Managing the Growth of Nuclear Power: Nuclear Renaissance or Not?

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Since 2005, more than 65 countries have expressed interest in joining the 30 countries, plus Taiwan, that currently operate nuclear power reactors. These countries are motivated chiefly by concerns about energy security and climate change, but their interest has been buoyed particularly by the recent enthusiasm for nuclear power that rivals the optimism of the 1950s and 1960s.

This enthusiasm undoubtedly has been dampened by the recent chain of events at Japan's Fukushima Daiichi nuclear power reactors, which has left publics and governments alike wondering what is next for nuclear energy. The March 11, 2011, earthquake and tsunami that devastated Japan and killed tens of thousands of people resulted in partial core meltdowns at three reactors at the Fukushima Daiichi power plant. Problems keeping the shutdown reactors and their spent fuel pools cool without off-site electricity produced hydrogen explosions and disseminated radiation, some of it detected at very long ranges. At this writing, several countries that now operate nuclear power plants, including the United States, have announced intentions to conduct safety reviews. China, which has the largest number of nuclear power plants under construction, has announced a temporary suspension of construction. Italy has announced a year-long delay in moving forward with its plans for four power reactors.

The long-term impact of the Fukushima accident on nuclear power in Japan and worldwide is hardly knowable at this point, as the crisis is not over and the contributing factors will likely be revealed only over time. Although many countries may regard the possibility of another such event combining earthquake and tsunami to be very low, particularly for them, the difficulties Japan—a highly sophisticated and technologically competent country—experienced because of the lack of electricity is likely to raise questions about the costs and risks of nuclear power.

Drivers of Nuclear Enthusiasm

Energy security has become a chief concern for many countries as oil and natural gas prices have risen. Since nuclear energy only produces electricity, the notion that it can reduce dependence on foreign oil is only valid for those countries that still use oil for electricity. While this may have been more prevalent before 1973, it is now the exception to the rule. Oil dependency (even in Japan and France, two countries that rely on nuclear power) persists because it is used heavily in transportation and industry sectors. Nuclear energy is less affected by price fluctuations because fuel is a smaller contribution to the cost of electricity than is the case for coal or natural gas, and it is less vulnerable to supply interruptions than oil or gas.

A second source of enthusiasm for nuclear energy has been concern about climate change. In the last ten years, observers have frequently remarked that nuclear energy must be part of the future energy mix because of its low carbon emissions. In the wake of Fukushima, some observers continue to opine that nuclear energy is worth the risk because of climate change. In mitigating climate change, however, two factors work against nuclear energy as a preferred option: the preparedness of the industry for rapid expansion and cost. Simply put, there are much less expensive and quicker options to reduce CO_2 emissions. Even under optimistic projections of nuclear energy growth, nuclear power provides a much smaller contribution to CO_2 emission reductions than measures such as efficiency and fuel-switching.[1]

Trajectories of growth

There are many projections for nuclear power growth, but these must be carefully scrutinized for their assumptions. Plans for nuclear power construction historically have been subject to change. Public acceptance, cost and financing issues all play critical roles. Because of the prestige that is attached to nuclear power, some countries may announce ambitious plans that are never fully realized. For example, if all countries followed through on their current proposals to build nuclear power plants, the number of reactors worldwide would double in the next twenty years. Yet, some of these countries have had plans for decades to build nuclear power reactors, with little evident progress.

Scenarios for growth assume significant government support for nuclear power. In fact, without significant government support, the worldwide share of nuclear energy in electricity generation is expected to decline from 14% to 10% in 2030. This is partly because electricity demand is expected to double by 2030.

The most ambitious scenarios for nuclear growth assume certain CO_2 emission reductions. Most observers agree that for nuclear power to have a significant impact on climate change, existing capacity would have to double or triple. This could mean growth from 441 reactors (with 369 gigawatts-electric, [GWe] output) to 800 or 1,200 GWe by 2050. In the 2003 MIT study, *Future of Nuclear Power*, the high scenario for growth (significant enough to have an impact on climate change) assumed 1,500 GWe by 2050.

