAEA and Special Representative for International Nuclear Cooperation (UAE)
- Amb. John Bernhard, Ambassador to the IAEA from Denmark (retired) (Denmark)
- Amb. Kenneth Brill, Ambassador to the IAEA from the United State (retired) (U.S.)
- Armond Cohen, Co-Founder and Executive Director, Clean Air Task Force (U.S.)
- Mary Alice Hayward, Vice President of Strategy, Government and International Relations, AREVA (U.S.)*
- Caroline Jorant, President, SDRI Consulting; Former Director for Non-Proliferation and International Institutions, AREVA (France)
- Kenneth N. Luongo, President, Partnership for Global Security; Former Senior Advisor to the U.S. Secretary of Energy for Nonproliferation Policy (U.S.)
- Melissa Mann, President, URENCO USA, Inc. (U.S.)
- Dr. Richard Meserve, President Emeritus, Carnegie Institute for Science; Former U.S. Nuclear Regulatory Commission Chairman (U.S.)
- Dr. Anita Nilsson, President AN & Associates; Former Director of Nuclear Security at the IAEA (Sweden)
- Robert Nordhaus, Partner, Van Ness Feldman; Former General Counsel, U.S. Department of Energy (U.S.)**
- Dr. Everett L. Redmond II, Senior Technical Advisor, New Reactor & Advanced Technology, Nuclear Energy Institute (U.S.)
- Richard Rosenzweig, Former Chief Operating Officer, Natsource; Former Chief of Staff, U.S. Secretary of Energy (U.S.)
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*Ms. Hayward left the working group in January 2017 when she began a new job at the International Atomic Energy Agency. Her contributions to the project before that time are greatly appreciated.

**Mr. Nordhaus passed away in December 2016. We greatly appreciated his contributions to the project and mourn the loss of a valued colleague.

This project has been made possible by the generous support of the Carnegie Corporation of New York and the John D. and Catherine T. MacArthur Foundation.

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