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# *Introduction: Planning a Responsible Nuclear Energy Future*

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Nuclear energy is a twentieth-century innovation but until recently has not spread beyond a relatively small number of industrialized nations (see maps on pages 4 and 5). All this is about to change. With global electricity demand increasing dramatically and greenhouse gas emissions and energy security becoming national priorities, developed and developing countries alike are reexamining nuclear energy as a means of providing a reliable and scalable source of low-carbon power.

The International Energy Agency (IEA) projects that global electricity demand will increase 2.2 percent a year to 2035, with about 80 percent of that growth occurring in emerging economies outside the Organization for Economic Cooperation and Development (OECD).[1] Even if new policy initiatives are introduced to lower carbon dioxide ($CO_2$) emissions and combat global climate change, global energy-related $CO_2$ emissions are expected to increase 21 percent between 2008 and 2035.[2] Emerging market economies account for all of this projected increase in emissions. In the face of rising prices and increasing volatility in the oil market, many of these economies have shifted their attention to nuclear energy as a means of reducing dependence on oil (often a major source of their power generation), improving their balance of payments, and bolstering national energy security.[3]

Currently, 440 reactors with a total capacity of 375 gigawatts (GWe) are in operation worldwide.[4] As of March 2011, 65 nuclear reactor units, with a total capacity of 63 GWe, are under construction.[5] And as of April 2011, 158 projects are also on order or planned and 326 proposed.[6] These preparations

for replacing or expanding reactor fleets and for new entries to the marketplace follow a decades-long lull in construction and suggest a "nuclear renaissance" has begun. While "renaissance" implies a revival or return to a better time, the global expansion of nuclear energy in the coming decades will differ in several respects from the way civilian nuclear power developed between the late 1950s and mid-1980s.

First, the scope and pace of this new deployment could be significantly larger than in previous periods of expansion: some recent analyses put installed nuclear capacity up at 550–850 GWe by 2035, depending on assumptions about the implementation of low-carbon energy policies.[7] In IEA projections, a 50 percent cut in energy-related $CO_2$ emissions by 2050 would require global capacity to reach 1,200 GWe, a net addition of 30 GWe each year over the next forty years.[8] To put this figure into perspective, during the period of nuclear power's most rapid expansion (1981–90), capacity increased by only 20 GWe a year, slowing to an annual average of 4 GWe from 1991 to 2006.[9] To achieve large-scale reductions in energy-related $CO_2$ emissions, nuclear capacity must therefore grow not only faster but also for several decades longer than during nuclear energy's previous "golden age." (As the preface indicates, safety concerns arising in the aftermath of the Fukushima accident will slow or scale back nuclear power expansion globally in the short term. At the same time, the longer-term impact of Fukushima on global nuclear power expansion will be less adverse, especially in emerging market countries.)

Also different today is the number of countries seeking to build their *first* nuclear power reactor. Some sixty-five countries have expressed interest in or are actively planning for nuclear power.[10] As the International Atomic Energy Agency (IAEA) points out, however, most of these countries are merely "considering" the range of issues involved in nuclear power development. Many of them cannot realistically afford the large costs associated with civilian nuclear power programs. According to some analyses, countries with a GDP of less than $50 billion could not spend several billion dollars building a reactor.[11] In addition, many aspirant countries still lack the electricity grids required for nuclear power: electricity systems with a capacity below 10 GWe are unlikely to be able to accommodate a nuclear reactor.[12] Some countries could address this issue by expanding electricity interconnections with neighboring states or developing power export arrangements; however, these alternatives are not widely available and in any case would take time to implement.

At the same time, a number of countries have credible plans to become new nuclear energy states (NNES). The IAEA has indicated that ten to twenty-five countries might begin operating their first plants by 2030, whereas since Chernobyl only three—China, Mexico, and Romania—have brought nuclear plants online for the first time.[13] The following list shows the stages of progress of

eleven emerging market countries in their efforts to develop a civilian nuclear energy program:[14]

—Power reactors under construction: Iran.[15]

—Contracts signed, legal and regulatory infrastructure well developed: United Arab Emirates (UAE), Turkey.

—Committed plans, legal and regulatory infrastructure developing: Vietnam, Jordan.