What's really happening

Much of the current construction (65 plants being built, with some projects more than 10 years old) is occurring in Asia. China has 27 projects underway. Korea is building 5 additional nuclear power plants to complement the 21 operating already; and Japan has two under construction, with 6 more planned to add to the 54 reactors now in operation (notwithstanding the current situation). India also has ambitious plans to expand its current capacity (19 power reactors with 9 GWe) sevenfold to 63 GWe by 2050.

Although the United States leads nuclear electricity production in the world, with 104 reactors operating, no new reactors have been licensed for several decades. Recent incentive programs have resulted in 17 license applications (as of December 2010), for constructing and operating 26 new reactors. These are all for advanced (Generation III and III+) light-water reactors[2] and include five different designs: the AP-1000 (Westinghouse-Toshiba), the ESBWR (GE-Hitachi), AREVA's European Pressurized Reactor (EPR), the Advanced Boiling Water Reactor (GE-Hitachi) and the Advanced Pressurized Water Reactor (Mitsubishi). However, no concrete has yet been poured, and expansion of the loan guarantee program (from $18 billion to $54 billion) for new nuclear power plants does not seem to be enough to realize significant expansion. In the United States, nuclear energy is unlikely to be able to compete with natural gas unless pricing is imposed on CO_2 emissions. Currently, most industry experts predict that only four to eight reactors will be constructed in the United States by 2020.

Among the 65 countries interested in nuclear power, Iran is closest to completing construction of a reactor at Bushehr. The United Arab Emirates, Turkey and Vietnam are furthest along in planning reactors. In December 2009, the UAE awarded a $20 billion contract to a Korean consortium headed by the Korea Electric Power Company (KEPCO) for four power reactors. Turkey and Vietnam have signed agreements with Rosatom for nuclear power reactors. Other countries in various stages of the planning process include: Jordan, Egypt, Morocco, Libya, Saudi Arabia, Oman, Qatar, Bahrain, Yemen and Kuwait in the Middle East; Bangladesh, Philippines, Indonesia, Malaysia, and Thailand in Southeast Asia; Azerbaijan, Belarus, and Kazakhstan in Central Asia; and Nigeria, Ghana, Algeria and Tunisia in Africa. Countries that have expressed interest but have not yet defined goals include Israel, Chile, and Venezuela.

Risks of a nuclear renaissance: magnitude of expansion, locations, new kinds of reactors, and fuel cycle technologies

A significant expansion and distribution of nuclear reactors could pose safety, security and proliferation risks. With 500 reactors operating, if the likelihood of a serious accident involving damage to the reactor core is estimated at 1 in 20,000 reactor operating years, such an accident could be expected every 40 years. With 1,000 reactors, the frequency could be every 20 years. A lot depends on where reactors are located, their design, and implementation of safety and maintenance measures. Similar concerns may be in order for nuclear security. Building reactors in countries that experience political instability or terrorist attacks could increase the security risks. Finally, countries that are new to nuclear power must develop appropriate regulatory infrastructure and safety and security cultures, all of which may take time. The appended table lists countries and their commitments to relevant international agreements and conventions regarding nuclear safeguards, physical protection and nuclear safety.

Other risks could emerge from new suppliers and new technologies. China, Korea, and India have all expressed an interest in exporting power reactors. Although China and Korea are members of the Nuclear Suppliers Group (NSG), they have not engaged in nuclear cooperation on a large scale before. India, which is not a member of the NSG, is reportedly interested in selling its heavy-water reactors, which are widely regarded to pose greater proliferation risks than light-water reactors (the predominant type of reactors worldwide). Russia is promoting floating reactors, which can be towed to locations and then removed after their useful life, but the security and safety of such reactors has not been thoroughly evaluated.

A significant expansion could also mean an expansion of fuel cycle capabilities—that is, not just building of power reactors, but also uranium enrichment and reprocessing plants. Such technologies can be used to make fuel for peaceful nuclear power or fissionable material for nuclear weapons. Currently, such capabilities reside in the five nuclear weapon states and a handful of non-nuclear weapon states (Japan, Brazil, Germany and Netherlands for enrichment, and Japan for reprocessing). Expanding these capabilities to additional countries would increase proliferation and nuclear security risks. Such facilities require enormous inspection effort and, even then, the potential for significant quantities of material to be unaccounted for is high. Moreover, the International Atomic Energy Agency (IAEA) is already operating under a constrained budget. More importantly, the acquisition of these kinds of capabilities that is most critical to nuclear weapons programs and expansion, therefore, should be minimized.

