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Nuclear Power Makes A Comeback

Are the Risks Worth the Rewards?

An Invited Comment by Len Ackland

When President Barack Obama committed the United States in April 2009 to "take concrete steps towards a world without nuclear weapons," I was elated. The President noted in Prague that "the existence of thousands of nuclear weapons is the most dangerous legacy of the Cold War. No nuclear war was fought between the United States and the Soviet Union, but generations lived with the knowledge that their world could be erased in a single flash of light … Today, the Cold War has disappeared but thousands of those weapons have not."

As a journalistandeducator who has researched and written about the danger of nuclear weapons for more than 30 years, I was relieved to finally hear this accurate perspective coming from the nation's top elected official. The use of nuclear weapons is still humanity's fastest route to environmental catastrophe. The hazards exist and the risks are far too high, demonstrated by how close the world came to devastation during the 1962 Cuban Missile Crisis and given the anticipated consequences of a regional nuclear war or terrorist acquiring a bomb (Ackland 2007).

Then when President Obama endorsed nuclear power in his January 2010 State of the Union address, I was perplexed. Placed first in his list of tasks needed to promote clean energy, Mr. Obama said the United States must build "a new generation of safe, clean nuclear power plants in this country." Later in his speech he ignored the direct

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links between nuclear power and the technology's dark side when he stressed that "we're also confronting perhaps the greatest danger to the American people—the threat of nuclear weapons."

He singled out Iran and North Korea, criticizing "those nations that insist on violating international agreements in pursuit of nuclear weapons." Iran claims that its nuclear program is intended solely to produce nuclear power. While dubious, as documented by a recent article in Germany's *Der Spiegel*, Iran's claims do suggest the very real connections between nuclear weapons and power, which I'll come back to below (Follath 2010).

Climate Change and Nuclear Power

Nuclear power is enjoying a public relations renaissance lately, touted by many—including some former opponents—as a viable clean energy source to mitigate climate change. Nuclear power, so the argument goes, spews far less carbon dioxide (the major industrial contributor to greenhouse warming) into the atmosphere than competing fossil fuels like coal and oil. But climate change, while serious, isn't everything. This line of thinking ignores the even larger perils from a large increase in the use of reactors to boil water for electricity.

By choosing to treat nuclear power and nuclear weapons as completely discrete subjects, President Obama is following a long line of politicians, industry executives, scientists, and others who have promoted the benefits of nuclear power while either neglecting, minimizing, or dismissing the appreciable risks and unknowns involving this technology.

Tied to this approach, some nuclear power proponents fall back on their expertise and the complexity of the topic to claim a technical mandate for their positions. This reminds me of the "nuclear priesthood" that I encountered in the weapons field when I was editor during the Cold War's waning years of the *Bulletin of the Atomic Scientists*. The weapons priests employed an "if you knew what I know, then you would agree with me" strategy. The late physicist Edward Teller, "father of the H-Bomb," was the icon for this tactic. Variations of these appeals to authority occur in today's energy discussion, especially with regard to "educating" the public.

"Governments should communicate with stakeholders and the public to explain the role of nuclear energy in the national energy strategy, seeking to build public support through involvement in the policy-making process," the pro-nuclear International Energy Agency and Nuclear Energy Agency recommend in their joint July 2010 report, *Technology Roadmap: Nuclear Energy*. While noting some continuing public concerns about nuclear power, the report says worries about "security of energy supply and the threat of global climate change have tended in recent years to increase public recognition of the benefits of nuclear energy" (IEA/NEA 2010, p. 39).

Climate change mitigation is the latest argument for some nuclear proponents in recent years—including a few prominent environmentalists—who say the risks from nuclear reactors are simply outweighed by the risks of human-induced rapid climate change. Global warming is "the greatest danger that civilization has faced so far," writes James Lovelock, the well-known creator of the Gaia hypothesis that the earth is a self-regulating organism, in a May 2004 article. He concludes, "only one immediately available source does not cause global warming and that is nuclear energy" (Lovelock 2004).

