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Nuclear energy in developing countries

After 20 years of stagnation, plans to use nuclear power for electricity generation are being revived around the world, usually for the following reasons:

- Nuclear-generated electricity contributes little, on a life-cycle basis, to greenhouse gas emissions and could therefore help in solving global warming problems.
- The eventual introduction of a carbon tax on fossil fuel use, as one instrument to reduce greenhouse gas emissions from thermoelectric stations, would make nuclear-generated electricity more competitive vis-à-vis the use of natural gas and other fossil fuels for that purpose.
- Nuclear energy can contribute to energy security, reducing or eliminating the need for natural gas or other fossil fuels now used frequently for electricity generation.

These are sensible reasons for countries to examine the nuclear option seriously. There are, however, other factors that are much more difficult to analyze because of their political nature, namely the "status" and prestige associated with mastering nuclear technologies. This factor certainly played a role in the efforts of the United Kingdom and France to develop nuclear weapons as an instrument to gain a place at the table among the great powers. In developing countries, nuclear technology has often been viewed as a passport to the first world and to the bureaucratic self-aggrandizement of the nuclear establishment, factors evident in the development of the nuclear capacity of India, for example. It is widely believed that elements of the Indian scientific community, rather than the Indian military, have led the push for India's nuclear weapons program.[1] This is not surprising considering the influence the U.S. Department of Energy's national laboratories have had in decisions to expand research, development, and deployment of new generations of nuclear reactors, despite lack of enthusiasm from the nuclear industry. This was also the case in Brazil, where scientists in the 1950s not only considered building a nuclear reactor with natural uranium and graphite – capable thus of producing plutonium – but also started work on ultracentrifuges to enrich uranium.[2]

To promote a nuclear energy "renaissance," the U.S. government included, in the Energy Policy Act of 2005, significant incentives to encourage the private sector to build new power reactors. For the first reactors built, such incentives (in the form of subsidies and guarantees) are estimated to have the potential to reduce the cost of electricity produced by 30 percent. Although such policies led to a flurry of applications to build new reactors, none has so far been constructed.

Despite the U.S. government's efforts to revive nuclear energy, the prospects for nuclear are not considered very bright in those countries that are part of the Organisation for Economic Co-operation and Development (OECD): the worldwide projections for 2030 by the International Atomic Energy Agency (IAEA) predict, essentially, zero growth in nuclear power generated in the period 2003–2030 from OECD countries.[3] The hopes of a nuclear industry renaissance, therefore, lie almost exclusively in the non-OECD countries, where the installed power is expected to grow from 57 to 132 gigawatts (a net addition of some 75 large nuclear reactors). The French company AREVA, with the active support of the French government, has been engaged in lobbying to sell reactors to a large number of developing countries around the world, at least 13 of which are in the Middle East. Presently only 7.5 percent of existing reactors are in non-OECD countries (mainly in China and India), and since most of them are small, the power generated by them represents only 4.3 percent of total nuclear-generated electricity. According to IAEA projections, this fraction will grow to 15 percent by 2030.

Recently, 50 developing countries[4] that do not have nuclear reactors for electricity production expressed to the IAEA interest in acquiring their first nuclear power plant. Such countries have a gross domestic product (GDP) ranging from US$6 billion (Haiti) to US$657 billion (Turkey) and electric grids ranging from 0.1 gigawatt (Haiti) to 31 gigawatts (Turkey). It is unlikely that countries with a GDP smaller than US$50 billion would be able to purchase a nuclear reactor worth at least a few billion dollars. In addition, electric grids, for technical reasons, must have a minimum of 10 gigawatts to accommodate a large nuclear reactor. Eliminating the countries that do not fit these criteria, we are left with a short list of 16 countries that could be considered serious candidates for purchasing large nuclear reactors: Algeria, Belarus, Chile, Egypt, Greece, Indonesia, Kazakhstan, Kenya, Malaysia, Philippines, Poland, Saudi Arabia, Thailand, Turkey, United Arab Emirates, and Venezuela.