—Well-developed plans but commitment pending: Thailand, Indonesia, Egypt, Kazakhstan.

—Developing plans: Saudi Arabia, Malaysia.

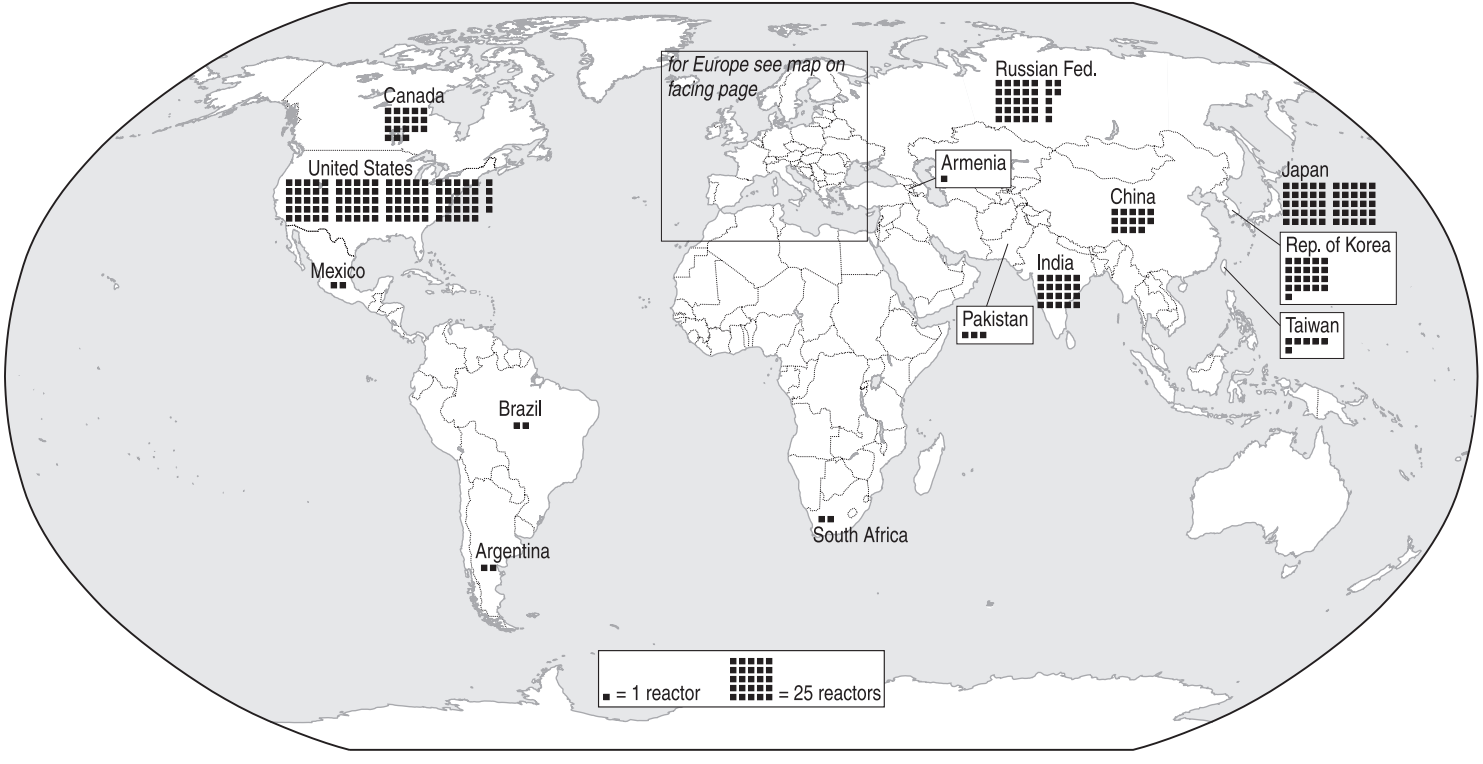
Emerging market nations entertaining the construction of new nuclear power capacity face several critical issues. Domestically, each must establish strong institutions and viable regulatory frameworks addressing health, safety, proliferation, and environmental concerns while ensuring that adequate human and financial resources are available for these tasks. Even if a state is willing to buy a nuclear reactor on a "turnkey" basis (paying for an outside operator to build and run the system), it must still train its own nationals in these various respects and establish a strong academic and industrial culture in all aspects of commercial nuclear operations in order to achieve a sound, sustainable program. The NNES will need to build these capabilities in a sufficient and timely manner.