Relatively rapid climate change poses risks thoroughly documented by the Intergovernmental Panel on Climate Change reports and elsewhere—reports that have withstood full-throated attacks from climate change skeptics, despite minor errors and some scientists' shoot-self-in-foot e-mails. I won't deal much with climate change, which environmental writer Dianne Dumanoski describes in her book *The End of the Long Summer* (Dumanoski 2009).

But you needn't accept dire climate change scenarios to appreciate the extremely high risks posed by nuclear power. Indeed, Wall Street's skepticism about the safety of nuclear investments is a large part of the reason the Bush and Obama administrations have backed loan guarantees, now pushed up to $54 billion, for new nuclear plant construction in the United States. If nuclear technology is as good as advocates say, why does the industry still require huge subsidies after decades of such support? From 1943 through 1999, the nuclear industry received 95 percent of the $150 billion (in 1999 dollars) in federal subsidies that went to wind, solar, and nuclear power (Goldberg 2000).

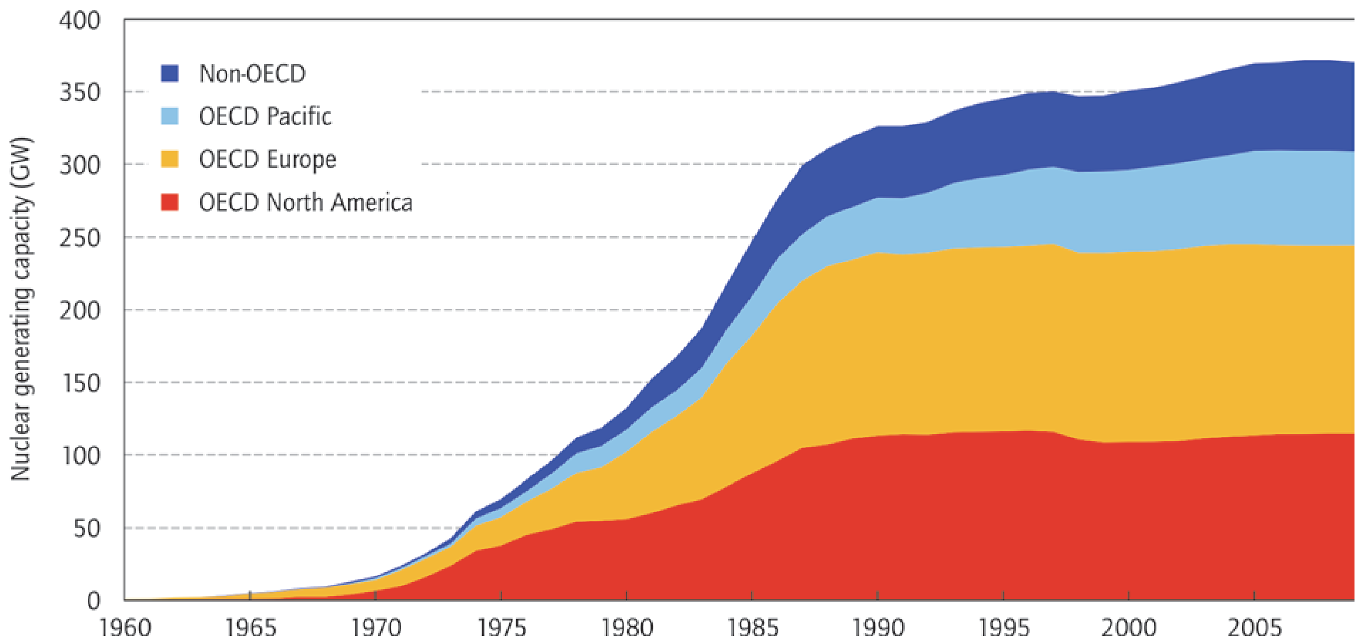
A point frequently lost in the arguments regarding solutions to rapid climate change is that nuclear power relates to the question of *electricity* production, not total primary *energy*, which includes oil and other sources of greenhouse gases. The single largest source of global greenhouse gases—electricity and heat production—accounts for some 41 percent of carbon dioxide emissions, primarily due to coal-fired power plants (IEA 2008). Thus, while the world's 439 operating commercial nuclear power plants, with a capacity of 373 gigawatts (billion watts), provide 14 percent of the world's electricity, they account for about six percent of primary energy (IEA/NEA 2010). That means that nuclear plants—which are relatively "clean" atmospherically given their lack of carbon dioxide emissions and even counting in the emissions from processes used to build the facilities—currently play a minor role in reducing overall greenhouse gases.