The United Arab Emirates took a positive step in 2009 by announcing it would rely on the international market for fuel services such as enrichment and reprocessing, but other states are wary of closing off future options. Some states, such as Jordan and South Africa, may want to exploit uranium resources. Other states oppose new restrictions on the basis of what they perceive as their "rights" to the peaceful uses of nuclear energy under the Nuclear Nonproliferation Treaty (NPT).

The United States has been seeking, through its bilateral nuclear cooperation agreements, to obtain commitments from states not to enrich uranium or reprocess spent fuel. Other major suppliers from France (AREVA), Korea (KEPCO), and Japan (Toshiba, Hitachi, Mitsubishi) have not made abstention from sensitive technology acquisition or development a requirement for their nuclear cooperation. The Obama administration itself does not appear to have a unified policy in this regard, and officials reportedly seek such commitments as they are able to obtain.

Brakes on the renaissance? Cost, safety, waste, and proliferation

Most observers agree that nuclear energy requires large government support and subsidies because of the enormous up-front investment costs. While a natural gas plant in the United States costs $310 million and 36 months to build, typical nuclear power projects cost $5 billion or more and at least 5 years for construction, not counting licensing and regulatory schedules.[3] For countries embarking on nuclear power programs, the IAEA estimates that it could take 15 years before the first reactor produces electricity. Recent reactor deals have involved considerable financing packages from vendors/governments. In the United States, the cost of new nuclear power plants has been the biggest hurdle by far.

Safety issues are always a concern with respect to nuclear power, but may now receive even more attention in light of the Fukushima accident. New designs may be scrutinized even more thoroughly for safety improvements, and regulatory agencies could revise their requirements regarding passive safety features (that do not require operator actions) and back-up power in the event of a loss of off-site electricity.

A key consideration will be how to handle existing power reactors. The nuclear industry had been relatively optimistic about extending licenses for nuclear power plants over 40 years old, even to 80 years. Virtually all the nuclear power plants in the United States have had their licenses extended beyond 40 years. The Fukushima accident, at a minimum, could launch reviews of extension decisions (as it has done in Germany) and could affect publics' willingness to extend licenses for the oldest plants, since 5 of the 6 Fukushima Daiichi reactors were close to 40 years old. The need to replace aging reactors constitutes a significant challenge for the growth of nuclear power.

One positive outcome of the Fukushima accident would be to initiate realistic public discussions about how to handle nuclear waste. The vulnerability of spent fuel pools at Fukushima Daiichi demonstrates the risks of putting off decisions indefinitely and could help promote dry cask storage of spent nuclear fuel. Concerns about how to handle nuclear waste could slow down new programs for nuclear power as countries study their options more seriously.

Managing nuclear growth

The United States has been a leader in nuclear nonproliferation for decades, but its influence over the decisions of other states regarding nuclear energy is likely to be limited by the strength of its own nuclear industry. If the United States is unable to pressure other countries to limit their fuel cycle activities through its bilateral nuclear cooperation agreements, there are still a few avenues to pursue more manageable nuclear power growth. The U.S. government should:

- Become a leader in supporting renewable energy and efficiency overseas, which carry no risks of nuclear proliferation, nuclear accidents or burdens of nuclear waste.

- Offer its expertise in nuclear safety and regulation to all new nuclear energy states.
- Press the Nuclear Suppliers Group to adopt the Model Additional Protocol as a condition of supply, and encourage all countries to incorporate a requirement for the Additional Protocol in nuclear cooperation agreements and in vendor contracts.[4]
- Work with partners to ensure that the IAEA has adequate funding. IAEA responsibilities have outpaced budgets for decades and, if an expansion of nuclear energy entails an increase in fuel cycle facilities, the safeguards burdens could increase dramatically.
- Press industry to supply nuclear reactors and their components responsibly. Vendors should agree on minimum requirements for the sale of nuclear reactors and components and make these standard clauses in contracts. It will be important to reach beyond the NSG to other potential suppliers, particularly India and Pakistan. Some of the minimum requirements might include signing existing safety, security, and nuclear waste conventions.
- Abandon current discussions with the Nuclear Suppliers Group on criteria for transferring enrichment and reprocessing technologies in favor of the existing policy of restraint.