## New States and Nonproliferation

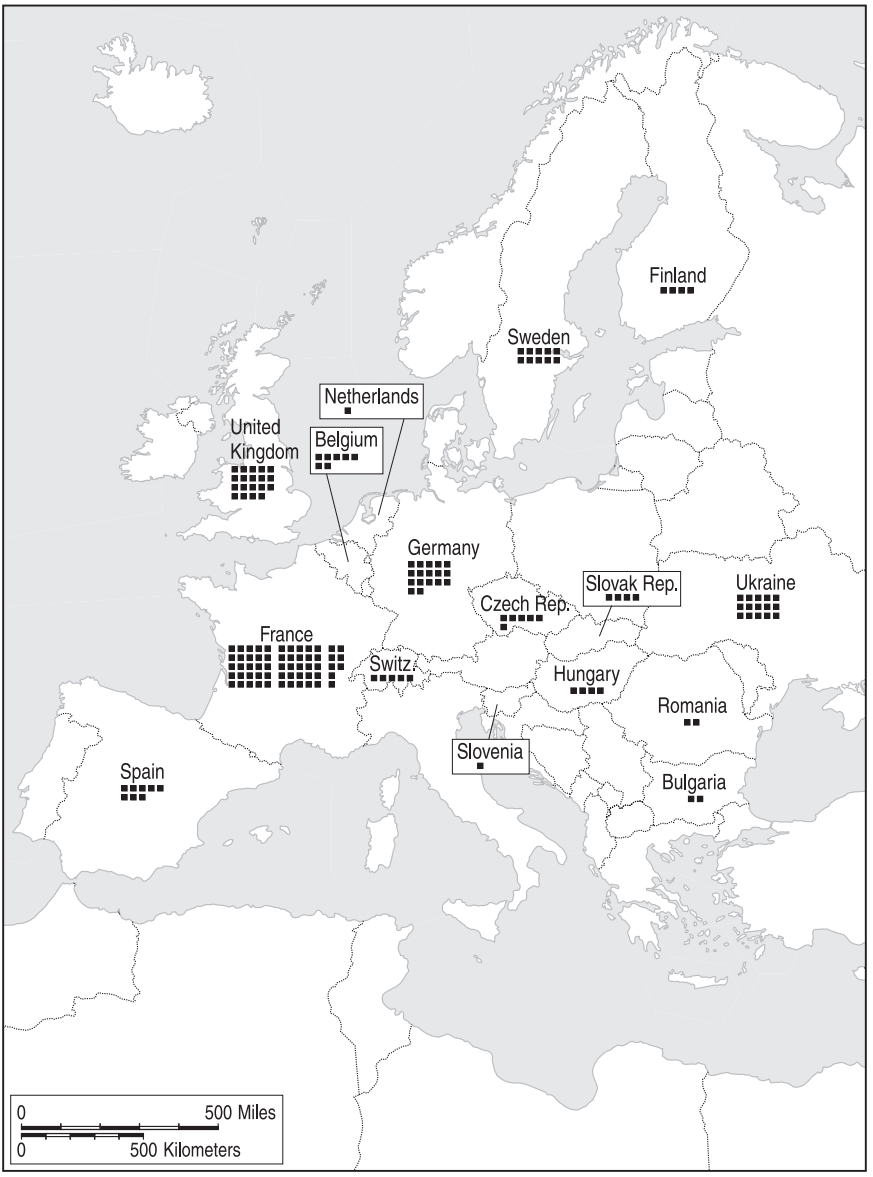
One of the biggest challenges in any expansion of the civilian nuclear sector is that of maintaining and strengthening the global regime for nuclear nonproliferation. The changing geopolitical and security environment, combined with the political instability of many regions and countries that aspire to develop civilian nuclear reactor technology, has already raised proliferation concerns. Nuclear power reactors could become attractive targets for terrorists, who might also seek access to fissile material for radiological dispersal devices ("dirty bombs") or for nuclear weapons. With such materials more widely available, the proliferation risks could mount. As commercial enrichment and recycling programs multiply, countries may be tempted also to develop latent nuclear weapons capabilities, especially if they aspire to attain regional predominance, international standing, or the capabilities of regional rivals.