Commercial nuclear reactors are located in 30 countries, including seven of the nine nations which also possess nuclear weapons. The United States operates the largest number, with 104 plants producing about 20 percent of the nation's electricity. Worldwide, 61 plants are listed as under construction. Some have had that status for decades while one-third were begun since 2008. It typically takes between seven to 10 years to plan, license, and build reactors. China, which operates 12 reactors, has 23 under construction and plans to double that number (IAEA 2010; IEA/NEA 2010).

The International Energy Agency/Nuclear Energy Agency July report calls for tripling nuclear power capacity to 1,200 gigawatts by 2050, which would then produce 24 percent of global electricity consumed by a world population topping nine billion. Assuming the construction of large reactors between one and 1.7 gigawatts each, the agencies conclude that at least 800 plants, or an average of 20 plants a year for the next 40 years, are needed. The price

World Nuclear Generating Capacity, 1960 to 2009

Source: International Atomic Energy Agency, Power Reactor Information System



tag is estimated at $4 trillion (IEA/NEA 2010). By 2050 most of the current plants will be decommissioned and added to the mounting volume of global nuclear waste. Along with the new plants, numerous other facilities necessary for the production of nuclear power will also need to be built, as noted below.

More than doubling the number of nuclear reactors in the world will multiply the already high risks associated with this technology. The major risks are weapons proliferation (because weapons and power production are fraternal twin technologies nurtured by the same uranium umbilical cord), reactor accidents (epitomized by Chernobyl), and the disposal of nuclear waste (to prevent radioactive inheritance by future generations).

List Your Risk, Take Your Pick

People prioritize those risks differently. In Germany a robust debate over nuclear power has been going on for decades and resulted in a 2002 law to phase out the country's 17 plants by 2022 and replace their output with renewable energy. Nuclear waste has been a rallying point (Ackland 2009). Felix Christian Matthes, an analyst at the Ecological Institute in Berlin, told me last year that the German public's opposition to nuclear power—now being tested by a new conservative coalition government elected in September 2009—stems first from waste issues, then accidents, and then, much farther down the scale, proliferation. "For me," he added, "it's accidents, proliferation, and then waste."

Nuclear waste is tangible and visible. Moreover, no country has yet opened a site to safely dispose of the long-term, high-level waste created in the core of reactors, so it's understandable that the public in Germany and other countries consider that the biggest problem. And Matthes's top ranking for accident risks is derived in part from the geography of densely populated Germany, where 82 million people live in an area the size of Montana. A major nuclear accident there could have devastating results.

The possibility and reach of accidents became clear when the 1986 Chernobyl accident in Ukraine spread radiation widely through the atmosphere—a warning to the world about the risks of using complex nuclear technology to boil water into steam to spin turbines to produce electricity. But nuclear proponents point to the industry's overall impressive safety record since the first commercial reactors went online in the late 1950s. Accidents like Chernobyl are relegated to the category of "low probability-high consequence" risks, the same category of risk that oil drilling was in until the Deepwater Horizon disaster in the Gulf of Mexico last April. More should question whether such risks, whether from oil drilling or nuclear power, are worth taking (Gimein 2010).