What are the real motivations for these countries in introducing nuclear reactors to their energy system?[5] Concerns about greenhouse gas emissions do not have a high priority in developing nations: neither the Kyoto Protocol nor any other international agreement constrains those emissions for them (they were exempted to assist their development). Additionally, experience shows that in industrialized countries, financing the up-front investments needed for nuclear plants is a major challenge. In most of these countries, nuclear power expanded only when governments facilitated private investment, a practice that is at odds with present strong market liberalization policies. For developing countries, the pivotal problem is the allocation of scarce governmental resources; financial authorities cannot easily justify subsidizing nuclear energy at the expense of more pressing needs in health, education, and poverty reduction.

Nor is the need for energy a sufficient compulsion. Most of the anticipated growth in nuclear energy in the developing world is commonly ascribed to China and India. In recent years, they have become prime markets for nuclear technology imports because their indigenous nuclear programs have been, at best, qualified successes. Yet those countries, and indeed the rest of the developing world, have abundant non-nuclear energy alternatives, too. Cleaner and more efficient coal-burning technologies would reduce emissions not only of greenhouse gases, but also of soot and other by-products that cause local and regional pollution – and they could prove to be easier or less expensive to implement. The average efficiency of coal-burning thermoelectric generation stations is around 30 percent now and could be improved with current technology to reach the significantly higher average efficiency of such plants in the United States or Japan,[6] to say nothing of carbon capture and storage (CCS), which could be available in a few years. Also, many developing nations have underexploited hydroelectric power options: worldwide only around one-third of economically viable hydroelectric potential has been tapped so far, and in sub-Saharan Africa that figure is far smaller. Other renewable energy sources, particularly biofuels for transportation, also have good prospects.[7]

Therefore, excluding the intention to develop nuclear weapons for reasons of national security, the only sensible justification for developing countries to go nuclear is to enhance security of supply. This was an important consideration some 30 years ago in France and Japan, both of which installed large parks of nuclear reactors. Today nuclear electricity accounts for 78 percent of the total electricity produced in France, and 30 percent in Japan. However, there is a fundamental difference between the problems of these countries decades ago and the developing countries today. France and Japan didn't have other options, having exhausted at that time indigenous fuels (or hydro) to generate electricity. The choice was to import fossil fuels (gas and oil, and even coal) or set up nuclear reactors. That's not the case today for many developing countries, including the 16 in Table 1.

The meaning of energy security when nuclear energy is involved, however, is a double-edged sword: there is no clear distinction between the technology needed for the peaceful uses of nuclear energy (such as the production of electricity) and the manufacture of nuclear weapons. Nuclear reactors need enriched uranium to function, and if the enrichment plants producing the fuel for reactors are devoted to producing uranium with a high degree of enrichment (above 80 percent), that product can be used for weapons. Pakistan followed this route, using information obtained about centrifuges enrichment by a Pakistani technician from a URENCO enrichment plant. Even if a reactor operates with a low degree of enrichment (3 or 5 percent), which is the case for most commercial nuclear reactors, plutonium that can be separated chemically and used for weapons is produced in the fuel elements. India did this as early as 1974, using an imported research reactor from Canada, and North Korea did the same more recently, in a small power plant.

Presently, Brazil, Germany, Iran, Japan, The Netherlands, the United States, China, Russia, India, and Pakistan have enrichment facilities. Russia has an enrichment capacity of approximately 35,000 ton separative work unit (SWU)[8]/year, and all other countries together have another 30,000 ton SWU/

Table 1
Potential Non-Nuclear Sources of Electricity and Their Ratios of Reserves to Production, in Years, in 16 Developing Countries

Country	Potential source(s), with ratio(s) of reserves to production (R/P) in years
Algeria	Abundant natural gas (R/P=43)
Belarus	Natural gas from Russia
Chile	Abundant hydro and good geothermal potentials
Egypt	Abundant natural gas (R/P=43)
Greece	Abundant coal (R/P=55) and peat, good geothermal and wind potentials
Indonesia	Abundant biomass, geothermal energy, natural gas (R/P=33), oil (R/P=10), hydro
Kazakhstan	Very abundant natural gas (R/P>100) and oil (R/P=80)
Kenya	Abundant biomass, good geothermal potential
Malaysia	Biomass, natural gas available (R/P=35)
Philippines	Abundant biomass and geothermal resources
Poland	Abundant coal (R/P=47 to 108)
Saudi Arabia	Abundant oil (R/P=66) and natural gas
Thailand	Abundant biomass, coal (R/P=63 to 96) and natual gas also available (R/P=12)
Turkey	Vast hydro resources (216 TWh technically and 130 TWh economically exploitable, compared to 73 TWh planned, 11 TWh under construction and 35 TWh installed by end 2005)
United Arab Emirates	Very abundant oil (R/P=97) and natural gas (R/P>100), small country with low demand
Venezuela	Abundant hydro, oil (R/P=73) and natural gas (R/P>100) resources