An expansion of nuclear energy could further tax an already stressed nonproliferation regime. In light of Article IV of the Nuclear Nonproliferation Treaty (NPT), which states that the treaty shall not affect the "inalienable right . . . to develop research, production and use of nuclear energy for peaceful purposes without discrimination . . . and the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information

*Nuclear Power Plants in Operation*




Source: Power Reactor Information System, IAEA, as of July 2011.


Finland
Sweden
Netherlands
United Kingdom
Belgium
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Slovak Rep.
Ukraine
Czech Rep.
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for the peaceful uses of nuclear energy, " some nations are considering acquisition of fuel cycle capabilities as a way to avoid further dependence on foreign suppliers when they develop nuclear power.[16] The NPT contains no provisions to restrict acquisition of such capabilities, although members of the Nuclear Suppliers Group (a voluntary group of nations that restricts nuclear exports) have long practiced restraint on technology transfers of sensitive components of the fuel cycle.

A sharp increase in the demand for nuclear fuel could enhance the commercial attractiveness of uranium enrichment and reprocessing, enticing new entrants into the market.[17] Nations with large uranium resources might seek to add value to their uranium exports by moving further up the chain of production or by expanding current capabilities (Australia, Canada, Kazakhstan, and South Africa have all discussed this option recently). Even if the high cost of fuel cycle activities proves to be a disincentive to their development, the NNES—especially in emerging markets—may consider fuel supply security and exercising sovereign rights under Article IV of the NPT more relevant than economic drivers in their decisions about enrichment or reprocessing.[18] With governments playing an increasing role in securing and meeting nuclear contracts, political motivations might also enter into assessments of the nuclear capabilities necessary for recipient countries. The great danger in the race to build out new capacity is that some new players may not take proliferation concerns as seriously as existing service providers.

To address these issues, there has been a reinvigorated discussion of multilateral nuclear approaches (MNAs). MNAs establish a framework to safeguard Article IV rights, specifically by limiting the diffusion of sensitive nuclear materials and technologies while concurrently guaranteeing long-term supply of nuclear fuel to civilian nuclear power programs. Some steps in this direction include two recently approved fuel banks: the Russian-backed International Uranium Enrichment Center in Angarsk and the IAEA Nuclear Threat Initiative Fuel Bank.[19]

The institutional challenges to the nonproliferation regime are compounded both by the actions of rogue states such as Iran's clandestine nuclear program and North Korea's nuclear weapons testing and new uranium enrichment program, and by non-state activities such as the operations of black market nuclear networks arranged by Pakistani scientist A. Q. Khan. Confidence in the regime's ability to respond to and resolve proliferation threats has thus fallen. New technologies may put further stress on the nonproliferation system. Particularly worrying are the expansion of centrifuge technology, commercialization of the laser enrichment process, development and deployment of next-generation reprocessing techniques that require advanced safeguards, and the potential spread of fast reactors.

Although the impact of these dynamics is difficult to foresee, the nonproliferation regime needs to keep pace with the rapidly changing, complex nuclear market, especially those developments and activities that facilitate the expansion of uranium enrichment and spent fuel reprocessing. This is a major challenge for a nonproliferation regime already under stress.

## A Renaissance and Industry

The nuclear nonproliferation regime is based on inspections, export controls, and physical protection implemented at the national and international levels through laws, treaties, agreements, regulations, protocols, and other mechanisms. Companies operating in the civilian nuclear industry serve as a linchpin in this system. It cannot work unless they comply with the nonproliferation framework and communicate and cooperate with governments, regulators, and regional and international bodies. Industry's views of the costs and benefits of a significant expansion of nuclear energy must factor into assessments of the potential impact of such an expansion on the nonproliferation regime.