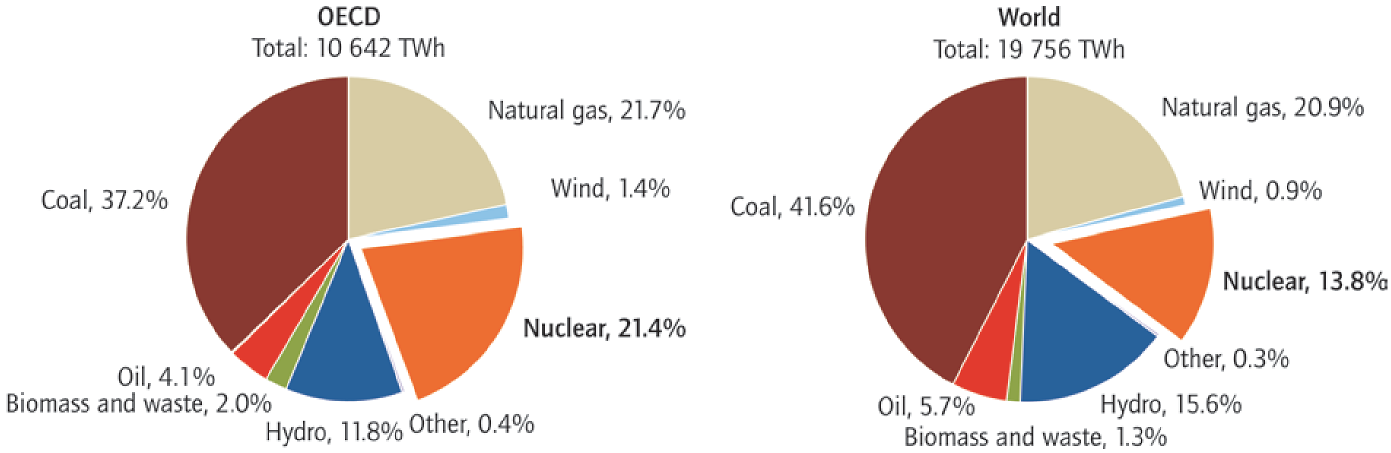
Accidents come second on my own list of nuclear risks. First place goes to weapons proliferation and its contemporary ally, nuclear terrorism. But I respect those who rank the issues differently. In taking on the powerful nuclear establishment, groups often don't converge their arguments in opposition. Aside from the big three nuclear risks of proliferation, accidents, and waste, many other risks are seen by specialists and from the local level. Some scholars worry, for example, about the security and sabotage of nuclear reactors or their destruction by terrorists or conventional war. On the local level, examples include a fight over renewed uranium mining in New Mexico in an Indian Country still suffering public health effects from more than 1,000 abandoned uranium mines causing contaminated water and housing (Paskus 2009). In western Colorado, a plan to build the nation's first uranium mill in 25 years has stirred a health vs. jobs debate (Rice 2010).

Uranium mines and mills are at the front end of the nuclear fuel cycle, the cradle-to-grave process for the materials used to produce (or "fuel") nuclear power or bombs. Details of the fuel cycle often make the subject seem impenetrable to laypeople, but the basics are straightforward. They help explain the two major points of intersection between nuclear power and nuclear weapons programs.

The production process begins with uranium, the heaviest naturally occurring element on Earth, with an atomic number of 92—the number of positively charged protons in the nucleus of each uranium atom, matched

Electricity Generation by Source, Worldwide and OECD, 2007

Source: International Energy Agency,



by an equal number of orbiting electrons. The nucleus also contains neutrons, which have no electric charge, but, like protons, have an atomic weight of 1, in contrast to the weightless electrons. Uranium, like other elements, can have different numbers of neutrons in its atoms' nuclei—resulting in different atomic weights and slightly different chemical characteristics. These variants are called isotopes. Thus, 99.3 percent of natural uranium consists of uranium-238 (146 neutrons plus 92 protons) and 0.7 percent uranium-235 (143 neutrons plus 92 protons).