Source: *Survey of World Energy Resources* 2007 (World Energy Council, 2008).

year. About 100 to 120 ton SWU/year is required as the fuel loading of a typical 1,000 MW reactor. The existing enrichment capacity therefore is enough to supply the fuel needs to approximately 600 reactors of 1,000 MW, almost double the existing units in operation.

Although vendors are keen to sell nuclear reactors to developing countries, that by itself does not guarantee energy security since enriched uranium nuclear fuel has to be imported to keep the reactors operating. For that reason, many countries will certainly contemplate the desirability of enriching uranium domestically to avoid dependence on external supplies, which they may fear will come associated with political pressures and demands unrelated to nuclear issues. Two outstanding examples are the cases of Iran and Brazil. In the 1970s, both countries signed agreements with the Federal Republic of Germany to install enrichment plants; the agreements were blocked by the United States. In both cases it became clear that the United States was denying access to nuclear fuels if political conditions were not met. In the case of Iran, the perception was that the United States wanted to promote regime change; in the case of Brazil, that the United States was acting on suspicions that the military government had plans to manufacture nuclear weapons. These perceptions led both governments to encourage national efforts to enrich uranium domestically, rather than to accept the limitations imposed by the United States.

Over the years, nuclear reactors for electricity production were installed in nine developing countries: Argentina, Brazil, China, India, Iran, Mexico, Pakistan, South Africa, and North Korea. Of these countries, five – China, India, Pakistan, South Africa, and North Korea – developed nuclear weapons (although South Africa later dismantled theirs). Argentina and Brazil embarked on programs that could have led to weapons, but decided to abandon the programs in 1991. Only Mexico does not have enrichment facilities. It is unclear at this time if North Korea has them, although it has facilities to reprocess nuclear fuel and separate weapons-grade plutonium. The others installed such facilities despite the fact that the number of reactors in operation in these countries did not justify (from an economic viewpoint) the investments in such large-scale facilities. There is thus a fundamental contradiction between efforts to avoid the proliferation of nuclear weapons and enthusiasm for the spread, for commercial reasons, of nuclear reactors to many developing countries. Recent efforts by North Korea, Iraq, and Iran evidence this contradiction.

These problems are not new; they started in the beginning of the nuclear age, as early as 1945. At that time, the United States had a monopoly on the technology and infrastructure needed to make nuclear weapons, ranging from the uranium ore itself to the purification and enrichment (to the high levels needed for weapons) processes to the know-how in building weapons. With such clout, the United States tried to put nuclear energy developments under international control. The Soviet Union, confident that it could develop nuclear weapons to break the U.S. monopoly, found this unacceptable. U.S. policy-makers were probably under the delusion that it would take the Soviet Union a long time to build its own nuclear devices; but within only four years of the Hiroshima/Nagasaki explosions, the Soviets had done so.

To keep some control of the spread of nuclear technology, President Eisenhower's 1953 program Atoms for Peace offered U.S. help to countries with interest in the civilian uses of nuclear energy. Under the program, reactors using highly enriched uranium were donated to a number of countries for research purposes and for industrial and medical applications. The rationale for such a move – stimulated by well-intentioned leading scientists in the United States, such as I. I. Rabi – was that the spread of nuclear technology was inevitable, so efforts should be made to restrict it to peaceful uses. The United States, which then controlled the worldwide production of enriched uranium (besides the Soviet Union), established tight export control of sensitive nuclear materials. Of course, the program also had commercial motivations: it promised to create a market for nuclear equipment produced in the United States.

Over the years, the United States and the Soviet Union exported hundreds of research reactors using highly enriched uranium to many developing countries. Some of the spent fuel from the reactors was returned to the United States and the Soviet Union, and new shipments of fuel and other materials were closely monitored. In practice, however, the program, despite its positive aspects in making available the use of radioactive isotopes in industry and medicine, often worked against the goal of discouraging nuclear proliferation, because the dissemination of nuclear reactor technology led to the training of thousands of scientists and technicians and the spread of sensitive dangerous materials (such as highly enriched uranium and plutonium). This was certainly the case in India, where an active nuclear establishment was built around the eminent scientist Homi J. Bhabba.