For the nuclear industry, a renaissance offers new commercial opportunities. According to the World Nuclear Association (WNA), "There is a tiger-like market out there right now of aggressive capitalist activity that is occurring in anticipation of a huge growth in the global nuclear industry. . . . In the 21st century, the nuclear industry will build hundreds, then thousands of power reactors worldwide."[20]

Many high-level industry leaders have confirmed repeatedly their commitment to nonproliferation, and companies are aware that "the nuclear industry, as well as the arms control and nonproliferation communities, must join governments in ensuring that the nuclear renaissance takes place under conditions that minimize the risk of proliferation."[21] Industry concurs that any major breach of safety, security, or proliferation safeguards could prove fatal. At the same time, the general view in the industry is that a renaissance does not pose a threat to the nonproliferation regime, and that the current legal and regulatory framework is working well—albeit with some need for improvement.[22] While the industry acknowledges and accepts the importance of its role in maintaining the integrity of and strengthening the nonproliferation regime, it sees rogue states and illicit networks, not commercial entities, as the main threats to the nonproliferation regime. Accordingly, it usually looks to government to take the lead in resolving these problems. Fearing potential market disruptions and adverse effects on its own commercial interests, industry tends to be wary of relying on multilateral mechanisms to ensure the security of fuel supplies and limit the spread of sensitive fuel cycle technologies.

As new countries enter the civilian nuclear sector and challenges to the nonproliferation regime become more acute, it is imperative to reexamine many existing assumptions on the part of industry and governments in the interests of closer cooperation in meeting those challenges. How, for example, can the commercial opportunities associated with a nuclear renaissance be reconciled with the need to strengthen the nonproliferation regime? If industry is the "first line of defense," as prominent analysts of nuclear security matters have suggested, how can industry play a more active and enhanced role alongside governments in strengthening the nonproliferation regime as new states begin nuclear power development?[23] Are there better ways to balance business and nonproliferation objectives in the twenty-first century?

## The Brookings Study

To explore these questions, the Brookings Institution turned to major stakeholders in the civilian nuclear industry for their views on the existing nonproliferation regime, particularly its weaknesses, the challenges of an expansion in nuclear power, and the role of industry in strengthening the regime. Opinions were compiled from in-depth interviews, discussions, and an anonymous survey of three sets of stakeholders in the nuclear community: commercial nuclear industry entities, including uranium mining companies, reactor vendors, enrichment and reprocessing service providers, and nuclear power utilities; nongovernment organizations; and government agencies and nuclear regulators.

The written survey consisted of two parts. The first asked participants their general views on the nonproliferation regime, and the second asked participants to evaluate the effectiveness and feasibility of ten MNAs pertaining to various aspects of the nuclear fuel cycle and six proposals for industry self-regulation. "Effectiveness" refers to the likelihood that the nonproliferation regime will be strengthened; "feasibility" refers to the logistical and political ease of implementation (for details of the implementation and results of the survey, see the appendix).

This book presents and assesses the results of this research and offers recommendations. The discussion is organized in two parts: part 1 examines the changing proliferation dynamic through the shifting landscape of nuclear energy and nonproliferation. It opens in chapter 2 with Sharon Squassoni's discussion of the emerging challenges for the nuclear nonproliferation regime. Despite many improvements since the early 1990s in response to discoveries of clandestine programs and networks in Iraq, Iran, North Korea, and Pakistan, significant institutional, structural, and operational problems remain to be addressed. Some of these are long-standing issues inherent in the framework of the NPT, such as the tensions surrounding peaceful uses of nuclear energy (Article IV) and disarmament obligations (Article VI). To add to these concerns, political

expedience at times overrides nonproliferation objectives, and the resources needed to improve IAEA capabilities remain in short supply. A dramatic expansion of civilian nuclear energy programs may generate new challenges surrounding the increased production, storage, and transport of nuclear materials; the potential spread of enrichment and recycling facilities; and the development of new fuel cycle and reactor technologies.

In chapter 3, Sharon Squassoni and John P. Banks turn to the commercial dimensions of the so-called renaissance, focusing on the nuclear fuel cycle and possible effect of commercial trends on the nonproliferation regime. In their view, the high capital costs and technical specialization required for most stages of the fuel cycle (especially enrichment and reprocessing) provide significant economic disincentives for *new* market entrants for the foreseeable future. Overall, the nuclear industry has consolidated but also become globalized, with many parts of the fuel cycle—including mining, enrichment, and reactor construction—resting in several global companies. Squassoni and Banks argue for close scrutiny of the potential impact of new technologies such as laser enrichment and next-generation recycling techniques on the nuclear nonproliferation regime.