Uranium-235 is the isotope needed for chain reactions because when its nucleus is hit with neutrons it splits, or fissions, into other elements while releasing the tremendous energy that holds nuclei together. To concentrate the amount of uranium-235 in order to create self-sustaining chain reactions in power plants or bombs, natural uranium is milled to refine the uranium into yellowcake. That is then converted into uranium hexafluoride gas and enriched by centrifuges or other means to separate the uranium-235 and uranium-238 isotopes.

Nuclear power reactors operate with controlled chain reactions fueled by uranium enriched to three to five percent uranium-235, while uranium bombs are uncontrolled, explosive chain reactions using about 90 percent uranium-235 as fuel. The United States proceeded directly to "highly enriched uranium" for the bomb it dropped on Hiroshima, Japan in 1945, which had an explosive force equivalent to 13,000 tons of TNT and instantly killed tens of thousands of people. It released radiation that increased the casualty count over time.

Uranium Enrichment Crossover Point

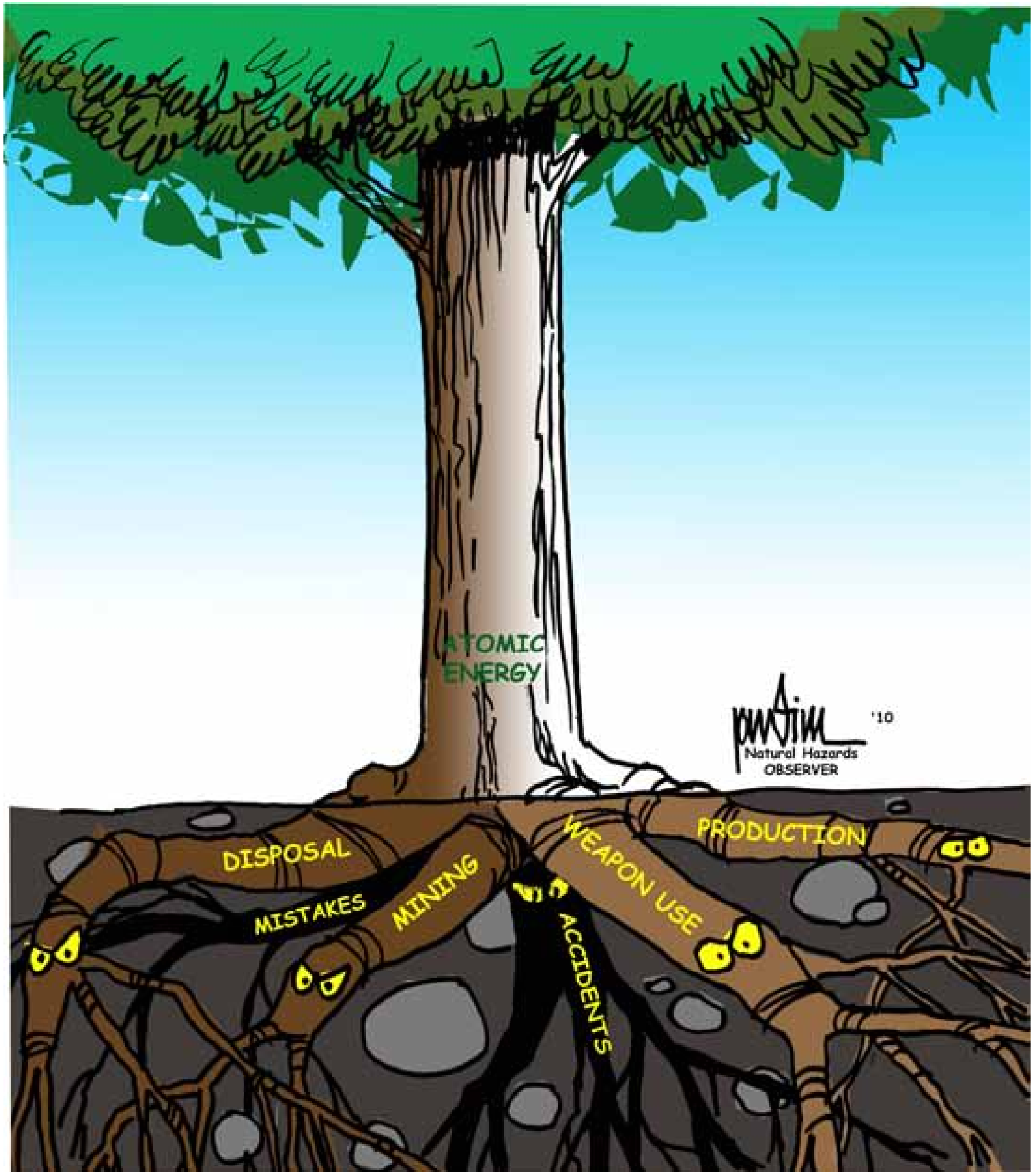
The current dispute over Iran's nuclear intentions vividly illustrates that uranium enrichment is the first potential crossover point between nuclear power and weapons. Iran insists that it only wants to create nuclear power, a claim greeted with skepticism by much of the international community. One challenge in determining a country's goals is that in enriching uranium-235 from 0.7 percent to about 4 percent requires about 70 percent of the total energy needed to enrich it to the weapons-grade 90 percent (Broad 2010). Also, centrifuge enrichment can be easily hidden. "A typical centrifuge plant has several thousand centrifuges, but the entire collection fits comfortably inside a space no larger than a movie theater," Berkeley physicist Richard A. Muller (2008) writes in the nuclear section of his clear, accessible book *Physics for Future Presidents.* "Such systems can produce enough enriched uranium for several nuclear bombs a year."