In the 1950s and early 1960s, the United Kingdom, France, and China developed nuclear weapons without significant external help (except possibly in the case of China, which was assisted to some degree by the Soviet Union). The technical barriers to developing nuclear weapons using materials produced in those nuclear reactors nominally dedicated to peaceful uses aren't insurmountable; and the contention that nuclear technology cannot be developed indigenously by developing countries has proved to be false. That any modern industrialized country could develop nuclear weapons led to determined effort in the late 1960s to stop the further proliferation of such weapons to other states (horizontal proliferation). In the 1960s there were also very strong concerns with testing nuclear weapons in the atmosphere, and with the frightening increase of nuclear weapons in the five countries that possessed them, especially the United States and the Soviet Union, both with their thousands of weapons (vertical proliferation).

The Non-Proliferation Treaty (NPT) adopted in 1968 is the main instrument used to address these problems. The Treaty divided states in two categories: nuclear-weapons states (NWS), defined as those that had "manufactured and exploded a nuclear weapon or other explosive nuclear device prior to January 1967" (the United States, the Soviet Union, the United Kingdom, France, and China), and non-nuclear-weapons states (NNWS), which "undertake...not to manufacture or otherwise to acquire nuclear weapons or other nuclear explosive devices." In return for this undertaking, NNWS are entitled to "participate in the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of atomic energy." This "grand bargain" was very difficult to achieve, though. The NNWS kept the "inalienable" right to the use of nuclear energy for peaceful purposes, and the NWS agreed to pursue negotiations leading to nuclear disarmament. These negotiations led practically nowhere, and today the NWS commitment to pursue nuclear disarmament is generally considered mostly a rhetorical gesture. A few countries, such as India, Pakistan, Israel, Brazil, and Argentina, wanted to keep their options open, and so did not accept the limitations imposed by the Treaty; indeed, India, Pakistan, and Israel produced weapons in the subsequent years.

The NPT gave the IAEA the job of establishing safeguards and overviewing activities of the signatories in the nuclear area in order to avoid proliferation. Today, essentially all nuclear facilities in NNWS are under safeguards. Nevertheless, the regime was not in the past sufficient to deter countries from developing nuclear capability, so the nuclear powers have tried other approaches to prevent, inhibit, or delay the appearance of new NWS. In addition to physical security measures to secure enriched uranium and plutonium and measures to keep tight control on exports, two other approaches have been tried by the United States to curb the proliferation of nuclear weapons:

- Sanctions ("sticks") to punish nations that embark in such a direction. Libya's renunciation of its nuclear program is often given as an example of the success of this approach.
- Rewards ("carrots"), such as trade or financial benefits. North Korea's behavior (although somewhat erratic) is given as an example of success with this approach.

All of these mechanisms have delayed, to some extent, several countries' efforts toward acquiring the capacity to develop nuclear weapons.

A specific security measure that proved moderately successful was the Reduced Enrichment for Research and Test Reactors (RERTR) program, started by the United States before 1980 and soon followed by a similar program from the Soviet Union. The 250 research and test reactors in use in 1978 were reduced to approximately 134 by 2007, and most of the remaining ones are in the former Soviet Union and in the United States.[9] However, more recently, and particularly after the terrorist attacks of September 11, 2001, it was realized that the stocks of enriched uranium still remaining represented a real threat of proliferation in some problematic countries, and that redoubled efforts should be undertaken to recover the material. As an example, in 2002 the Nuclear Threat Initiative safely moved 48 kg of highly enriched uranium (enough to manufacture two nuclear weapons) from the defunct Vinca nuclear reactor near Belgrade to a facility in Russia. Another example is Congo, which received the HEU research reactor that the United States displayed in 1958 at the second Atoms for Peace conference. Less than two years later, Belgian colonial rule in Congo ended. In 1970, the United States replaced the HEU reactor with a TRIGA (Mark II) reactor operated with LEU. In the process, two fuel rods with fresh fuel went missing; only one was eventually found.[10]

The nuclear renaissance now promoted by the United States has some similarities with the Atoms for Peace program of President Eisenhower – and runs the risk of repeating and amplifying the problems created by that program. Setting up dozens, perhaps hundreds of large nuclear reactors in developing countries means that enormous amounts of enriched uranium will be necessary. The plutonium produced in these reactors could be used for weapons and, further, the enormous amount of radioactive products in the spent fuel in the uranium rods will have to be disposed of.