In chapter 4, Charles Ebinger and Sharon Squassoni explore the unique challenges of expanding nuclear power capacity in emerging economies, especially in some of the key supplier countries and those likely to become NNES in the coming decades. As they point out, countries decide to pursue nuclear power for various reasons: skyrocketing electricity demand, energy security, concern about dependence on imported fossil fuels as well as declining export revenues from sales of oil and natural gas, climate change, national prestige, balance of power with respect to regional rivals, among others. Acquisition strategies range from relying on foreign firms to run an entire nuclear program to purchasing equipment and services on a turnkey basis. Each instance depends on detailed training and assistance.

Part 2 of the volume presents the results of our research into industry's views, beginning in chapter 5 with Sharon Squassoni, who analyzes the first half of our survey, in which industry and nonindustry participants were asked broad questions about current challenges to the nuclear nonproliferation regime and possible solutions. In general, industry respondents did not view a nuclear renaissance as a threat to the nonproliferation regime. They believe that the current legal and regulatory framework is sufficient and working, and that the major weaknesses and threats emanate from political actors, namely, "rogue" governments or non-state actors engaged in illicit or illegal activities. According to one industry respondent, "Commercial entities are not where the risk lies." Rather, most pointed to the spread of enrichment and reprocessing capabilities, and the lack of enforcement mechanisms in the regime. Industry is by and large optimistic about the role that technology can play in strengthening the

nonproliferation regime, acknowledging, however, that technology alone is not the solution.

Nonindustry responses reflected similar concerns about enforcement and the risks associated with the spread of sensitive nuclear technologies but pointed out a broader range of threats, including terrorist access to nuclear materials, weapons, and highly enriched uranium (HEU) stockpiles, along with the challenge of ensuring that NNES develop a comprehensive regulatory infrastructure. Here, too, respondents said technology—including new recycling methods—could reduce proliferation risks, but like those in industry saw some risks in laser enrichment and fast breeder reactors.

Industry's perspective on MNA proposals is elaborated in chapter 6, where Lawrence Scheinman and Govinda Avasarala provide historical context illustrating that since the dawn of the NPT the international community has struggled to guarantee the Article IV rights of non–nuclear weapon states to develop nuclear energy for peaceful purposes, while also preventing the spread of nuclear weapons. Various multilateral concepts have emerged to allow these states to gain access to nuclear fuel, sensitive fuel cycle technologies, or both. In light of the impending nuclear renaissance—particularly the potential large-scale expansion in nuclear power capacity and addition of many NNES—a number of recent MNA proposals have suggested diverse ways to multilateralize the fuel cycle. As Scheinman and Avasarala point out, however, these ideas reflect a growing schism between nuclear weapons states that want to impose conditions on access to sensitive fuel cycle technologies and states without such weapons that view this as an infringement on their sovereignty and a denial of their Article IV rights. When asked to rank the effectiveness and feasibility of ten MNA proposals (encompassing nuclear fuel banks, centralized facilities, lease/take-back programs, international storage or repositories, fuel guarantees, and market mechanisms), industry respondents found all the proposals unfeasible, with the exception of an IAEA-administered international enriched-uranium fuel bank accessible to all countries in compliance with NPT regulations (proposal 2). Their foremost concern was the commercial impact of MNAs, particularly possible disruptions to what the industry views as a well-functioning and efficient market. Second, many expressed reservations about the financial and technical mechanics and logistics of implementation and raised questions about location, financing, ownership, and liabilities connected with new multilateral facilities or arrangements. Third, participants questioned the ability of some MNAs to stop determined proliferators. Finally, industry cited the political hurdles in implementation, especially in dealing with the back end of the fuel cycle.