The second potential crossover point between power and weapons occurs because the vast majority of nuclear power reactors in the world also produce quantities of plutonium-239, the infamous fissionable element. Plutonium-239, used to make powerful nuclear bombs, is a byproduct of a chain reaction which essentially burns the uranium-235 fuel (concentrated to about four percent). The other 96 percent of the fuel, which has been pressed into pellets and then loaded into thin rods, is made up of uranium-238. Some of the neutrons from the fissioning uranium-235 in the reactors are absorbed by the uranium-238. Through a series of reactions plutonium-239 is produced. Plutonium comprises about one percent of the spent reactor fuel. After the spent fuel rods are removed from the reactor the plutonium must then be separated, or "reprocessed," from other elements before it can be fabricated for use in weapons. This is what North Korea did when it dropped out of the Nuclear Non-Proliferation Treaty. In October 2006, Nortyh Korea tested a plutonium bomb.

Plutonium-239, used by the United States for its first atom bomb test in New Mexico in 1945 and then the bomb dropped on Nagasaki, has long been the material of choice for nuclear weapons. Today it takes just 13 pounds of plutonium for a bomb compared with 33 pounds of uranium-235 (Muller 2008). Nations with nuclear weapons arsenals typically have dedicated military reactors to produce plutonium, but dual-use power and weapons reactors can also operate. Chernobyl was such a reactor. Sophisticated nuclear weapons nations use fission bombs to trigger hydrogen bombs with 1,000 times the explosive force of a fission bomb.

Scientists agree that acquiring the fissile materials plutonium-239 or uranium-235 is the most difficult part of making a nuclear bomb. Harvard's Matthew Bunn notes, "Making the needed nuclear material has always been the most challenging and costly element of national nuclear weapons programs, having consumed some 90 percent of the resources devoted to the Manhattan Project" (Bunn 2010). And Muller writes that once in possession of uranium-235, designing a Hiroshima-style bomb "is perhaps even within the means of small terrorist organizations." He argues that plutonium-239 is easier to acquire and extract from reactor waste "if you know enough about radiochemistry techniques." But terrorist groups, in contrast to nations with industrial capability, would be unlikely to try to build a plutonium bomb, which requires sophisticated implosion techniques (Muller 2008).