Associated with the nuclear renaissance are Generation IV (GEN IV) reactors operating with recycled plutonium. Future nuclear systems, such as those that are studied in the GEN IV program and the so-called advanced Fuel Cycle Initiative from the United States, are all aimed at making nuclear energy more sustainable, either by increasing system efficiency or by using closed fuel cycles in which fissile materials are either partially or totally recycled. Such an approach will involve large reprocessing of fuel rods to extract plutonium. Significant scientific and technical challenges must be resolved before these systems are ready for deployment, which is not expected before 2035 – 2040.[11]

It is clear, therefore, that a renaissance would exacerbate two sets of problems that exist already with the present generation of nuclear reactors:

1) Transportation of fuel rods shipped from producing countries and the return of spent fuel (unless they are reprocessed locally); and

2) Building up local enrichment facilities to avoid external dependence.

The widespread circulation of fissile materials – particularly in some politically problematic countries – increases the probability of a fraction of this material falling into the hands of a terrorist group.

Such concerns led a group of very senior former U.S. government officials – George P. Shultz, William J. Perry, Henry A. Kissinger, and Sam Nunn (branded as the "gang of four")[12] – to the conviction that there is no solution to the problem of the spread of nuclear weapons except to seek "a world without nuclear weapons." Naive as it might sound – and none of these former senior officials could be considered "pacifists" or naive – the proposal made some sense from the U.S. perspective. They pointed out that "nuclear weapons were essential to maintaining international security during the Cold War because they were a means of deterrence," which was made obsolete by the end of the Cold War. Presently, however, there is the possibility of nuclear weapons falling into the hands of non-state organizations (and terrorists) to which the concept of nuclear deterrence does not apply at all. Eliminating nuclear weapons altogether and strictly controlling the circulation of materials usable for the manufacture of nuclear weapons would be the only solution to avoid that nightmare.

There is a less benign interpretation of the motivations of Shultz and colleagues, namely that whereas immediately after the end of World War II the only way to stop the Soviet Union from overrunning Western Europe was to strengthen the nuclear weapons capacity of the United States, today the situation has reversed itself. Western Europe is in no real danger from Russian takeover today, and U.S. conventional forces are dominant all over the world, with hundreds of military bases spread around the world. If nuclear weapons are indeed abandoned, that will not weaken U.S. power, but increase it.

One way of tightening control on fissile materials and discouraging nuclear proliferation is to revive and strengthen the NPT, which could be achieved in 2010 by addressing the thorny question of implementation of Article VI. This is well in line with President Obama's statement that he "will make the goal of eliminating all nuclear weapons a central element in our nuclear policy."

Some developing countries, particularly Brazil, which is considered one of the countries capable of producing nuclear weapons – but decided in 1991 not to do so – have recently adopted positions that signal the urgency of coming to terms with the problem of nuclear disarmament, thus strengthening, in some ways, the gang of four's proposal. The Brazilian government's recently issued "National Defense Strategy" states clearly that the country "will not adhere to proposed additions [meaning the Additional Protocol] to the NPT which increase restrictions contained in it without progress by the nuclear weapons states in what is the central premise of the Treaty: their own nuclear disarmament."

The Additional Protocol is presently one of the thorny issues in the efforts to curb nuclear proliferation. There are proposals to make its acceptance a precondition for technical help and access to technology from the Nuclear Suppliers Group, and to make it mandatory to signatories of the NPT, to which several countries have objected. Brazil has refused to accept the Additional Protocol because it claims to have developed, indigenously, ultracentrifuges that use an improved technology, and because unannounced inspections by the IAEA in non-declared nuclear facilities could jeopardize industrial secrets. Brazil otherwise accepts inspections in all declared nuclear facilities, including enrichment facilities, where precautions are taken not to reveal technical characteristics of the centrifuges.