Nevertheless, industry recognized the potential value, indeed even the necessity of MNAs in order to strengthen the nonproliferation regime while facilitating a nuclear renaissance. Companies need to be assured that any MNA approach

fortifies and complements the current market, rather than weakens it with new untried mechanisms. Research feedback leads Scheinman and Avasarala to argue for further development and implementation of a "black-box" approach, granting operators the use of fuel cycle technologies but without access to critical design and technical information supporting those technologies. This concept offers a certain comfort level since it is already in operation in the Enrichment Technology Corporation, a joint venture between AREVA and URENCO, as well as in EURODIF. For example, AREVA and URENCO are applying it in the United States in the establishment of two new enrichment facilities. Such an arrangement, say the authors, could be a template for an NNES, or possibly a private utility, to become an investor or partner with an established commercial entity in the creation of a multilateral fuel cycle center of either global or regional dimensions. All parties could share in the benefits of the venture, Article IV rights would be respected, and nonproliferation objectives would be met by limiting the number of facilities capable of producing weapons-usable material.

In chapter 7, Michael Moodie and John P. Banks evaluate industry's response to self-regulatory approaches to strengthening the nonproliferation regime. These include more proactive steps by industry to prevent the proliferation of weapons as well as existing national and international compliance obligations under the global nonproliferation framework. When asked to rank the effectiveness and feasibility of a code of conduct, whistle-blower programs, black-box technology, accreditation of sensitive fuel cycle materials and technology, and a government-industry conference to enhance cooperation, industry respondents tended to view these proposals with skepticism and caution. Their primary concerns were the potential adverse commercial impacts, questionable added value given existing legal and regulatory requirements, need for more information on how self-regulation approaches would function, and assurances that they could be implemented uniformly and fairly across the industry.

Since the self-regulatory concepts were not uniformly rejected by industry (with the exception of the whistle-blower proposal), they may offer a way forward. For one thing, industry is familiar enough with several of the approaches to view them as feasible. As already mentioned, this is the case with the black-box concept. Some proposals are also acceptable to the nonindustry group. Moreover, both industry and nonindustry respondents seem to think that an enhanced partnership between industry and government is needed to strengthen the nonproliferation regime. Moodie and Banks thus explore how the model of the sustained government-industry dialogue used in negotiating the Chemical Weapons Convention could serve not only as a template for sustained dialogue in the nuclear industry but also as a mechanism for reaching a consensus on the development and implementation of effective self-regulatory and MNA schemes.

## Conclusion

With commercial activity now gearing up in the global nuclear fuel cycle, access to nuclear fuel cycle activities and materials is on the brink of expanding, posing serious proliferation risks. Most notably, enrichment and recycling can produce the fissile material required for nuclear weapons, while experience in civilian nuclear power can be used as a platform for developing nuclear expertise useful for a weapons program.

The world needs to be assured that nonproliferation objectives are receiving adequate attention, through stronger institutions, legal and regulatory frameworks, human capabilities, and appropriate infrastructure designed to meet these objectives. To be sure, many countries and companies are already engaged in nonproliferation activities. However, given the weakened state of the regime, the new threats it faces, and the dire consequences of weapons proliferation in a post–cold war world, much more needs to be done to safeguard a nuclear renaissance. With industry at the center of this increased commercial activity, it is reasonable to assume that it should have an increased role in preventing proliferation, or at least in helping shape future civilian use of nuclear energy in a way that mitigates proliferation.

Just as a sufficient safety infrastructure and culture needs to be established to support a rapid build-out of new reactors, nonproliferation also needs to be a priority for all parties while a global expansion takes place. Industry and nonindustry alike must not shy away from the seminal issues in this regard—to ensure that proliferation prevention remains front and center, that industry is balancing nonproliferation and commercial objectives, that government-owned companies do not place commercial or political objectives first, and that industry and government work together, with due respect for each other's goals and concerns.

Past proliferation shocks have prompted new approaches to combating proliferation. A resurgence of nuclear commerce may provide an opportunity to draw upon the strengths of the nuclear industry to help shore up commercial, national, and international efforts to reduce proliferation risks. This book offers insights into some trends in industry thinking and reactions to some of the critical challenges, along with suggestions for ensuring that peaceful nuclear energy remains just that.

## Notes

1. International Energy Agency (IEA), *World Energy Outlook 2010* (Paris, 2010). The 2.2 percent figure is under the IEA's New Policies Scenario, "which assumes the introduction of new measures (but on a relatively cautious basis) to implement the broad

policy commitments that have already been announced, including to reduce greenhouse gas emissions and . . . phase out fossil energy subsidies."