Today, in addition to the nine nations with nuclear weapons (the United States, Russia, United Kingdom, France, China, Israel, India, Pakistan, and North Korea), 18 other countries possess enough plutonium or highly-enriched uranium "to require the highest international standards of security," writes Bunn in his report *Securing the Bomb 2010* (Bunn 2010). He notes that such security standards have not yet been achieved, although some progress is being made. Bunn's focus is the danger that terrorists could acquire and use a bomb, a risk that President Obama called "the most immediate and extreme threat to global security" in his 2009 speech in Prague.



The danger of terrorists acquiring a nuclear bomb is much different than the risk that nations will use a nuclear power program as a pretext for acquiring bomb materials, as North Korea did and Iran is suspected of planning. But international efforts to secure the nuclear fuel cycle to prevent countries from enriching uranium to weapons-grade levels or reprocessing plutonium for bombs have lagged. Ideas about ways to provide such security, such as creating international nuclear "fuel banks," are spelled out in publications such as the special fall 2009 and winter 2010 issues of *Daedalus,* the magazine of the American Academy of Arts and Sciences. However, little real progress has been made, for political reasons.

Unknowns and Optimism

"Will the growth of nuclear power lead to increased risks of nuclear weapons proliferation and nuclear terrorism? Will the nonproliferation regime be adequate to ensure safety and security in a world more widely and heavily invested in nuclear power?" analysts Steven Miller and Scott Sagan ask in the introduction to the *Daedalus* double issue. Their answer: "It depends."

"On what will it depend?" they continue. "Unfortunately, the answer to that question is not so simple and clear, for the technical, economic, and political factors that will determine whether future generations will have more nuclear power without more nuclear proliferation are both exceedingly complex and interrelated" (Miller and Sagan 2009).

Unknowns and a heavy dose of optimism dominate the July 2010 International Energy Agency/Nuclear Energy Agency report when it mentions potential solutions to proliferation as well as risks such as accidents and waste posed by nuclear power. A few examples:

- "Particularly if nuclear power is to play a greatly increased role, and is to be used in a wider range of countries, appropriate nonproliferation controls will need to be in place . . . Several international projects and proposals aimed at achieving this are being promoted by individual countries or groups of countries, and are being considered at the IAEA [International Atomic Energy Agency]."
- Existing reactors are called Generation II, with the "latest designs" known as Generation III or III+. "The designs offer improved performance and reliability, greater fuel efficiency, enhanced safety systems and produce less radioactive waste." On the following page, however, the report states that only one such reactor design is currently operating and when it describes the

new French reactors, under construction in Finland and France, it fails to mention the delays and big cost overruns for these projects.

• The report also notes that nuclear power programs "will need to be implemented in an increasing number of newly industrializing countries, where most of the increase in energy and electricity demand will occur" and that these nations will need to develop a "safety culture."

If something goes awry, however, the risk is that investments in nuclear power will end up being completely wasted. "A terrorist nuclear bomb, or a major sabotage of a nuclear facility—a 'security Chernobyl'—would doom any prospect for gaining the public, government, and utility support needed for large-scale growth of nuclear power, putting tens of billions of dollars in future revenue at risk," Bunn writes. "In some countries it might even lead to pressures to close major operating facilities" (Bunn 2010).

Proponents of nuclear power, and even some who are more skeptical, suggest that there is no viable alternative. Physicist Muller, summarizing the issue and giving advice to a future president, writes, "Despite the public opposition, nuclear power is likely to be an important part of our future energy needs. Somehow you need to convey to the public that their fear has come from ignorance, not from knowledge, and that you know what you are talking about" (Muller 2008).

It seems to me, however, that fear of nuclear power's risks is warranted, with few realistic solutions in sight—particularly for the dangers of proliferation, terrorist acquisition of bombs, and accidents. And the debate and emphasis on renewables in Germany, where the most profound public discussion of nuclear power has been occurring, suggests that an alternative path exists. The conservatively estimated $4 trillion needed to expand nuclear reactors around the world would go a long way to developing renewable and sustainable clean energy sources.

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