Phasing out nuclear weapons will not come easy, but the many steps that could be taken in that direction (some of which were listed quite clearly in the gang of four's proposal) could help dramatically in "devaluing" the possession of nuclear weapons. Progressive intermediate steps include:

- Extending key provisions of the Strategic Arms Reduction Treaty of 1991;
- Adopting a process for bringing the Comprehensive Test Ban Treaty (CTBT) into effect;
- Adopting an effective Fissile Missile Cutoff Treaty (FMCT); and
- Developing an international system to manage the nuclear fuel cycle. On this particular point there are a number of proposals to establish multinational centers for enrichment of uranium and a "fuel bank" under IAEA control. The purpose of such a system would be to provide for reliability of nuclear fuel, reserves of enriched uranium, infrastructure assistance, financing, and spent-fuel management, to ensure that the means to make nuclear weapons materials aren't spread around the globe.

The strengthening of the NPT is also made more urgent by the fact that the U.S.-India nuclear deal dealt a serious blow to the safeguards regime of the IAEA. As a non-signatory of the NPT and having nuclear weapons, India could not receive the technical assistance of NWS. These requirements were bent to accommodate the geopolitical and commercial interests of the United States. What's more alarming, the deal was approved unanimously by the Nuclear Suppliers Group, which makes decisions by consensus.

This controversial approval by the Nuclear Suppliers Group can only be understood by assuming that some of the participants foresaw themselves as someday being in the same position of India, and wanted to guarantee for themselves the same benefits and technical assistance India would get from the NWS (although India has a military program that will not be under IAEA safeguards). Others are betting that the nuclear energy renaissance will indeed take place, and see themselves as suppliers of raw materials or enriched uranium. This expectation is clearly one of the justifications for the Rezende plant in Brazil, since it is unlikely that the internal market will be large enough to justify large investment in facilities. From that perspective, it is clear that the expectation of a nuclear renaissance is already undermining the NPT.

ENDNOTES

[1] Harold Brown, "New Nuclear Realities," *The Washington Quarterly* 31 (1) (Winter 2008/2009): 7–22.

[2] José Goldemberg, "Lessons from the Denuclearization of Brazil and Argentina," *Arms Control Today* (April 2006): 41–43.

[3] *Energy, Electricity, and Nuclear Power: Developments and Projections – 25 Years Past and Future* (Vienna, Austria: International Atomic Energy Agency, 2007).

[4] Those 50 countries are Algeria, Bahrain, Bangladesh, Belarus, Bolivia, Chile, Croatia, Dominican Republic, Egypt, El Salvador, Estonia, Georgia, Ghana, Greece, Haiti, Indonesia, Israel, Jamaica, Jordan, Kazakhstan, Kenya, Kuwait, Latvia, Libya, Malaysia, Mongolia, Morocco, Myanmar (Burma), Namibia, Nigeria, Oman, Peru, Philippines, Poland, Qatar, Saudi Arabia, Senegal, Singapore, Sri Lanka, Sudan, Syria, Tanzania, Thailand, Tunisia, Turkey, United Arab Emirates, Uruguay, Venezuela, Vietnam, and Yemen; author's personal correspondence with H. H. Rogner of the IAEA, September 2008.

[5] José Goldemberg, "The Limited Appeal of Nuclear Energy," *Scientific American* (June 2007).

[6] "Lighting the Way: Toward a Sustainable Energy Future" (InterAcademy Council, 2007); www.interacademycouncil.net.

[7] *World Energy Assessment: Energy and the Challenge of Sustainability*, ed. José Goldemberg (New York: United Nations Development Programme, 2000).

[8] A measure of the work done by a machine or plant that separates uranium into streams with higher and lower fractions of U-235.

[9] Ole Reistad and Styrkaar Hustveit, "HEU Fuel Cycle Inventories and Progress on Global Minimization," *The Nonproliferation Review* 15 (2) (2008): 265–282.

[10] Zia Mian and Alexander Glaser, "A Frightening Nuclear Legacy," *Bulletin of the Atomic Scientists* (September/October 2008): 42–47.

[11] Frank von Hippel, "Nuclear Fuel Recycling: More Trouble than It's Worth," *Scientific American* (April 2008).

[12] George P. Shultz, William J. Perry, Henry A. Kissinger, and Sam Nunn, "Call for a World Free of Nuclear Weapons," *The Wall Street Journal*, January 4, 2007, and "Toward a Nuclear Free World," *The Wall Street Journal*, January 15, 2008.