2. Ibid.

3. Natural gas in the form of liquefied natural gas (LNG) is used extensively in the power sector in several large Asian economies, typically purchased under long-term contracts with prices indexed to oil.

4. World Nuclear Association (WNA), "World Nuclear Power Reactors and Uranium Requirements" (London, April 1, 2011).

5. Data from the Power Reactor Information System, International Atomic Energy Agency (www.iaea.org/cgi-bin/db.page.pl/pris.reaucct.htm). Note: 1GWe = 1,000 MW, which is about the size of a typical nuclear power plant. We use GWe throughout to denote electric gigawatts.

6. WNA, "World Nuclear Power Reactors and Uranium Requirements."

7. See IEA, *World Energy Outlook 2010*. This is the IEA's range for three scenarios. Several other organizations, including the IAEA and the WNA, have developed high-end growth scenarios with projections of global nuclear capacity reaching nearly 750 GWe by 2030.

8. IEA and OECD Nuclear Energy Agency, "Technology Roadmap: Nuclear Energy," 2010, p. 17.

9. Keystone Center, "Nuclear Power Joint Fact-Finding" (Keystone, Colo., June 2007), p. 25.

10. International Atomic Energy Agency (IAEA), "International Status and Prospects of Nuclear Power" (Vienna, September 2, 2010), p. 10. Of these, twenty-one countries are in the Asia Pacific region, twenty-one in Africa, twelve in Europe (predominately in Eastern Europe), and eleven in Latin America.

11. Jose Goldemberg, "Nuclear Energy in Developing Countries," *Daedalus* (Journal of the American Academy of Arts and Sciences) 138 (Fall 2009): 72.

12. IAEA, "International Status and Prospects of Nuclear Power" (Vienna, September 2008), p. 35.

13. IAEA, "International Status and Prospects of Nuclear Power" (Vienna, September 2010), p. 11.

14. Adapted from the World Nuclear Association, with the focus on developing countries.

15. The details of Iran's nuclear program are a matter of enormous international discussion and debate. While it is clear that the country has made significant progress in building a nuclear power reactor, most attention on the country's nuclear activities relate to the ambiguity of its intentions and the security implications of the development of an Iranian nuclear weapons capability. The political and security-related complexities of Iran's nuclear program are beyond the scope of this volume. Similarly, given the clandestine nature of the development of the Iranian nuclear program and the lack of ongoing involvement in the program by the established commercial nuclear industry, it is the authors' view that the case of Iran is of limited relevance to this study.

16. For the full text of the NPT, see IAEA, "Treaty on the Non-Proliferation of Nuclear

Weapons," INFCIRC/140 (April 22, 1970) (www.iaea.org/Publications/Documents/Infcircs/Others/infcirc140.pdf).

17. "Nuclear Choice: Time to Invest in Uranium?" *Financial Times,* March 25, 2010.

18. In the case of reprocessing, the extent of economically recoverable uranium resources also plays a role. The Massachusetts Institute of Technology (MIT) recently concluded that "uranium resources will not be a constraint for a long time," even with uranium costs increasing 50 percent as a result of "a world with ten times as many LWRs [light-water reactors] and each LWR operating for 60 years." See MIT, "The Future of the Nuclear Fuel Cycle" (Cambridge, Mass., 2010), p. 4.

19. These are discussed in chapter 6.

20. John Ritch, director general of the World Nuclear Association, as quoted in "The Tough Sell of Nuclear Investing," *MarketWatch,* May 20, 2010 (www.marketwatch.com/story/nuclear-investing-a-tough-sell-but-can-pay-off-2010-05-20?pagenumber=1).

21. Anne Lauvergeon, "The Nuclear Renaissance: An Opportunity to Enhance the Culture of Nonproliferation," *Daedalus* 138 (Fall 2009): 93.

22. For the purposes of this study, industry is defined as uranium mining companies, reactor vendors, enrichment and reprocessing service providers, and nuclear power utilities.

23. See Gretchen Hund and Amy Seward, "Broadening Industry Governance to Include Nonproliferation" (Richland, Wash.: Pacific Northwest Center for Global Security, August 21, 2008), p. 3; and David Albright, *Peddling Peril, How the Secret Nuclear Trade Arms America's Enemies* (New York: Free Press, 2010), pp. 227–43.