References

1 See discussion of this in Sharon Squassoni, *Nuclear Energy: Rebirth or Resuscitation?* Carnegie Endowment for International Peace, February 2009, pp. 19-28.

2 Nuclear reactor designs are categorized by "generation"; that is, Generation I, II, III, III+, and IV. First generation reactors (prototypes) have largely been phased out. Gen II reactors comprise the bulk of operating power reactors today. Gen III reactors incorporate some passive safety features and are designed for longer (60 years) lives. Gen III+ incorporate additional passive safety features (relying on gravity or natural convection for cooling) and will have longer burn-up of fuel and reduced fuel consumption and waste. See Nuclear Reactors: Generation to Generation, by Stephen Goldberg and Robert Rosner, available at http://www.amacad.org/publications/nuclearReactors.aspx

3 This estimate is for a natural gas combined cycle plant producing 560 MWe, whereas nuclear power plants are typically twice as large. See http://www.netl.doe.gov/KMD/cds/disk50/NGCC%20Plant%20Case_FClass_051607.pdf for parameters of this 2007 estimate. Costs for all generation options are provided in a November 2010 update to the Energy Information Administration's Annual Energy Outlook, available at http://www.eia.gov/oiaf/beck_plantcosts/?src=email

4 The Nuclear Suppliers Group, created in 1975, is a voluntary group of 46 countries that harmonize their export controls for nuclear and dual-use exports as an adjunct to the Nuclear Nonproliferation Treaty. The Model Additional Protocol (INFCIRC/540) was adopted by NPT signatories in 1997 to provide additional inspection access and information to the IAEA in the wake of revelations about Iraq's clandestine nuclear weapons program.

Table I

New nuclear power aspirants (as of March 2011): A snapshot of their safety, security, waste and nonproliferation commitments

Country	GWe	Target Date	Safeguards CSA	AP	Safety CNS	Security CPPNM	Waste**	Liability (Vienna Convention or CSC)
Turkey	3-4?	2014	Y	Y	Y	Y	N	N
Bangladesh	2	2015	Y	Y	Y	Y	N	N
Jordan	.5	2015	SQP	Y	N	N	N	N
Egypt	1	2015	Y	N	Y	N	N	VC
Morocco	?	2016	Y	N*	N	Y	Y	VC*
Azerbaijan	1		Y	Y	N	Y	N	N
Belarus	4	2016	Y	N*	Y	Y	Y	VC
Iran	6	2016	Y	N*	N	N	N	N
UAE	4	2017	SQP	Y	N	Y	N	N
Vietnam	15-16	2020-30	Y	N*	Y	Y	N	N
Thailand	4	2021	Y	N*	N	N	N	N
Israel	1		N	N	N	Y	N	VC*
Saudi Arabia	?		SQP	N	N	N	N	N
Oman	?		N	N	N	Y	N	N
Qatar	?		SQP	N	N	Y	N	N
Bahrain	?		SQP	N*	N	N	N	N
Kuwait	?		SQP	Y	Y	Y	N	N
Malaysia	5	2025	Y	N*	N	N	N	N
Indonesia	6	2025	Y	Y	Y	Y	N	CSC*
Kazakhstan	.6	2025	Y	Y	N	Y	N	N
Nigeria	4	2025	Y	Y	Y	Y	Y	VC
Algeria	5?	2027	Y	N	Y	Y	N	N
Ghana	1	2030	Y	Y	N	Y	N	N
Tunisia	.5	2030	Y	N*	Y	Y	N	N
Yemen	?	2030	SQP	N	N	Y	N	N
Philippines	1	2030	Y	Y	N	Y	N	VC, CSC*
Libya	1	2050	Y	Y	N	Y	N	N
Venezuela	4?	2050	Y	N	N	N	N	N

Abbreviations: GWe = Gigawatts, electric; CSA = comprehensive safeguards agreement (INFCIRC/153); AP = Model Additional Protocol; SQP = Small Quantities Protocol; CNS = Convention on Nuclear Safety; CPPNM = Convention on the Physical Protection of Nuclear Material; CSC = Convention on Supplementary Compensation

Notes: * = signed, not ratified

** = Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (INFCIRC/546)